ENCYCLOPÆDIA BRITANNICA

NINTH EDITION

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A

DICTIONARY

OF

ARTS, SCIENCES, AND GENERAL LITERATURE

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VOLUME XV

NEW YORK: CHARLES SCRIBNER'S SONS

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LOO

LOO (formerly called LANTERLOO), a round game of cards. Loo may be played by any number of persons; from five to seven makes the best game. "Three-card loo" is the game usually played. A pack of fifty-two cards is required. The players being seated, the pack is shuffled and a card dealt face upwards to each. The player to whom a knave falls has the first deal, the player to his left deals next, and so on in rotation. Each player is entitled to a deal, *i.e.*, the game should not be abandoned till it returns to the original dealer; but, if there is a loo in the last deal of a round, the game continues till there is a hand without a loo. The pack is cut to the dealer, who deals three cards to each player and an extra hand called *miss*. The dealer turns up the top of the undealt cards for trumps. The dealer is sometimes permitted to deal the cards in any order he pleases; but the best rule is to require that the cards be dealt one at a time in rotation, as at whist. During the deal each player contributes to the *pool* a sum previously agreed upon, the dealer contributing double. The unit for a single stake should be divisible by three without a remainder, *e.g.*, three counters or three pence. The players are bound to put in the stake before the deal is completed; sometimes a penalty is enforced for neglect. The deal being completed and the pool formed, each player in rotation, beginning from the dealer's left, looks at his cards, and declares whether he will play, resign, or take miss. If the former, he says "I play." If he takes miss he places his cards face downwards in the middle of the table, and takes up the extra hand. If he resigns, he similarly places his cards face downwards in the middle of the table. If miss is taken, the subsequent players only have the option of playing or resigning. A player who takes miss must play. Those who have declared to play, and the one—if there is one—who has taken miss, then play one card each in rotation, beginning from the dealer's left, the cards thus played constituting a *trick*. The trick is won by the highest card of the suit led, or, if trumped, by the highest trump, the cards ranking as at whist. The winner of the trick leads to the next, and so on, until the hand is played out. The cards remain face upwards in front of the persons playing them.

Rules of Play.—If the leader holds ace of trumps he must lead it (or king, if ace is turned up). If the leader has two trumps he must lead one of them, and if one is ace (or king, ace being turned up) he must lead it. With this exception the leader is not bound to lead his highest trump if more than two declare to play; *but if there are only two declared players* the leader with more than one trump must lead the highest. Except with trumps as above stated he may lead any card he chooses. The subsequent players must head the trick if able, and must follow suit if able. Holding none of the suit led, they must head the trick with a trump, if able. Otherwise they may play any card they please. The winner of the first trick is subject to the rules already stated respecting the lead, and in addition he must lead a trump if able (called *trump after trick*).

When the hand has been played out, the winners of the tricks divide the pool, each receiving one-third of the amount for each trick. If only one declared to play, the dealer plays miss either for himself or for the pool. If he plays for the pool he must declare before seeing miss that he does not play for himself. Any tricks he may win, when playing for the pool, remain there as an addition to the next pool.

If each declared player wins at least one trick it is a *single*, *i.e.*, a fresh pool is made as already described; but if one of the declared players fails to make a trick he is *looed*. Then, only the player who is looed contributes to the next pool, together with the dealer, who puts in a single stake. If more than one player is looed, each has to contribute. At *unlimited loo* each player looed has to put in the amount there was in the pool. But it is generally agreed to *limit* the loo, so that it shall not exceed a certain fixed sum. Thus, at eighteen-penny loo, the loo is generally limited to half a guinea. If there is less than the limit in the pool the payment is regulated as before; but if there is more than the limit, the loo is the fixed sum agreed on.

The game is sometimes varied by *forces*, *i.e.*, by compelling every one to play, either whenever there is no loo the previous deal (*a single*), or whenever clubs are trumps (*club law*). When there is a force no miss is dealt. *Irish loo* is played by allowing declared players to exchange some or all of their cards for cards dealt from the top of the pack. There is no miss, and it is not compulsory to lead a trump with two trumps, unless there are only two declared players. At *five-card loo* each player has five cards instead of three, and a single stake should be divisible by five. *Pam* (knave of clubs) ranks as the highest trump, whatever suit is turned up. There is no miss, and cards may be exchanged as at Irish loo. If ace of trumps is led, the leader says "Pam be civil," when the holder of that card must pass the trick if he can do so without revoking. A flush (five cards of the same suit, or four with Pam) *loos the board*, *i.e.*, the holder receives the amount of a loo from every one, and the hand is not played. A trump flush takes precedence of flushes in other suits. If more than one flush is held, or if Pam is held, the holder is exempted from payment. As between two flushes which do not take precedence, the elder hand wins.

Declaring to Play, and Playing (three-card loo).—Play on two trumps. The first to declare should play on an honour in trumps and an ace in plain suits. Play also on king of trumps; but some players throw up king of trumps single unless with it another king or a guarded queen is held. Also play on one trump with two other cards as high as queens; some players throw up this hand. Holding a trump and two aces, lead the trump if three others declare to play; but otherwise lead an ace. Do not play on a hand without a trump; except, play on any cards that give a reasonable chance of a trick, or take miss, if the amount in the pool is considerable, and the loo is limited. If the number of players is less than five, or if several throw up, weaker hands may be played; on the other side, if several have declared to play, only a very strong hand should be risked. If there are only three left in, all others having thrown up, miss should be taken, but not when there are more than two to follow the player whose turn it is to declare.

Laws of Loo.—These vary greatly, and should be agreed on before commencing to play. The ordinary rules, which loo the player for nearly every error, are very bad. The following are based on the laws of the late Blenheim Club. 1. First knave deals. 2. Each player has a right to shuffle. 3. The player to the dealer's right cuts the pack. 4. The dealer must deliver the cards, one by one, in rotation, as at whist, and must deal one card for miss at the end of each round; he must turn up the top card of the undealt cards for trumps. 5. If the dealer deals without having the pack cut, or shuffles after it is cut, or deals except as provided in law 4, or deals two cards together and then deals a third without rectifying the error, or exposes a card, or deals too many cards, he forfeits a single to the pool, and deals again.[1] 6. The player to the left of the dealer deals next. If a player deals out of turn, he may be stopped before the trump card is turned, otherwise the deal stands good, and the player to his left deals next. 7. Players must declare to play in rotation, beginning to the dealer's left. A player looking at his cards before his turn forfeits a single to the pool. 8. A player who declares before his turn, or who exposes a card, forfeits a single to the pool, and must throw up his hand.[2] 9. If a declared player exposes a card before his turn to play, or plays out of turn, or before all have declared, or detaches a card so that it can be named by any other declared player, or revokes, he must leave in the pool any tricks he may make, and forfeit four times the amount of a single. If he makes no trick he is looed, and there is no further penalty. 10. If the leader holds ace of trumps and does not lead it (or king, ace being turned up), or if he holds two trumps and does not lead one, or the highest of two or more trumps when there are only two declared players (unless his cards are sequence cards or cards of equal value), or if a player does not head the trick when able, or if he does not lead trump after trick (if he holds a trump), he is liable to the same penalty as in law 9.[3] 11. In case of revokes or errors in play the hand must be replayed if so desired by any one except the offender. 12. The place of an aftercomer is decided by dealing a card between every two of the players. The aftercomer sits where the first knave falls. (H. J.)

LOOCHOO. See Lew-chew Islands.

LOOM. See Weaving.

LOOM, or Loon (Icelandic, *Lómr*), a name applied to water-birds of three distinct Families, all remarkable for their clumsy gait on land.[4] The first of them is the *Colymbidæ*, to which the term Diver (*q.v.*) is nowadays usually restricted in books; the second the *Podicipedidæ*, or Grebes (see vol. xi. p. 30); and the third the *Alcidæ*. The form Loo*n* is most commonly used both in the British Islands and in North America for all the species of the genus *Colymbus*, or *Eudytes* according to some ornithologists, frequently with the prefix Sprat, indicating the kind of fish on which they are supposed to prey; though it is the local name of the Great Crested Grebe (*Podiceps cristatus*) wherever that bird is sufficiently well known to have one; and, as appears from Grew (*Mus. Reg. Soc.*, p. 69), it was formerly given to the Little Grebe or Dabchick (*P. fluviatilis* or *minor*) as well. The other form Loo*m* seems more confined in its application to the north, and is said by Mr T. Edmonston (*Etym. Gloss. Shetl. and Orkn Dialect*, p. 67) to be the proper name in Shetland of *Colymbus septentrionalis*[5]; but it has come into common use among Arctic seamen as the name of the species of Guillemot (*Alca arra* or *bruennichi*) which in thousands throngs the cliffs of far northern lands, from whose (hence called) "loomeries" they obtain a considerable stock of wholesome food, while the writer believes he has heard the word locally applied to the Razorbill (*q.v.*). (A. N.)

LOPE DE VEGA. See Vega Carpio.

LOPEZ, Carlos Antonio (1790–1862), a Paraguayan ruler of great ability, born at Asuncion, November 4, 1790, was educated in the ecclesiastical seminary of that city, and by his ability attracted the hostility of the dictator, Francia, in consequence of which he was forced to keep in hiding for several years. He acquired, however, by study, so unusual a knowledge of law and governmental affairs that, on Francia's death in 1840, he soon acquired an almost undisputed control of the Paraguayan state, which he maintained uninterruptedly until his own death in 1862. He was successively secretary of the ruling military *junta* (1840–41), one of the two consuls (1841–44), and president with dictatorial powers (1844–1862) by successive elections for ten and three years, and in 1857 again for ten years, with power to nominate his own successor. Though nominally a president acting under a republican constitution, he ruled despotically, the congress assembling only rarely and on his call, and then only to ratify his decrees. His government was in general directed with wise energy towards developing the material resources and strengthening the military power of the country. His jealousy of foreign approach several times involved him in diplomatic disputes with Brazil, England, and the United States, which nearly resulted in war, but each time he extricated himself by skilful evasions. Paraguay rapidly advanced under his firm and, on the whole, patriotic administration. He died September 10, 1862.

LOPEZ, Francisco Solano (1826–1870), eldest son of Carlos Antonio Lopez above noticed, was born near Asuncion, Paraguay, July 24, 1826. During his boyhood his father was in hiding, and in consequence his education was wholly neglected. Soon after his father's accession to the presidency, Francisco, then in his nineteenth year, was made commander-in-chief of the Paraguayan army, during the spasmodic hostilities then prevailing with the Argentine Republic. After receiving successively the highest offices of the state, he was sent in 1853 as minister to England, France, and Italy, to ratify formally treaties made with these powers the previous year. He spent a year and a half in Europe, and succeeded in purchasing large quantities of arms and military supplies, together with several steamers, and organized a project for building a railroad and establishing a French colony in Paraguay. He also formed the acquaintance of Madame Lynch, an Irish adventuress of many talents and popular qualities, who became his mistress, and strongly influenced his later ambitious schemes. Returning to Paraguay, he became in 1855 minister of war, and on his father's death in 1862 at once assumed the reins of government as vice-president, in accordance with a provision of his father's will, and called a congress by which he was chosen president for ten years. He had long cherished ambitious designs, and now set himself to enlarge the army, and purchase in Europe large quantities of military stores. In 1864 he began open aggression on Brazil by demanding, in his self-styled capacity of "protector of the equilibrium of the La Plata," that Brazil should abandon her armed interference in a

[1] The law which loos a player for misdealing is atrocious, and should always be opposed.

[2] Forfeits of a single go to increase the pool already formed, and see note to law 5.

[3] Tricks left in the pool and fines under laws 9 and 10 go to the next pool and not to the pool already formed. Many players inflict the penalty of a loo for the offences named in laws 9 and 10; but the rule above, as played at the Blenheim, is the best.

[4] The word also takes the form "Lumme" (*fide* Montagu), and, as Professor Skeat observes, is probably connected with *lame*. The signification of *loon*, a clumsy fellow, and metaphorically a simpleton, is obvious to any one who has seen the attempt of the birds to which the name is given to walk.

[5] Dunn and Saxby, however, agree in giving "Rain-Goose" as the name of this species in Shetland.

revolutionary struggle then in progress in Uruguay. No attention being paid to his demand, he treacherously seized a Brazilian merchant steamer in the harbour of Asuncion, and threw into prison the Brazilian governor of the province of Matto Grosso who was on board. In the following month (December 1864) he despatched a force to invade Matto Grosso, which seized and sacked its capital Cuyabá, and took possession of the province and its diamond mines. Lopez next sought to send an army to the relief of the Uruguayan president Aguirro against the revolutionary aspirant Flores, who was supported by Brazilian troops. The refusal of the Argentine president, Mitre, to allow this force to cross the intervening province of Corrientes, was seized upon by Lopez as an occasion for war with the Argentine Republic.

A congress, hastily summoned and composed of his own nominees, bestowed upon Lopez the title of marshal, with extraordinary war powers, and on April 13, 1865, he declared war, at the same time seizing two Argentine war-vessels in the bay of Corrientes, and on the next day occupied the town of Corrientes, instituted a provisional government of his Argentine partisans, and summarily announced the annexation to Paraguay of the provinces of Corrientes and Entre Rios. Meantime the party of Flores had been successful in Uruguay, and that state on April 18 united with the Argentine Republic in a declaration of war on Paraguay, the news of the treacherous proceedings of Lopez having then but just reached Buenos Ayres. On May 1st Brazil joined these two states in a secret alliance, which stipulated that they should unitedly prosecute the war "until the existing government of Paraguay should be overthrown," and "until no arms or elements of war should be left to it." This agreement was literally carried out.

The war which ensued, lasting until April 1, 1870, was on the largest scale of any that South America had experienced, and was carried on with great stubbornness and with alternating fortunes, though with a steadily increasing tide of disasters to Lopez (see PARAGUAY). In 1868, when the allies were pressing him hard before the various strongholds still remaining to him in Paraguay, his mind, naturally suspicious and revengeful, led him to conceive that a conspiracy had been formed against his life in his own capital and by his chief adherents. His bloodthirsty rage knew no bounds. In a short time several hundred of the chief Paraguayan citizens were seized and executed by his order, including his brothers and brothers-in-law, cabinet ministers, judges, prefects, military officers of the highest grade, the bishops and priests, and nine-tenths of the civil officers, together with more than two hundred foreigners, among them several members of the different diplomatic legations.

Lopez was at last driven with a mere handful of troops to the northern frontier of Paraguay, where on April 1, 1870, he was surprised by a Brazilian force and killed as he was endeavouring to escape by swimming the river Aquidaban. His ill-starred ambition had in a few years reduced Paraguay from the prosperity which it had enjoyed under his father to a condition of hopeless weakness, and it has since remained a virtual dependency of Brazil.

LORCA, a town of Spain, in the province of Murcia, on the right side of the Sangonera (here called the Guadalentin), by which it is separated from the suburb or quarter of San Cristobal. It is situated about 38 miles west from Cartagena, and 37 south-west from Murcia, at the foot of the Sierra del Caño. The principal buildings are the collegiate church of San Patricio, with a Corinthian façade, and the parish church of Santa Maria, in the Gothic style. The principal manufactures are soda, saltpetre, gunpowder, and cloth; the trade, apart from that which these articles involve, is insignificant. The population of the municipality was 52,934 in 1877.

Lorca (Arab. *Lurka*) is the *Eliocroca* of the *Itin. Ant.*, and probably also the *Ilorci* of Pliny (iii. 3). It was the key of Murcia during the Moorish wars, and was frequently taken and retaken. On April 30, 1802, it suffered severely by the bursting of the reservoir known as the Pantano de Puentes, in which the waters of the Guadalentin were stored for purposes of irrigation; the Barrio de San Cristobal was completely ruined, and more than six hundred persons perished in the disaster. In 1810 it suffered greatly from the French.

LORENZO MARQUES, or LOURENÇO MARQUES, the chief place, and indeed the only European settlement, in the district of its own name in the Portuguese province of Mozambique in south-eastern Africa, is situated on Delagoa Bay, at the mouth of the Lorenzo Marques or English River, in 25° 58′ S. lat. and 32° 30′ E. long. At the time of Mr Erskine's visit in 1871 it was a poor place, with narrow streets, fairly good flat-roofed houses, grass huts, decayed forts, and rusty cannon, enclosed by a wall 6 feet high recently erected and protected by bastions at intervals. In 1878 Governor Castelho returned the white population of all the district (whose area is estimated at 210,000 square miles) as 458, and the natives as from 50,000 to 80,000. A commission sent by the Government in 1876 to drain the marshy land near the settlement, to plant the blue gum tree, and to build a hospital and church, only partly accomplished its task, and other commissions have succeeded it. In 1878–79 a survey was taken for a railway from Lorenzo Marques to the Transvaal (see *Bol. da Soc. de Geogr. de Lisboa*, 1880), and the completion of this enterprise will make the settlement (which already possesses the best harbour on the African coast between the Cape and Zanzibar) a place of considerable importance. It became a regular port of call for the steamers of the British India Steam Navigation Company in 1879, and for those of the Donald Currie line in 1880. Since 1879 it is also a station on the telegraph line between Aden and South Africa. Both Germany and England maintain consular agents in the settlement.

See DELAGOA BAY, vol. vii. p. 40; and Lobo de Bulhaes, *Les Colonies portugaises* (Lisbon, 1878).

LORETO, a city in the province and circondario of Ancona, Italy, is situated some 15 miles by rail south-west from Ancona on the Ancona-Foggia railway, 16 miles north-east from Macerata, and 3 from the sea. It lies upon the right bank of the Musone, at some distance from the railway station, on a hill-side commanding splendid views from the Apennines to the Adriatic. The city itself consists of little more than one long narrow street, lined with booths for the sale of rosaries, medals, crucifixes, and similar objects, the manufacture of which is the sole industry of the place. The population in 1871 was only 1241; but, when the suburbs Montereale, Porta Marina, and Casette are included, the population is given as 4755, that of the commune being 8083. The number of pilgrims is said to amount to about 500,000 annually. The principal buildings, occupying the four sides of the piazza, are the college of the Jesuits, the Palazzo Apostolico (designed by Bramante), and the architecturally insignificant cathedral church of the Holy House (Chiesa della Casa Santa). The handsome façade of the church was erected under Sixtus V., who fortified Loreto and gave it the privileges of a town (1586); his colossal statue stands in the middle of the flight of steps in front. Over the principal doorway is a life-size bronze statue of the Virgin and Child by Girolamo Lombardo; the three superb bronze doors executed under Paul V. (1605–21) are also by Lombardo, his sons, and his pupils. The richly decorated campanile, by Vanvitelli, is of great height; the principal bell, presented by Leo X. in 1516, weighs 11 tons. The interior of the church has mosaics by Domenichino and Guido Reni, a beautiful bronze font and other works of art; but the chief object of interest is the Holy House itself, which occupies a central place. It is a plain brick building, measuring 28 feet by 12½, and 13½ feet in height; it has a door on the north side and a window on the west; and a niche contains a small black image of the Virgin and Child, in Lebanon cedar, and richly adorned with jewels. St Luke is alleged to have been the sculptor; its workmanship suggests the latter half of the 15th century. Around the Santa Casa is a lofty marble screen, designed by Bramante, and executed under Popes Leo X., Clement VII., and Paul III., by Andrea Sansovino, Girolamo Lombardo, Bandinelli, Guglielmo della Porta, and others. The four sides represent the Annunciation, the Nativity, the Arrival of the Santa Casa at Loreto, and the Nativity of the Virgin respectively. The treasury of the church contains a large variety of rich and curious votive offerings.

The legend of the Holy House, by which Loreto became what has been not inappropriately called the Christian Mecca, seems to have sprung up, how is not exactly known, at the close of the crusading period. It is briefly referred to in the *Italia Illustrata* of Flavius Blondus, secretary to Popes Eugenius IV., Nicholas V., Calixtus III., and Pius II. (*ob.* 1464); it is to be read in all its fulness in the "Redemptoris mundi Matris Ecclesiæ Lauretana historia," by a certain Teremannus, contained in the *Opera Omnia* (1576) of Baptista Mantuanus. According to this narrative the house at Nazareth in which Mary had been born and brought up, had received the annunciation, and had lived during the childhood of Jesus and after His ascension, was converted into a church by the apostles, and worship continued to be held in it until the fall of the kingdom of Jerusalem. Threatened with destruction by the Turks, it was carried by angels through the air and deposited (1291) in the first instance on a hill at Tersato in Dalmatia (some miles inland from Zengg), where an appearance of the Virgin and numerous miraculous cures attested its sacredness, which was confirmed by investigations made at Nazareth by messengers from the governor of Dalmatia. In 1294 the angels carried it across the Adriatic to a wood near Recanati; from this wood (lauretum), or from the name of its proprietrix (Laureta), the chapel derived the name which it still retains ("sacellum gloriosæ Virginis in Laureto"). From this spot it was afterwards (1295) removed to the present hill, one other slight adjustment being required to fix it in its actual site. Bulls in favour of the shrine at Loreto were issued by Sixtus IV. in 1491 and by Julius II. in 1507, the last alluding to the translation of the house with some caution ("ut pie creditur et fama est"). The recognition of the sanctuary by subsequent pontiffs has already been alluded to. In the end of the 17th century Innocent XII. appointed a "missa cum officio proprio" for the feast of the Translation of the Holy House, and the Festum Translationis Almæ Domus Lauretanæ B. M. V. is still enjoined in the Spanish Breviary as a "duplex majus" (December 10). In the sixth lesson it is stated that "the house in which the Virgin was born, having been consecrated to the divine mysteries, was by the ministry of angels removed from the power of the infidels first to Dalmatia and afterwards to the Lauretan field during the pontificate of Celestine V. That it is the identical house in which the Word was made flesh and dwelt among men is attested by papal documents, by the veneration of all the world, by continued miracles, and by the grace of heavenly blessings."

LORIENT, capital of an arrondissement in the department of Morbihan, and of one of the five maritime prefectures of France, a military port and fortified place, stands on the right bank of the Scorff, at its confluence with the Blavet, in 47° 45′ N. lat. and 3° 31′ W. long., on the railway line from Nantes to Brest, at a distance of 117 miles from the former and 111 from the latter. The town, which is modern and regularly built, contains no buildings of special architectural or antiquarian interest; it derives all its importance from its naval establishments lining the right bank of the river, which include sail-making works, cooperages, and shops for all kinds of ship carpentry. The rope-work forms a parallelogram more than 1000 feet in length by 100 broad. The foundries, fitting shops, and smiths' shops are on an equally extensive scale, the forges numbering eighty-four. Of the graving docks the largest is 509 feet in length, about 98 in breadth, and more than 26 feet in depth below low-water mark. The Prée, an area of 40 acres reclaimed from the sea, contains boatbuilding yards, steam saw-mills, and wood stores; a floating bridge 900 feet long connects it with the shipbuilding establishments of Caudan, which occupy the peninsula formed by the confluence of the Scorff and the Blavet. Apart from its naval constructions, in which Lorient holds the first rank in France, it has an important place in the manufacture of marine artillery. Private industry is also engaged in engine making. The trade in fresh fish and sardines within the arrondissement reaches an annual value of 35 millions of francs. South from the town, also on the Scorff, is the harbour, which comprises a dry dock and a wet dock, measuring about 1650 feet by 200. The roadstead, formed by the estuary of the Blavet, is accessible to vessels of the largest size; the entrance, 3 or 4 miles south from Lorient, which is defended by numerous forts, is marked on the east by the peninsula of Gâvre (an artillery practising ground) and the fortified town of Port Louis; on the west are the fort of Loqueltas, and, higher up, the battery of Kernevel. In the middle of the channel is the granite rock of St Michel, occupied by a powder magazine. Opposite it, on the right bank of the Blavet, is the mouth of the river Ter, with fish and oyster breeding establishments, from which 10 millions of oysters are annually obtained. Above Lorient on the Scorff, here spanned by a suspension bridge, is Kerantrech, a pretty village surrounded by numerous country houses. The population of Lorient in 1876 was 35,165, including 6360 of the military and official class.

Lorient has taken the place of Port Louis as the port of the Blavet. The latter stands on the site of an ancient hamlet which was fortified during the wars of the League and handed over by Mercœur to the Spaniards. After the treaty of Vervins it was restored to France, and it received its name of Port Louis under Richelieu. Some Breton merchants trading with the Indies had established themselves first at Port Louis, but in 1628 they built their warehouses on the other bank. The Compagnie des Indes, created in 1664, took possession of these, giving them the name of Lorient. In 1745 the company, then at the acme of its prosperity, owned thirty-five ships of the largest class and many others of considerable size. The failure of the attempt of the English under Lestock against Lorient is still commemorated by the inhabitants by an annual procession on the first Sunday of October. The decadence of the company dates from 1753. In 1782 the town was acquired by purchase by Louis XVI., on the bankruptcy of its former owners, the Rohan-Guéméné family.

LORRAINE (Lotharingia, Lothringen) is geographically the extensive Austrasian portion of the realm allotted by the partition treaty of Verdun in August 843 to the emperor Lothair I., and inherited by his second son, King Lothair II., 855–869, from whose days the name *Regnum Lotharii* first arose. This border-land between the realms of the Eastern and Western Franks in its original extent took in most of the Frisian lowlands between the mouths of the Rhine and the Ems, and a strip of the right shore of the Rhine to within a few miles of Bonn. In the neighbourhood of Bingen it receded from the left shore of the river so as to exclude the dioceses of Worms and Spires, but to admit a certain connexion with Alsace. Towards the west it included nearly the whole territory which is watered by the rivers Moselle and Meuse, and spread over the dioceses of Cologne, Treves, Metz, Toul, Verdun, Liége, and Cambrai. Hence this artificial realm embraced, broadly speaking, almost all modern Holland and Belgium (with the exception of Flanders), part of the Prussian Rhine provinces, and what is still called Lorraine, partly French and partly German, divided, however, from Alsace and the Palatinate by the natural frontier line of the Vosges and the Haardt mountains. Its inhabitants were soon called *Hlotharii*, *Lotharienses*, *Lotharingi*. Lotharingia, as the designation of the country, hardly appears before the middle of the 10th century.

Up to this time Lorraine had belonged alternately to the eastern and the western kingdom ever since Louis the German and Charles the Bald divided the realm of Lothair II. more ethnographically by the treaty of Meersen, August 8, 870. After the deposition in 887 of the emperor Charles III., who for a short time appeared at the head of the three reunited realms, the country still remained distinct, though the invasions of the Northmen and feudal disintegration creeping in from the west vied to tear it to pieces. Yet the emperor Arnulf, after his success against the Scandinavians, restored some order, and made his son Zwentebulch king over that part of the empire in 894. But he never overcame the difficulties inherent in a country peopled by Franks, Burgundians, Almains, Frisians, and Scandinavians, speaking various Romance and Teutonic dialects, the western group being evidently attracted by the growth of a French, the eastern by that of a German nationality. King Zwentebulch quarrelled with certain powerful lords, offended mortally the bishops, especially that of Treves, and finally lost his life in battle on the 13th August 900. In the days of Louis the Child, the last of the eastern Carolings, there rose to ducal dignity Reginar Long-neck, count of Haspengau, Hennegau, or Hainault, who owned a number of fiefs and monasteries in the diocese of Liége. He found it profitable to adhere to Charles, king of the Western Franks, especially after Louis's death in 911. His son Gisilbert from 915 began to rule the Lotharingians likewise in opposition to Conrad I. and Henry I., who were the successors of Louis the Child, with the exception, however, of Alsace and the Frisian districts, which now separated, definitively to remain with the German kingdom. By the treaty of Bonn (921) the Lotharingian duchy was ceded formally to France, until Henry I., profiting by the disunion between Charles the Simple and his rivals, subdued Gisilbert and his dominion (925), and about 928 returned it to him with the hand of his daughter as a member of the German kingdom, though rather more independent than other duchies. Its western frontier now appears to have extended up to the Dutch Zealands.

Henry's son, the great Otto I., when his brother rebelled in conjunction with Eberhard and Gisilbert, the dukes of Franconia and Lotharingia, beat and annihilated these two vassals (939), and secured the latter country by a treaty with the French king Louis IV., who married Gisilbert's widow, entrusting it consecutively to his brother Henry, to a Duke Otto, and from 944 to Conrad the Red, his son-in-law. Chiefly with the help of the Lotharingians he invaded France in order to reinstate the king, who had been dethroned by his proud vassals. But a few years later, when Liudulf, the son of King Otto and the English Edith, and Duke Conrad, discontented with certain measures, rose against their father and lord, the ever-restless spirit of the Lotharingians broke out into new commotions. The stern king, however, suppressed them, removed both his son and his son-in-law from their offices, and appointed his youngest brother, the learned and statesmanlike Brun, archbishop of Cologne and chancellor of the realm, to be also duke or, as he is called, archduke of Lotharingia. Brun snatched what was still left of demesne lands and some wealthy abbeys like St Maximine near Treves from the rapacious nobles, who had entirely converted the offices of counts and other functionaries into hereditary property. He presided over their diets, enforced the public peace, and defended with their assistance the frontier lands of Germany against the pernicious influence of the death struggle fought between the last Carolings of Laon and the dukes of Paris. Quelling the insurrections of a younger Reginar in the lower or ripuarian regions, he admitted a faithful Count Frederick, who possessed much land in the Ardennes, at Verdun, and at Bar, to ducal dignity. Although the emperor, after Brun's early death, October 10, 965, took the border-land into his own hands, he connived, as it appears, at the beginning of a final division between an upper and a lower duchy,—leaving the first to Frederick and his descendants, while the other, administered by a Duke Gottfrid, was again disturbed by a third Reginar and his brother Lambert of Louvain. When Otto II. actually restored their fiefs to them in 976, he nevertheless granted the lower duchy to Charles, a son of the Caroling Louis IV., and his own aunt Gerberga. Henceforth there are two duchies of Lorraine, the official name applying originally only to the first, but the two dignitaries being distinguished as *Dux Mosellanorum* and *Dux Ripuariorum*, or later on *Dux Metensis* or *Barrensis* and *Dux Lovaniensis*, *de Brabantia*, *Bullionis*, or *de Limburg*. Both territories now swarmed with ecclesiastical and temporal lords, who struggled to be independent, and, though nominally the subjects of the German kings and emperors, frequently held fiefs from the kings and the grand seigneurs of France.

Between powerful vassals and encroaching neighbours the imperial delegate in the lower duchy could only be a still more powerful seigneur. But Duke Charles became the captive of the bishop of Laon, and died in 994. His son, Duke Otto, dying childless (1004), left two sisters married to the counts of Louvain and Namur. Between 1012 and 1023 appears Duke Gottfrid I., son of a count of Verdun, and supporter of the emperor Henry II., who, fighting his way against the counts of Louvain, Namur, Luxemburg, and Holland, is succeeded by his brother Gozelo I., hitherto margrave of Antwerp, who since 1033, with the emperor's permission, ruled also Upper Lorraine, and defended the frontier bravely against the incursions of Count Odo of Blois, the adversary of Conrad II. At his death (1046) the upper duchy went to his second son Gottfrid, while the eldest, Gozelo II., succeeded in the lower, until he died childless (1046). But Gottfrid II. (the Bearded), an energetic but untrustworthy vassal, rebelled twice in alliance with King Henry I. of France and Count Baldwin V. of Flanders against the emperor Henry V., who opposed a union of the duchies in such hands. Lower Lorraine therefore was given (1046) to Count Frederick of Luxemburg, after whose death (1065) it was nevertheless held by Gottfrid, who in the mean time, being banished the country, had married Beatrice, the widow of Boniface of Tuscany, and acted a prominent part in the affairs of Italy. As duke of Spoleto and champion of the Holy See he rose to great importance during the turbulent minority of Henry IV. When he died December 21, 1069, his son Gottfrid III., the Hunchbacked, succeeded in the lower duchy, who for a short time was the husband to Matilda of Canossa, the daughter of Boniface and Beatrice. Soon, however, he turned his back on Italy and the pope, joined Henry IV., fought with the Saxon rebels and Robert of Flanders, and in the end was miserably murdered by an emissary of the count of Holland, February 26, 1076. Conrad, the emperor's young son, now held the duchy nominally till it was granted 1088 to Gottfrid IV., count of Bouillon, and son of Ida, a sister of Gottfrid III., and Count Eustace of Boulogne, the hero of the first crusade, who died king of Jerusalem in 1100. After him Henry, count of Limburg, obtained the country; but, adhering to the old emperor in his last struggles, he was removed by the son in May 1106 to make room for Gottfrid V., the great-grandson to Lambert I., count of Lorraine, a descendant of the first ducal house, which had been expelled by Otto the Great. Nevertheless he joined his predecessor in rebellion against the emperor (1114), but returned to his side in the war about the see of Liége. Later on he opposed King Lothair III., who in turn supported Walram, son of Henry of Limburg, but died in peace with Conrad

III., January 15, 1139. His son Gottfrid VI. was the last duke of Lower Lorraine, and second duke of Brabant. Henceforth the duchy split definitely into that of Limburg, the inheritance of the counts of Verdun, and that of Louvain or Brabant, the dominion of the ancient line of the counts of Haspengau. Various fragments remained in the hands of the counts of Luxemburg, Namur, Flanders, Holland, Juliers, &c.

Upper Lorraine, a hilly table-land, is bordered on the east by the ridge of the Vosges, on the north by the Ardennes, and on the south by the table-land of Langres. Towards the west the open country stretches on into Champagne. The Meuse and the Moselle, the latter with its tributaries Meurthe and Saar, run through it from S.E. to N.W. in a direction parallel to the ridge of the Argonnes. In this country Duke Frederick was succeeded by his son and grandson till 1033. Afterwards Gozelo I. and Gottfrid the Bearded, Count Albert of Alsace and his brother or nephew Gerard, held the duchy successively under very insecure circumstances. The ducal territories were even then on all sides surrounded and broken in upon, not only by those of the three bishops, but also by the powerful counts of Bar. Moreover, when in 1070 a new dynasty was established in Theodoric, son of Count Gerard of Alsace, his brother Gerard of Vaudemont became the founder of a separate line. The former political and feudal ties still connected the duchy with the empire. The bishops were the suffragans of the archbishop of Treves, who rose to be one of the prince-electors. The dukes, however, descending from Theodoric in the male line, though much weakened by the incessant dilapidation of their property, for two centuries adhered generally to the emperor. Duke Simon I. was step-brother of the emperor Lothair III.; his son Matthew I. intermarried with the Hohenstaufen family. His son and grandsons appear traditionally on the side of Henry VI., Philip, Frederick II., and but rarely prefer the Welfish opponent. Later on Theobald II. and Frederick IV. supported Albert and Frederick of Austria against Louis the Bavarian. Yet during the same age French feudalism and chivalry, French custom and language, advanced steadily to the disadvantage of German policy and German idioms amongst knights and citizens. King Philip Augustus already promoted Frenchmen to the sees of Cambrai, Verdun, and Toul. Though remaining a fief of the empire, the duchy of Lorraine itself, a loose accumulation of centrifugal elements, was irresistibly attracted by its western neighbour, although the progress of French monarchy for a time was violently checked by the English invasion. Duke Rudolf, a great grandson of Rudolf of Hapsburg, died at Crécy among the French chivalry, like his brother-in-law the count of Bar. To his son John, who was poisoned at Paris (1391), Charles, called the Bold, succeeded, while his brother Frederick, who was slain at Agincourt, had annexed the county of Vaudemont by right of his wife. Charles, who died in 1431 without male issue, had bestowed his daughter Isabella in marriage on René, count of Anjou, and titular king of Naples, Sicily, and Jerusalem, and also a French vassal for fragments of the duchy of Bar, and the fiefs of Pont à Mousson and Guise. However, when he obtained by right of his wife the duchy of Lorraine, he was defeated by Anthony, the son of Frederick of Vaudemont. But by his daughter Iolanthe marrying Frederick II., Count Anthony's son and heir, the duchies of Lorraine and Bar were in the end united by René II. with the county of Vaudemont and its dependencies Aumale, Mayenne, and Elbœuf. In the meantime all these prospects were nearly annihilated by the conquests of Charles of Burgundy, who evidently had chosen Lorraine to be the keystone of a vast realm stretching from the North Sea to the Mediterranean. This new border empire, separating Germany from France, fell almost instantly to pieces, however, when the bold Burgundian lost his conquests and his life in the battle of Nancy, January 4, 1477. After this the duchy tottered on, merging ever more into the stream of French history, though its bishops were princes of the empire and resided in imperial cities. At the death of René II. (1508), his eldest son Anthony, who had been educated in the court of France, inherited Lorraine with its dependencies. The second, Claude, was first duke of Guise, and the third, John, alternately or conjointly with his nephew Nicolaus, bishop of Metz, Toul, and Verdun, better known as the cardinal of Lorraine. Still the old connexion reappeared occasionally during the French wars of the emperor Charles V. In 1525 the country was invaded by German insurgents, and Lutheranism began to spread in the towns. When Maurice, elector of Saxony, and the German princes rose against the emperor (1552), they sold the three bishoprics and the cities of Toul, Metz, and Verdun, as well as Cambrai, to King Henry II., and hailed him as imperial vicar and *vindex libertatis Germaniæ*. In vain did Charles V. lay siege to Metz for nearly three months; the town, already entirely French, was successfully defended by the duke of Guise. German heresy also lost its hold in these territories owing to the Catholic influence of the house of Guise, which ruled the court of France during an eventful period. Charles II., the grandson of Duke Anthony, who as a descendant of Charles the Caroling even ventured to claim the French crown against the house of Bourbon, had by his wife, a daughter of King Henry II., two sons. But Henry, the eldest, brother-in-law to Henry of Navarre, leaving no sons, the duchy at his death, July 31, 1624, reverted to his brother Francis, who, on November 26, 1625, resigned it in favour of his son Charles III., the husband of Duke Henry's eldest daughter. Siding against Richelieu with the house of Austria and Duke Gaston of Orleans, Charles, after being driven out by the French and the Swedes, resigned the duchy, January 19, 1634; and like the three bishoprics it was actually allotted to France by the peace of Westphalia. The duke, however, after fighting with the Fronde, and with Condé and Spain against Turenne and Mazarin, and quarrelling in turn with Spain, was nevertheless reinstated by the treaty of the Pyrenees (1659) under hard conditions. He had to cede the duchy of Bar, to raze the fortifications of Nancy, and to yield the French free passage to the bishoprics and Alsace. But, restless as ever, after trying to be raised among the princes of the blood royal in return for a promise to cede the duchy, he broke again with Louis XIV., and was expelled once more together with his nephew and heir Charles IV. Leopold. Both fought in the Dutch war on the German side in the vain hope of reconquering their country. When Charles IV. after his uncle's death refused to yield the towns of Longwy and Nancy according to the peace of Nimeguen, Louis XIV. retained the duchy, while its proprietor acted as governor of Tyrol, and fought the Turks for the emperor Leopold I., whose sister he had married. In the next French war he commanded the imperial troops. Hence his son Leopold Joseph, at the cost of Saarlouis, regained the duchy once more by the treaty of Ryswick (1697). This prince carefully held the balance between the contending parties, when Europe struggled for and against the Bourbon succession in Spain, so that his court became a sanctuary for pretenders and persecuted partisans. His second son Francis Stephen, by a daughter of Duke Philip of Orleans, and his heir since 1729, surrendered the duchy ultimately, owing to the defeat of Austria in the war for the Polish crown (1735). This being lost by Stanislaus Leszczynski, the father-in-law of Louis XV., the usufruct of Lorraine and a comfortable residence at Nancy were granted to the

Polish prince till his death (1766). And now for more than a century all Lorraine and Alsace up to the Rhine were French. Meanwhile Francis Stephen, since 1736 the husband of Archduchess Maria Theresa, had obtained in compensation the grand-duchy of Tuscany, where the last of the Medici died in 1737. He became his wife's coregent in the Austrian provinces (1740), and was elected king of the Romans and crowned emperor 1745, the ancestor of the present rulers of Austria. When in the recent Franco-German war both Strasburg and Metz were taken by the German troops after a gallant defence, the French had to submit in the peace of Frankfort, May 10, 1871, to the political and strategical decisions of the conquerors. Old German territory, all Alsace, and a portion of Lorraine, the upper valley of the Saar, the strong fortresses of Diedenhofen (Thionville) and Metz on the Moselle, with the surrounding districts, viz., the greater part of the Moselle and the Meurthe departments, where here and there German is still the language of the inhabitants, were the spoils of victory. They are now united and administered in all civil and military matters as an imperial province of the new German empire.

See Calmet, *Histoire Ecclesiastique et civile de la Lorraine*, 3 vols.; Mascov, *Dissertatio de nexu Lotharingiæ regni cum imperio Romano Germanico*; Usinger, "Das deutsche Staatsgebiet bis gegen Ende des eilften Jahrhunderts," *Hist. Zeitschrift*, xxvii. 374; Waitz, *Deutsche Verfassungsgeschichte*, vols. v.–vii; Giesebrecht, *Geschichte der Deutschen Kaiserzeit*, vols. i.–v.; Henri Martin, *Histoire de France*, 17 vols.; Ranke, *Deutsche Geschichte im Zeitalter der Reformation*, 6 vols.; Ranke, *Französische Geschichte*, 5 vols.; A. Schmidt, *Elsass und Lothringen, Nachweis wie diese Provinzen dem deutschen Reiche verloren gingen*, 1859. (R. P.)

LORY, a word of Malayan origin signifying Parrot,[1] in general use with but slight variation of form in many European languages, is the name of certain birds of the order *Psittaci*, mostly from the Moluccas and New Guinea, which are remarkable for their bright scarlet or crimson colouring, though also, and perhaps subsequently, applied to some others in which the plumage is chiefly green. The "Lories" have been referred to a considerable number of genera, of which *Eclectus*, *Lorius* (the *Domicella* of some authors), *Eos*, and *Chalcopsittacus* may be here particularized, while under the equally vague name of "Lorikeets" may be comprehended the genera *Charmosyna*, *Loriculus*, and *Coriphilus*. By most systematists some of these forms have been placed far apart, even in different families of *Psittaci*, but Garrod has shown (*Proc. Zool. Society*, 1874, pp. 586–598, and 1876, p. 692) the many common characters they possess, which thus goes some way to justify the relationship implied by their popular designation. The latest and perhaps the most complete account of these birds is to be found in the first part of Count T. Salvadori's *Ornitologia della Papuasia e delle Molucche*, published at Turin in 1880, though he does not entirely accept Garrod's arrangement. Of the genus *Eclectus* the Italian naturalist admits five species, namely, *E. pectoralis* and *E. roratus*, (which are respectively the *polychlorus* and *grandis* of most authors), *E. cardinalis* (otherwise *intermedius*), *E. westermani*, and *E. cornelia*—the last two from an unknown habitat, though doubtless within the limits of his labour, while the first seems to range from Waigiou and Mysol through New Guinea, including the Kei and Aru groups, to the Solomon Islands, and the second is peculiar to the Moluccas and the third to Bouru, Amboyna, and Ceram. Still more recently Dr A. B. Meyer has described (*Proc. Zool. Society*, 1881, p. 917) what he considers to be another species, *E. riedeli*, from Cera or Seirah, one of the Tenimber group, of which Timor Laut is the chief, to the south-west of New Guinea.[2] Much interest has been excited of late by the discovery in 1873, by the traveller and naturalist last named, that the birds of this genus possessing a red plumage were the females of those wearing green feathers. So unexpected a discovery, which was announced by Dr Meyer on the 4th of March 1874, to the Zoological and Botanical Society of Vienna,[3] naturally provoked not a little controversy, for the difference of coloration is so marked that it had even been proposed to separate the Green from the Red Lories generically[4]; but now the truth of his assertion is generally admitted, and the story is very fully told by him in a note contributed to Gould's *Birds of New Guinea* (part viii., 1st October 1878), though several interesting matters therewith connected are still undetermined. Among these is the question of the colour of the first plumage of the young, a point not without important signification to the student of phylogeny.[5]

Though the name Lory has long been used for the species of *Eclectus*, and some other genera related thereto, some writers would restrict its application to the birds of the genera *Lorius*, *Eos*, *Chalcopsittacus*, and their near allies, which are often placed in a subfamily, *Loriinæ*, belonging to the so-called Family of *Trichoglossidæ*, or "Brush-tongued" Parrots. Garrod in the course of his investigations on the anatomy of *Psittaci* was led not to attach much importance to the structure indicated by the epithet "brush-tongued," stating (*Proc. Zool. Society*, 1874, p. 597) that it "is only an excessive development of the papillæ which are always found on the lingual surface." The birds of this group are very characteristic of the New-Guinea Subregion,[6] in which occur, according to Count Salvadori, ten species of *Lorius*, eight of *Eos*, and four of *Chalcopsittacus*; but none seem here to require any further notice,[7] though among them, and particularly in the genus *Eos*, are included some of the most richly-coloured birds to be found in the whole world; nor does it appear that more need be said of the so-called Lorikeets. (A. N.)

LOS ANGELES, a city of the United States, the capital of Los Angeles county, California, is situated in the lowland between the Sierra Madre and the Pacific, about 17 miles from the coast, on the west bank of a stream of its

[1] The anonymous author of a *Vocabulary of the English and Malay Languages*, published at Batavia in 1879, in which the words are professedly spelt according to their pronunciation, gives it "*looree*." Buffon (*Hist. Nat. Oiseaux*, vi. p. 125) states that it comes from the bird's cry, which is likely enough in the case of captive examples taught to utter a sound resembling that of the name by which they are commonly called. Nieuhoff (*Voyages par mer et par terre à differents lieux des Indes*, Amsterdam, 1682–92) seems to have first made the word "Lory" known (*cf.* Ray, *Synops. Avium*, p. 151). Crawfurd (*Dict. Engl. and Malay Languages*, p. 127) spells it "nori" or "nuri"; and in the first of these forms it is used, says Dr Finsch (*Die Papageien*, ii. p. 732), by Pigafetta. Aldrovandus (*Ornithologia*, lib. xi. cap. 1) noticed a Parrot called in Java "nor," and Clusius (*Exotica*, p. 364) has the same word. This will account for the name "noyra" or "noira" applied by the Portuguese, according to Buffon (*ut supra*, pp. 125–127); but the modern Portuguese seem to call a Parrot generally "Louro," and in the same language that word is used as an adjective, signifying bright in colour. The French write the word "Loury" (*cf.* Littré, *sub voce*). The Lory of colonists in South Africa is a TOURACOO (*q.v.*); and King Lory is a name applied by dealers in birds to the Australian Parrots of the genus *Aprosmictus*.

[2] There seems just a possibility of this, however, proving identical with either *E. westermani* or *E. cornelia*—both of which are very rare in collections.

[3] *Verhandl. z.-b. Gesellsch. Wien*, 1874, p. 179; and *Zool. Garten*, 1874, p. 161.

[4] *Proc. Zool. Society*, 1857, p. 226.

[5] The chemical constitution of the colouring matter of the feathers in *Eclectus* has been treated by Dr Krukenberg of Heidelberg (*Vergl. physiol. Studien*, Reihe ii. Abth. i. p. 161, reprinted in *Mittheil. Orn. Vereines in Wien*, 1881, p. 83).

[6] They extend, however, to Fiji, Tahiti, and Fanning Island.

[7] Unless it be *Oreopsittacus arfaki*, of New Guinea, remarkable as the only Parrot known as yet to have fourteen instead of twelve rectrices.

own name. It lies 483 miles by rail south-south-east of San Francisco on the Southern Pacific Railroad, and is connected by branch lines with Wilmington, Santa Monica (both on the coast), and Santa Ana. As the centre of a fine orange and grape growing country, and a resort for invalids, Los Angeles is a place of some importance; and since the opening of the railways it has been in full prosperity, the old adobe buildings rapidly giving place to more substantial structures. Founded in 1781 by the Spaniards, it received the name "Town of the Queen of the Angels" (*Pueblo de la Reina de los Angeles*) as a tribute to the beauty and pleasantness of the spot. It was the capital of the Mexican state of California from 1836 to 1846, in which latter year it was captured by United States forces. The population has increased from 5728 in 1870 to 11,311 in 1880.

LOT, the ancestor of Moab and Ammon, was the son of Haran and grandson of Terah, and accompanied his uncle Abraham in his migration from Haran to Canaan. At Bethel[1] Lot separated from Abraham, and, while the uncle went on to Hebron, the nephew settled in the district of Sodom. When Jehovah was about to destroy Sodom and the other cities of the plain two divine messengers appeared, spent the night in Lot's house, and next morning led Lot, his wife, and his two unmarried daughters out of the city. His wife looked back and was changed to a pillar of salt,[2] but Lot with his two daughters escaped first to Zoar and then to the mountains east of the Dead Sea, where the daughters, supposing themselves the only survivors of the catastrophe that had destroyed their home, planned and executed an incest by which they became mothers. The sons were the ancestors of Ammon and Moab. Such is the outline of the Jahvistic history of Lot, which the priestly narrator epitomizes in a few words, the only statement peculiar to his narrative being that in Gen. xi. 27-32. The account of Chedorlaomer's invasion and of Lot's rescue by Abraham belongs to an independent source, the age and historical value of which has been much disputed. See on the one hand Ewald, *Geschichte*, vol. i., and Tuch in his *Genesis*, and in an essay originally published in *Z.D.M.G.*, vol. i., and reprinted in the second edition of his *Genesis*, and on the other hand the essay in Nöldeke, *Untersuchungen*, and Wellhausen, *ut supra*, p. 414.

The name Lot (לוֹט) signifies "a veil," which has led Goldzieher, *Mythologie*, p. 216 *sq.*, to the arbitrary hypothesis that the story of Lot and his daughters is a myth about the night. Lot and his daughters passed into Arabic tradition from the Jews. The daughters are named Zahy and Ra'wa by Mas'ûdy, ii. 139; but other Arabian writers give other forms.

LOT, a south-westerly department of central France, corresponding to what was formerly known as Quercy (the country of the Cadurci), a district of the old province of Guyenne, is situated between 44° 12′ and 45° 5′ N. lat., and between 1° and ·2° 12′ E. long., and is bounded on the N. by Corrèze, on the W. by Dordogne and Lot-et-Garonne, on the S. by Tarn-et-Garonne, and on the E. by Aveyron and Cantal. Its extreme length, from north-east to south-west, is about 52 miles, and its breadth from north-west to south-east 31 miles, with an area of 2013 square miles. It slopes towards the south-west, from a maximum altitude of 2560 feet on the borders of Cantal to a minimum of 213 feet at the point where the river Lot quits the department, through a wide geological range beginning with primary rocks (granite, gneiss, mica-schists), which are succeeded by lias, oolitic limestone (occupying the greater portion of the area), chalks, and finally by Tertiary formations. The Lot, which traverses it from east to west, is navigable for the whole distance (78 miles) with the help of locks; its principal tributary within the department is the Célé (on the right). In the north of the department the Dordogne has a course of 37 miles; among its tributaries are the Cère, which has its rise in Cantal, and the Ouysse, a river of no great length, but remarkable for the abundance of its waters. The streams in the south of Lot all flow into the Tarn. By the Dordogne and Lot the surface is divided into a number of limestone plateaus known by the name of "causses"; that to the north of the Dordogne is called the Causse de Martel; between the Dordogne and the Lot is the Causse de Gramat or de Rocamadour; south of the Lot is the Causse de Cahors. These "causses," owing to the rapid disappearance of the rain through the faults in the limestone, have for the most part an arid appearance, and their rivulets are generally mere dry beds; but their altitude (from 700 to 1300 feet, much lower therefore than that of the similar plateaus in Lozère, Hérault, and Aveyron) admits of the cultivation of the vine; they also yield a small quantity of maize, wheat, oats, rye, and potatoes, and some wood. The deep intervening valleys are full of verdure, being well watered by abundant springs supplied by drainage from the plateaux above. The climate is on the whole that of the Girondine region; the valleys are warm, and the rainfall is somewhat above the average for France. The difference of temperature between the higher parts of the department belonging to the central plateau and the sheltered valleys of the south-west is considerable. Of the entire area of the department 691,920 acres are arable, 222,402 are forest land, 168,038 are occupied by vineyards, 64,250 are heath, and 61,778 are meadow. Sheep are the most abundant kind of live stock; but pigs, horned cattle, horses, asses, and mules, and goats are also reared, as well as poultry in large quantities, and bees. Wine is the principal product of the department, the most valued being that of Cahors or Côte du Lot. It is used partly for blending with other wines and partly for local consumption. The north-east cantons supply large quantities of chestnuts; apples, cherries, and peaches are common, and the department also grows tobacco and supplies truffles. The iron, lead, and zinc deposits are unimportant. Marble, millstones, limestone, and clay are obtained to some extent, but phosphate of lime is the most valuable mineral product of Lot. The manufactures are inconsiderable; but there are numerous mills, and wool spinning and carding as well as cloth making, tanning, currying, brewing, and agricultural implement making are carried on to some extent. The exports consist of grain, flour, wine, brandy, live stock, nuts, truffles, prunes, tobacco, wood, phosphate of lime, leather, and wool. The population in 1876 was 276,512. The three arrondissements are Cahors, Figeac, and Gourdon; there are twenty-nine cantons and three hundred and twenty-three communes.

LOT-ET-GARONNE, a department of south-western France, made up of Agenais and Bazadais, two districts of the former province of Guyenne, and Condomois and Lomagne, formerly portions of Gascony, lies between 43° 50′ and 44° 45′ N. lat., and 1° 7′ E. and 8′ W. long., and is bounded on the W. by Gironde, on the N. by Dordogne, on the E. by Lot and Tarn-et-Garonne, on the S. by Gers, and on the S.W. by Landes; its extreme length from south-west to north-east is 62 miles, and it has an area of 2067 square miles. The Garonne, which traverses the department from south-east to north-west, divides it into two unequal parts; in that to the north the slope is from east to west, while in that to the south it is directly from south to north. A small portion in the south-west belongs

[1] In Gen. xii. 10 *sq.*, where Abraham's visit to Egypt is recorded, there is no mention of Lot, and Wellhausen (*Jahrb. f. D. Theol.*, 1876, p. 413) has made it probable that this episode is no part of the Jahvistic narrative, to which the history of Lot mainly belongs.

[2] Such a pillar in the neighbourhood of Usdum is described by Lynch, *Narrative*, p. 307. See also Robinson, *Bib. Res.*, 2d ed., ii. 108.

to the sterile region of the Landes; the valleys of the Garonne and of the Lot (its greatest affluent here) on the other hand are proverbial for their fertility. The wildest part is in the borders of Dordogne, where oak, chestnut, and beech forests are numerous; the highest point is also here (896 feet). The Garonne, where it quits the department, is only some 33 or 36 feet above the sea-level; it is navigable throughout, with the help of its lateral canal, as also are the Lot and Bayse with the help of locks. The Dropt, a right affluent of the Garonne in the north of the department, is also navigable in the lower part of its course. The climate is that of the Girondine region, the mean temperature of Agen being 56°·6 Fahr., or 5° above that of Paris; the rainfall (31·5 inches) is also above the average of France. Of the entire area 741,342 acres are arable, 210,047 are vineyard, 172,980 under wood, 85,254 natural meadow, and 56,836 waste. Horned cattle are the chief live stock; next in order come pigs, sheep, horses, asses, and mules, and a small number of goats. Poultry and bees are also reared. Its wines and its cereals are a great source of wealth to the department; in 1875 488,000 quarters of grain and 14,000,000 gallons of wine were produced. Potatoes, beetroot, pulse, and maize are also largely grown; next come rye, barley, meslin, and buckwheat. In 1877 7759 acres produced 5,838,849 lb of tobacco, worth upwards of two million francs. Colza, hemp, and flax are also extensively cultivated. The fruit harvest (nuts, chestnuts, apricots) is large and valuable, the prunes which take their name from Agen being especially in demand. The forests in the south-west supply pine wood and cork. The forges, high furnaces, and foundries of the department are important; brazier's ware is also produced; and there are workshops for the manufacture of agricultural implements and other machines. The making of plaster, lime, and hydraulic cement, of tiles, bricks, and pottery, of confectionery and other eatables, and brewing and distilling, occupy many of the inhabitants. At Tonneins there is a national tobacco manufactory, and the list of industries is completed by the mention of boatbuilding, cork cutting, hat and candle making, wool spinning, weaving of woollen and cotton stuffs, tanning, paper making, oil making, and flour and saw milling. In 1876 the population was 316,920 (1100 Protestants). The inhabitants speak a patois in which elegant and graceful works have been written, such as the poems of Jasmin (*q.v.*). The arrondissements are four,—Agen, Marmande, Nérac, and Villeneuve; and there are thirty-five cantons and three hundred and twenty-five communes.

LOTHAIR I., Roman emperor, eldest son of Louis the Pious, was born in 795. At a diet held at Aix-la-Chapelle in 817 he received Austrasia with the greater part of Germany, and was associated with his father in the empire, while separate territories were granted to his brothers Louis and Pippin. This arrangement being modified in favour of Louis's youngest son Charles (afterwards Charles the Bald), the three brothers repeatedly rebelled, and for a time Lothair usurped supreme power. After the death of Louis in 840, Lothair, as his successor, claimed the right to govern the whole empire. His brothers Louis and Charles (Pippin being dead) united against him, and in 841 he was defeated in the great battle of Fontenay. On the 11th of August 843 the war was brought to an end by the treaty of Verdun, by which Lothair was confirmed in the imperial title, but received as his immediate territory only Italy (which he had ruled from 822) with a long narrow district reaching past the Rhone and the Rhine to the North Sea. His subsequent reign was full of trouble, for many of his vassals had become virtually independent, and he was unable to contend successfully with the Norsemen and the Saracens. In 855, weary of the cares of government, he divided his kingdom among his sons, and retired to the monastery of Prüm, where he died on the 28th of September of the same year. As emperor he was succeeded by his son Louis II.

LOTHAIR THE SAXON, German king and Roman emperor, was originally count of Suplinburg. In 1106 he was made duke of Saxony by the emperor Henry V., against whom he afterwards repeatedly rebelled. After the death of Henry V. in 1125, the party which supported imperial in opposition to papal claims wished to grant the crown to Duke Frederick of Swabia, grandson of Henry IV. The papal party, however, headed by Archbishop Adalbert of Mainz, managed to secure the election of Lothair, who obtained their favour by making large concessions by which he was afterwards seriously hampered. In 1133 he was crowned emperor in Rome by Innocent II., whom he had supported in a disputed papal election. In later times the church pretended that he had done homage to the pope for the empire, but what he really received in fief was the hereditary territory of the Countess Matilda. Meanwhile he had been engaged in bitter strife with the Hohenstaufen family, from whom he had demanded the allodial lands which they had inherited from the emperor Henry V. Duke Frederick of Swabia, and his brother Conrad, had resisted these pretensions; and Conrad had even been crowned king in Milan. The quarrel was ultimately settled by the lands in dispute being granted in fief to the house of Hohenstaufen. In order to strengthen his position, Lothair had given his daughter Gertrude (a child of eleven) in marriage to Henry the Proud, duke of Bavaria, whom he made also duke of Saxony. Henry was further enriched by receiving the hereditary and imperial territories of the Countess Matilda, so that the Guelphs became by far the most powerful family in the empire. Lothair secured other important adherents by giving North Saxony (afterwards Brandenburg) to Albert the Bear, and Thuringia (which he took from Landgrave Hermann) to Count Louis. In his relations to the neighbouring populations Lothair acted with great vigour. The duke of Bohemia and the duke of Poland were compelled to do homage, and the margraviate of Meissen and the county of Burgundy he gave to two of his supporters, the former to Count Conrad of Wettin, the latter to Duke Conrad of Zähringen. The kingdom of the Abotrites he granted to the Danish king Cnut; and Cnut's successor Magnus was forced to accept it as a fief of the empire. In 1136 Lothair undertook a second expedition to Italy for the defence of Pope Innocent II. against Roger of Sicily, and after accomplishing his object he died on the 3d of December 1137, in an Alpine hut near Trent, on his way back to Germany. During his reign the papacy gained ground in its rivalry with the empire, but he displayed courage and resource in maintaining the rights of the crown against all his secular opponents.

See Gervais, *Politische Geschichte Deutschlands unter der Regierung der Kaiser Heinrich V. und Lothar III.*, 1841–42; Jaffé, *Geschichte des deutschen Reichs unter Lothar dem Sachsen*, 1843.

LOTHIAN, Lothene, Laodonia, a name whose origin is unknown,[1] now preserved in the three Scottish counties of East, West, and Mid Lothian—Haddington, Linlithgow, and Edinburgh (*q.v.*)—originally extended from the Forth to the Tweed. The Forth separated it from Celtic Alba, and the Tweed from the southern part of Bryneich (Bernicia). Its western boundaries appear to have been the Cheviots and the Lowthers. After the Anglo-Saxon migration it formed part of the Anglian kingdom of Northumberland, founded by Ida the Flame-bearer in 547, which in its

[1] Loth, son of Anna, the sister of Arthur, a Scottish consul and lord of Laudonia (Fordun, iii. 24), the Llew of the Arthurian legend (Skene, *Four Books of Wales*, chap. iv.), is, of course, an eponymus.

widest extent, under the powerful Northumbrian kings of the 7th century, reached from the Humber to the Forth. A different but allied branch of the Angles settled along the tributaries of the Tweed, and the Cheviot, Lowther, Moorfoot, and Pentland (Pictish) hills separated the colonists of southern Scotland from the British kingdom of Strath Clyde or Cumbria. The victories of Catræth (596) and Dægsastan (603) in the reign of Ethelfrith represent the close of the struggle which drove the British or Cumbrian Celts (Cymry) into the western hill country, afterwards known as Westmoreland and Cumberland, and the Picts to the north of the Forth and Clyde, so that Anglian Northumberland secured the former river as its northern boundary, and even for a time threatened to pass it. Edwin of Deira (617–33), the chief king of England in his time, probably founded Edinburgh, although its Celtic name Dun Eden has been thought by some to suggest a different derivation. Egfrid at the close of the 7th century established an Anglian bishop at Abercorn on the Forth, but was defeated and slain at Nechtansmere, or Dunnichen, in Forfarshire by the Pictish king Brude (685), and Trumwine the bishop at Abercorn was forced to retire to Whitby. In the 8th century the Northumbrian kings were engaged in a conflict with Mercia, and in 827 the supremacy of Egbert, the founder of the West Saxon monarchy, was acknowledged, although on the part of the Northumbrians the recognition must have been at first almost nominal, for it was not until more than a century later that Athelstan, by the victory of Brunanburg (937) over the allied Welsh, Scots, and Northumbrian Danes, really extended the boundaries of the Wessex kingdom over the greater part of Northumbria, which was reduced to an earldom by Edred in 954. Athelstan had in 934 ravaged Scotland north of the Forth, and must for a time have reduced Lothian, the northern district of Northumberland, but it does not appear that either he or any of his successors had real sovereignty over Lothian, which was left to the rule of Northumbrian earls, sometimes of Anglian and at other times of Danish race. Its population continued Anglian, as is proved by the fact that there are no Danish monuments and few Danish place names between the Tweed and the Forth. The Scottish Celts, like the English Anglo-Saxons, were during this period occupied with warding off the Danes and Norsemen, but about the middle of the 9th century Kenneth Macalpine united the Scottish and Pictish kingdoms, and fixed the capital at Scone. This monarch is said by the Pictish chronicle to have six times invaded Saxony (the name given by the Celts to the Anglo-Saxon territory), and to have burnt Dunbar and Melrose. The Anglians of Northumbria had been converted to Christianity by Paulinus in 627, and reconverted by a Celtic mission from Iona between 635 and 651 under Aidan, who planted a mission station—a southern Iona—on the Holy Island, and became first bishop of Lindisfarne. Cuthbert, one of his successors in this bishopric, which had become Anglian and conformed to the Roman ritual and discipline after the council of Whitby (664), has the credit of spreading the gospel in Lothian, where he had been first monk and then prior of the recently founded monastery of Melrose.

About the middle of the 10th century (954-62) Edinburgh was abandoned by the Northumbrian Angles and occupied by Indulph, son of Constantine, king of the Scots. According to John of Wallingford and Roger of Wendover, Edgar the West Saxon king ceded in 966 Lothian to Kenneth III., son of Malcolm I., on condition that he should do homage for it and give pledges not to deprive the people of that region of their ancient customs, and that they should still retain the name and language of the Angles. This cession, which is not in the older chronicles, has been matter of controversy between Freeman (*Norman Conquest*, i., note B, p. 610), who accepts the statement, and E. W. Robertson (*Scotland under her Early Kings*, i. 390) and Skene (*Celtic Scotland*, i. 370), who reject it upon what appear better grounds. But the dispute is of small importance, as it is admitted on the authority of Simeon of Durham that, whether or not it was then ceded on condition of homage, it was annexed to Scotland by conquest in 1018 in consequence of the victory at Carham by Malcolm the son of Kenneth over the Northumbrian earl Eadulf Ciudel,—"Hoc modo," says Simeon writing before 1129, "Lodonium adjectum est regno Scotiæ." Canute and William the Conqueror made temporary conquests of Scotland including Lothian, and homage of various kinds was rendered to them and other Norman monarchs, but there is no trace of any special homage for Lothian except in two dubious charters by Edgar to William Rufus, so that it seems certain that from the beginning of the 11th century it was an integral part of Scotland. Freeman, in his *Historical Geography*, styles it an English earldom, but it is never so called in any authentic record. While it was an integral part of Scotland its population was recognized as a distinct branch of the Scottish nation, and the men of Lothian are frequently separately named, as in the contemporary account of the Battle of the Standard (1138). It also retained its language, customs, and laws, which were those of the Angles of Northumbria. Although united in civil government to Scotland, Lothian, or at least many places in it, continued ecclesiastically subject to the see of Durham, which had succeeded that of Lindisfarne, until the beginning of the 12th century (Stubbs and Haddan, *Concilia*, ii. p. 161), but it then came under the bishop of St Andrews, and was divided into three rural deaneries, the Merse, Haddington, and Linlithgow, with an archdeacon of Lothian, who first distinctly appears under that name at the commencement of the 13th century.

The division of Scotland into shires was probably made by David I., and Lothian included the shires of Berwick or the Merse (the march or borderland, as English Mercia and Spanish Murcia), Roxburgh, and Edinburgh, which included the constabularies of Haddington and Linlithgow, afterwards erected into separate counties. Its principal burghs — Berwick, Roxburgh, and Edinburgh — formed along with Stirling the court of the four burghs, whose laws were collected by David I. ("Leges Quatuor Burgorum," *Act. Parl. Scot.*, i. 327), and whose meeting-place was Haddington, but the frequent occupation of Berwick and Roxburgh by the English caused Lanark and Linlithgow to be substituted, and the place of meeting to be changed to Stirling in 1368. The convention of royal burghs may be traced back to this court.

The independence of Scotland, including Lothian, though frequently disputed by the English sovereigns, was always maintained by the Scotch, except when surrendered by William the Lion as a prisoner by the treaty of Falaise 1174, cancelled by Richard I. in 1189. It was finally acknowledged by Edward I. in the treaty of Brigham, but after the death of the Maid of Norway this acknowledgment was repudiated, and it was only finally established by the war of independence, and definitely recognized in the treaty of Northampton in 1328.

By a singular but fortunate series of events, of which the first was the marriage of Malcolm Canmore with the Saxon princess Margaret, Lothian, the Anglian part of the Scottish kingdom, though its borderland, became its centre. Edinburgh, its chief town, was from that time a favourite residence of the court, and under the Stuart kings became the capital of the kingdom. Its language, the dialect of northern England, became the basis of the Lowland Scots, at first called Inglys or English, but afterwards Scotch, when Celtic, Erse, or Gaelic had ceased to be spoken in the lowland districts, in distinction from southern English. Its customary law, with additions prior to the war of independence of Norman feudal institutions from England, is the basis of those parts of the common law of Scotland which are not taken from Roman jurisprudence. And it was from Lothian that Anglo-Saxon and Anglo-Norman civilization radiated to the remotest parts of the Highlands and Islands. (Æ. M.)

LOTTERIES. The word lottery has no very definite signification. It may be applied to any process of determining prizes by lot, whether the object be amusement, or gambling, or public profit. In the Roman Saturnalia and in the banquets of aristocratic Romans the object was amusement; the guests received *apophoreta.* The same plan was followed on a magnificent scale by some of the emperors. Nero excited the people by giving such prizes as a house or a slave. Heliogabalus introduced an element of absurdity,—one ticket for a golden vase, another for six flies. This amusing custom descended to the festivals given by the feudal and merchant princes of Europe, especially of Italy; and it afterwards formed a prominent feature of the splendid court hospitality of Louis XIV. In the Italian republics of the 16th century the lottery principle was applied to encourage the sale of merchandise. The lotto of Florence and the seminario of Genoa are well known, and Venice established a monopoly and drew a considerable revenue for the state. The first letters patent for a lottery in France were granted by Francis I., and in 1656 the Italian Tonti (the originator of "Tontines") opened another for the building of a stone bridge between the Louvre and the Faubourg St Germain. The institution became very popular in France, and gradually assumed an important place in the Government finance. The parliaments frequently protested against it, but it had the support of Mazarin, and Pontchartrain by this means raised the expenses of the Spanish Succession War. Necker, in his *Administration des Finances*, estimates the public charge for lotteries at 4,000,000 livres per annum. There were also lotteries for the benefit of religious communities and charitable purposes. Two of the largest were the *Loteries de Piété* and *des Enfans Trouvés.* These and also the great *Loterie de l'École militaire* were practically merged in the *Loterie Royale* by the famous decree of 1776, suppressing all private lotteries in France. The financial basis of these larger lotteries was to take $\frac{5}{24}$ths for expenses and benefit, and return $\frac{19}{24}$ths to the public who subscribed. The calculation of chances had become a familiar science. It is explained in detail by M. Caminade de Castres in *Enc. Méth. Finances*, ii., *s. v.* "Loterie." The names of the winning numbers in the first drawing were (1) *extrait,* (2) *ambe,* (3) *terne,* (4) *quaterne,* (5) *quine.* After this there were four drawings called *primes gratuites.* The *extrait* gave fifteen times the price of the ticket; the *quine* gave one million times the price. These are said to be much more favourable terms than were given in Vienna, Frankfort, and other leading European cities at the end of the 18th century. There is no doubt that lotteries had a demoralizing effect on French society. They were denounced by the eloquent bishop of Autun as no better than the popular games of *belle* and *biribi*; they were condemned on financial grounds by Turgot; and Condillac compared them to the debasement of money which was at one time practised by the kings of France. The *Loterie Royale* was ultimately suppressed in 1836. Under the law of 29th May 1844 lotteries may be held for the assistance of charity and the fine arts. The Société du Credit Foncier, and many of the large towns, are permitted to contract loans, the periodical repayments of which are determined by lot. This practice, which is prohibited in Germany and England, resembles the older system of giving higher and lower rates of interest for money according to lot. Lotteries were suppressed in Belgium in 1830, but they still figure largely in the State budgets of Germany, Holland, Spain, and Italy.

In England the earliest lotteries sanctioned by Government were for such purposes as the repair of harbours in 1569, and the Virginia Company in 1612. In 1696 by the Act 10 & 11 Will. III. c. 17 lotteries, with the exception of the Royal Oak lottery, were prohibited as common nuisances, by which children, servants, and other unwary persons had been ruined. This prohibition was in the 18th century gradually extended to illegal insurances on marriages and other events, and to a great many games with dice, such as faro, basset, hazard, except backgammon and games played in the royal palace. In spite of these prohibitions, the Government from 1709 down to 1824 showed a bad example to the nation by annually raising considerable sums in lotteries authorized by Act of Parliament. The prizes were in the form of terminable or perpetual annuities. The £10 tickets were sold at a premium of say 40 per cent. to contractors who resold them in retail (sometimes in one-sixteenth parts) by "morocco men," or men with red leather books who travelled through the country. As the drawing extended over forty days, a very pernicious system arose of insuring the fate of tickets during the drawing for a small premium of 4d. or 6d. This was partly cured by the Little Go Act of 1802, 42 Geo. III. c. 119, directed against the itinerant wheels which plied between the state lotteries, and partly by Perceval's Act in 1806, which confined the drawing of each lottery to one day. From 1793 to 1824 the Government made an average yearly profit of £346,765. Cope, one of the largest contractors, is said to have spent £36,000 in advertisements in a single year. The English lotteries were used to raise loans for general purposes, but latterly they were confined to particular objects, such as the improvement of London, the disposal of Cox's museum, the purchase of Tomkin's picture gallery, &c. Through the efforts of Lyttleton and others a strong public opinion was formed against them, and in 1826 they were finally prohibited. An energetic proposal to revive the system was made before the select committee on metropolitan improvements in 1830, but it was not listened to. By a unique blunder in legislation, authority was given to hold a lottery under the Act 1 & 2 Will. IV. c. 8, which provides a scheme for the improvement of the city of Glasgow. These "Glasgow lotteries" were suppressed by 4 & 5 Will. IV. c. 37. The statute law in Scotland is the same as in England. At common law in Scotland it is probable that all lotteries and raffles, for whatever purpose held, may be indicted as nuisances. The art unions are supposed to be protected by a special statute.

The American Congress of 1776 instituted a national lottery. The scheme was warmly advocated by Jefferson and other statesmen, and before 1820 at least seventy Acts were passed by Congress authorizing lotteries for various public purposes, such as schools, roads, &c.,—about 85 per cent. of the subscriptions being returned in prizes. A sounder opinion now prevails on this subject in America.

The only systematic work on this subject is the *Critique hist. pol. mor. econ. et comm. sur les loteries anc. et. mod. spirituelles et temporelles des États et des Églises*, Amsterdam, 1697, 3 vols., by the Bolognese historian Gregorio Leti. The subject is also dealt with by J. Dessaulx in his work *De la passion du jeu depuis les anciens temps jusqu' à nos jours*, Paris, 1779. (W. C. S.)

LOTUS-EATERS (Greek Λωτοφάγοι) were a Libyan tribe known to the Greeks as early as the time of Homer. Herodotus (iv. 177) describes their country as in the

Syrtic district, and says that a caravan route led from it to Egypt. The lotus still grows there in great abundance. It is a prickly shrub, the jujube tree, bearing a fruit of a sweet taste, compared by Herodotus to that of the date; it is still eaten by the natives, and a kind of wine is made from the juice (see JUJUBE). Marvellous tales were current among the early Greeks of the virtues of the lotus, as we see in *Odys.*, ix. 84. When Ulysses comes to the coast many of his sailors eat the lotus and lose all wish to return home. The idea has been worked up by Tennyson in a very fine poem. This lotus must not be confounded with the Egyptian plant, a kind of water-lily that grows in the Nile. See Ritter, *Erdkunde*, i.; and Heeren, *Ideen*, ii., or in *Historical Researches*, &c.

LOTZE, RUDOLPH HERMANN, one of the most eminent philosophers of our age, was born May 21, 1817, in Bautzen, in the kingdom of Saxony, and died at Berlin 1st July 1881. The incidents of the life of a philosopher, especially if his career has been exclusively an academic one, are usually passed over as unimportant. In external events no life could be less striking than that of Lotze, who, moreover, was of a retiring disposition, and was forced through delicate health to seclude himself from even such external excitement and dissipation as the quiet university town of Göttingen, where he passed nearly forty years of his life, might afford. His interests on the contrary, as exhibited in his various writings, are most universal; and in a surprising degree he possessed the power of appreciating the wants of practical life, and the demands of a civilization so complicated as that of our age, so full of elements which have not yet yielded to scientific treatment. But, although in his teachings he rose more than most thinkers beyond the temporary and casual influences which surrounded him, it was significant for the development of his ideas that the same country produced him which gave to Germany Lessing and Fichte, that he received his education in the gymnasium of Zittau under the guidance of eminent and energetic teachers, who nursed in him a love and tasteful appreciation of the classical authors, of which in much later years he gave a unique example in his masterly translation of the *Antigone* of Sophocles into Latin, and that, himself the son of a physician, he went to the university of Leipsic as a student of philosophy and natural sciences, but enlisted officially as a student of medicine. He was then only seventeen. It appears that thus early Lotze's studies were governed by two distinct interests and emanated from two centres. The first was his scientific interest and culture, based upon mathematical and physical studies, under the guidance of such eminent representatives of modern exact research as E. H. Weber, W. Volckmann, and G. T. Fechner. The others were his æsthetical and artistic predilections, which were developed under the care of C. H. Weisse. To the former he owes his appreciation of exact investigation and a complete knowledge of the aims of science, to the latter an equal admiration for the great circle of ideas which had been cultivated and diffused through the teachings of Fichte, Schelling, and Hegel. But each of these aspects, which early in life must have been familiar to him, exerted on the other a tempering and modifying influence. The true method of science which he possessed forced him to condemn as useless the entire form which Schelling's and Hegel's expositions had adopted, especially the dialectic method of the latter, whilst his love of art and beauty, and his appreciation of moral purposes, revealed to him the existence beyond the phenomenal world of a world of values or worths into which no exact science could penetrate. It is evident how this initial position at once defined to him a variety of tasks which philosophy had to perform. First there were the natural sciences themselves only just emerging from an unclear conception of their true method,—especially those which studied the borderland of physical and mental phenomena, the medical sciences, pre-eminently that science which has since become so popular, the science of biology. Lotze's first essay was his dissertation *De futuræ biologiæ principibus philosophicis*, with which he gained (1838) the degree of doctor of medicine, after having only four months previously got the degree of doctor of philosophy. Then, secondly, there arose the question whether the methods of exact science sufficed to explain the connexion of phenomena, or whether for the explanation of this the thinking mind was forced to resort to some hypothesis not immediately verifiable by observation, but dictated by our higher aspirations and interests. And, if to satisfy these we were forced to maintain the existence of a world of moral standards, it was, thirdly, necessary to form some opinion as to the relation of these moral standards of value to the forms and facts of phenomenal existence. These different tasks, which philosophy had to fulfil, mark pretty accurately the aims of Lotze's writings, and the order in which they were published. But, though he laid the foundation of his philosophical system very early, in his *Metaphysik* (Leipsic, 1841) and his *Logik* (1843), and commenced lecturing when only twenty-two years old on philosophical subjects, in Leipsic, though he accepted in 1844 a call to Göttingen to fill the chair of philosophy which had become vacant through the death of Herbart, he did not proceed to an exhaustive development of his peculiar views till very much later, and only during the last decade of his life, after having matured them in his eminently popular lectures, did he with much hesitation venture to present his ideas in something like a systematic form. The two small publications just referred to remained unnoticed by the reading public, and Lotze became first known to a larger circle through a series of works which had the object of establishing in the study of the physical and mental phenomena of the human organism in its normal and diseased states the same general principles which had been adopted in the investigation of inorganic phenomena. These works were his *Allgemeine Pathologie und Therapie als mechanische Naturwissenschaften* (Leipsic, 1842, 2d ed. 1848), the articles "Lebenskraft" (1843) and "Seele und Seelenleben" (1846) in Rud. Wagner's *Handwörterbuch der Physiologie*, his *Allgemeine Physiologie des Körperlichen Lebens* (Leipsic, 1851), and his *Medizinische Psychologie oder Physiologie der Seele* (Leipsic, 1852). When Lotze came out with these works, medical science was still much under the influence of Schelling's philosophy of nature. The mechanical laws, to which external things were subject, were conceived as being valid only in the inorganic world; in the organic and mental worlds these mechanical laws were conceived as being disturbed or overridden by other powers, such as the influence of final causes, the existence of types, the work of vital and mental forces. This confusion Lotze, who had been trained in the school of mathematical reasoning, tried to dispel. The laws which govern particles of matter in the inorganic world govern them likewise if they are joined into an organism. A phenomenon a, if followed by b in the one case, is followed by the same b also in the other case. Final causes, vital and mental forces, the soul itself can, if they act at all, only act through the inexorable mechanism of natural laws. If a is to be followed by d and not by b, this can only be effected by the additional existence of a third something c, which again by purely mechanical laws would change b into d. As we therefore have only to do with the study of existing complexes of material and spiritual phenomena, the changes in these must be explained in science by the rule of mechanical laws, such as obtain everywhere in the world. and only by such. One of the results of these investigations was to extend the meaning of the word mechanism, and comprise under it all laws which obtain in the phenomenal world, not excepting the phenomena of life and mind. Mechanism was the unalterable connexion of every phenomenon *a* with other phenomena *b*, *c*, *d*, either as following or preceding it; mechanism was the inexorable form into which the events of this world are cast, and by which they are connected. The object of those writings was to establish the all-pervading rule of mechanism. But the mechanical view of nature is not identical with the materialistic. In the last of the above-mentioned works the question is discussed at great length how we have to consider mind, and the relation between mind and body; the answer is—we have to consider mind as an immaterial principle, its action, however, on the body and *vice versa* as purely mechanical, indicated by the fixed laws of a psycho-physical mechanism. These doctrines of Lotze—though pronounced with the distinct and reiterated reserve that they did not contain a solution of the philosophical question regarding the nature, origin, or deeper meaning of this all-pervading mechanism, neither an explanation how the action of external things on each other takes place nor yet of the relation of mind and body, that they were merely a preliminary formula of practical scientific value, itself requiring a deeper interpretation—these doctrines were nevertheless by many considered to be the last word of the philosopher who, denouncing the reveries of Schelling or the idealistic theories of Hegel, established the science of life and mind on the same basis as that of material things. Published as they were during the years when the modern school of German materialism was at its height,[1] these works of Lotze were counted among the opposition literature which destroyed the phantom of Hegelian wisdom and vindicated the independent and self-sufficing position of empirical philosophy. Even philosophers of the eminence of J. H. Fichte (the younger) did not escape this misinterpretation of Lotze's true meaning, though they had his *Metaphysik* and *Logik* to refer to, though he promised in his *Allgemeine Physiologie* (1851) to enter in a subsequent work upon the "bounding province between æsthetics and physiology," and though in his *Medicinische Psychologie* he had distinctly stated that his position was neither the idealism of Hegel nor the realism of Herbart, nor materialism, but that it was the conviction that the essence of everything is the part it plays in the realization of some idea which is in itself valuable, that the sense of an all-pervading mechanism is to be sought in this that it denotes the ways and means by which the highest idea, which we may call the idea of the good, has voluntarily chosen to realize itself.

The misinterpretations which he had suffered induced Lotze to publish a small pamphlet of a polemical character (*Streitschriften*, Leipsic, 1857), in which he corrected two mistakes. The opposition which he had made to Hegel's formalism had induced some to associate him with the materialistic school, others to count him among the followers of Herbart, the principal philosopher of eminence who had maintained a lifelong protest against the development which Kant's doctrines had met with at the hands of Fichte, Schelling, and Hegel. Lotze publicly and formally denied that he belonged to the school of Herbart, though he admitted that historically the same doctrine which might be considered the forerunner of Herbart's teachings might lead to his own views, viz., the monadology of Leibnitz.

When Lotze wrote these explanations, he had already given to the world the first volume of his great work, *Mikrokosmus* (vol. i. 1856, vol. ii. 1858, vol. iii. 1864; 3d ed., 1876–1880). In many passages of his works on pathology, physiology, and psychology Lotze had distinctly stated that the method of research which he advocated there did not give an explanation of the phenomena of life and mind, but only the means of observing and connecting them together; that the meaning of all phenomena, and the reason of their peculiar connexions, was a philosophical problem which required to be attacked from a different point of view; and that the significance especially which lay in the phenomena of life and mind would only unfold itself if by an exhaustive survey of the entire life of man, individually, socially, and historically, we gain the necessary data for deciding what meaning attaches to the existence of this microcosm, or small world of human life, in the macrocosm of the universe. This review, which extends, in three volumes, over the wide field of anthropology, beginning with the human frame, the soul, and their union in life, advancing to man, his mind, and the course of the world, and concluding with history, progress, and the connexion of things, ends with the same idea which was expressed in Lotze's earliest work,—*Metaphysik*. The view peculiar to him is reached in the end as the crowning conception towards which all separate channels of thought have tended, and in the light of which the life of man in nature and mind, in the individual and in society, had been surveyed. This view can be briefly stated as follows. Everywhere in the wide realm of observation we find three distinct regions,—the region of facts, the region of laws, and the region of standards of value and worth. These three regions are separate only in our thoughts, not in reality. To comprehend the real position we are forced to the conviction that the world of facts is the field in which, and that laws are the means by which, those higher standards of moral and æsthetical value are being realized; and such a union can again only become intelligible through the idea of a personal Deity, who in the creation and preservation of a world has voluntarily chosen certain forms and laws, through the natural operation of which the ends of His work are gained.

Whilst Lotze had thus in his published works closed the circle of his thought, beginning with a conception metaphysically gained, proceeding to an exhaustive contemplation of things in the light it afforded, and ending with the stronger conviction of its truth which observation, experience, and life could afford, he had all the time been lecturing on the various branches of philosophy according to the scheme of academical lectures transmitted from his predecessors. Nor can it be considered anything but a gain that he was thus induced to expound his views with regard to those topics, and in connexion with those problems, which were the traditional forms of philosophical utterance. His lectures ranged over a wide field: he delivered annually lectures on psychology and on logic (the latter including a survey of the entirety of philosophical research under the title *Encyclopädie der Philosophie*), then at longer intervals lectures on metaphysics, philosophy of nature, philosophy of art, philosophy of religion, rarely on history of philosophy and ethics. In these lectures he expounded his peculiar views in a stricter form, and during the last decade of his life he embodied the substance of those courses in his *System der Philosophie*, of which only two volumes have appeared (vol. i. *Logik*, 1st ed., Leipsic, 1874, 2d ed., 1880; vol. ii. *Metaphysik*, 1879). The third and concluding volume, which was to treat in a more condensed form the principal problems of practical philosophy, of philosophy of art and religion, did not appear. A small pamphlet on psychology, containing the last form in which he had begun to treat the subject in his lectures (abruptly terminated through his death) during the sum-

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[1] See Vogt, *Physiologische Briefe*, 1845–47; Moleschott, *Der Kreislauf des Lebens*, 1852; Büchner, *Kraft und Stoff*, 1855.

mer session of 1881, has been published by his son. Appended to this volume is a complete list of Lotze's writings, compiled by Professor Rehnisch of Göttingen.

To understand this series of Lotze's writings, it is necessary to start with his definition of philosophy. This is given after his exposition of logic has established two points, viz., the existence in our mind of certain laws and forms according to which we connect the material supplied to us by our senses, and, secondly, the fact that logical thought cannot be usefully employed without the assumption of a further set of connexions, not logically necessary, but assumed to exist between the data of experience and observation. These connexions of a real not formal character are handed to us by the separate sciences and by the usage and culture of everyday life. Language has crystallized them into certain definite notions and expressions, without which we cannot proceed a single step, but which we have accepted without knowing their exact meaning, much less their origin. In consequence the special sciences and the wisdom of common life entangle themselves easily and frequently in contradictions. A problem of a purely formal character thus presents itself, viz., this—to try to bring unity and harmony into the scattered thoughts of our general culture, to trace them to their primary assumptions and follow them into their ultimate consequences, to connect them all together, to remodel, curtail, or amplify them, so as to remove their apparent contradictions, and to combine them in the unity of an harmonious view of things, and especially to make those conceptions from which the single sciences start as assumptions the object of research, and fix the limits of their applicability. This is the formal definition of philosophy. Whether an harmonious conception thus gained will represent more than an agreement among our thoughts, whether it will represent the real connexion of things, and thus possess objective not merely subjective value, cannot be decided at the outset. It is also unwarranted to start with the expectation that everything in the world should be explained by one principle, and it is a needless restriction of our means to expect unity of method. Nor are we able to start our philosophical investigations by an inquiry into the nature of human thought and its capacity to attain an objective knowledge, as in this case we would be actually using that instrument the usefulness of which we were trying to determine. The main proof of the objective value of the view we may gain will rather lie in the degree in which it succeeds in assigning to every element of culture its due position, or in which it is able to appreciate and combine different and apparently opposite tendencies and interests, in the sort of justice with which it weighs our manifold desires and aspirations, balancing them in due proportions, nor sacrificing to a one-sided principle any truth or conviction which experience has proven to be useful and necessary. The investigations will then naturally divide themselves into three parts, the first of which deals with those to our mind inevitable forms in which we are obliged to think about things, if we think at all (metaphysics), the second being devoted to the great region of facts, trying to apply the results of metaphysics to these, specially the two great regions of external and mental phenomena (cosmology and psychology), the third dealing with those standards of value from which we pronounce our æsthetical or ethical approval or disapproval. In each department we shall have to aim first of all at views clear and consistent within themselves, but, secondly, we shall in the end wish to form some general idea or to risk an opinion how laws, facts, and standards of value may be combined in one comprehensive view. Considerations of this kind will naturally turn up in the two great departments of cosmology and psychology, or they may be delegated to an independent research under the name of religious philosophy. We have already mentioned the final conception in which Lotze's speculation culminates, that of a personal Deity, Himself the essence of all that merits existence for its own sake, who in the creation and government of a world has voluntarily chosen certain laws and forms through which His ends are to be realized. We may add that according to this view nothing is real but the living spirit of God and the world of living spirits which He has created; the things of this world have only reality in so far as they are the appearance of spiritual substance, which underlies everything. It is natural that Lotze, having this great and final conception always before him, works under its influence from the very beginning of his speculations, permitting us—as we progress—to gain every now and then a glimpse of that interpretation of things which to him contains the solution of our difficulties.

The key to Lotze's theoretical philosophy lies in his metaphysics, to the exposition of which important subject the first and last of his larger publications have been devoted. To understand Lotze's philosophy, a careful and repeated perusal of these works is absolutely necessary. The object of his metaphysics is so to remodel the current notions regarding the existence of things and their connexions with which the usage of language supplies us as to make them consistent and thinkable. The further assumption, that the modified notions thus gained have an objective meaning, and that they somehow correspond to the real order of the existing world which of course they can never actually describe, depends upon a general confidence which we must have in our reasoning powers, and in the significance of a world in which we ourselves with all the necessary courses of our thoughts have a place assigned to them in harmony with the whole. The object therefore of these investigations is opposed to two attempts frequently repeated in the history of philosophy, viz.:—(1) the attempt to establish general laws or forms, which the development of things must have obeyed, or which a Creator must have followed in the creation of a world (Hegel); and (2) the attempt to trace the genesis of our notions, and decide as to their meaning and value (modern theories of knowledge). Neither of these attempts is practicable. The world of many things surrounds us; our notions, by which we manage correctly or incorrectly to describe it, are also ready made. What remains to be done is, not to explain how such a world manages to be what it is, nor how we came to form these notions, but merely this—to expel from the circle and totality of our conceptions those abstract notions which are inconsistent and jarring, or to remodel and define them so that they may constitute a consistent and harmonious view. In this endeavour Lotze discards as useless and untenable many favourite conceptions of the school, many crude notions of everyday life. The course of things and their connexion is only thinkable by the assumption of many things the reality of which (as distinguished from their existence in our thoughts) can be conceived only as a multitude of relations. This, standing in relation to other things, gives to a thing its reality. And the nature of this reality again can neither be consistently represented as a fixed and hard substance nor as an unalterable something, but only as a fixed order of recurrence of continually changing events or impressions. But, further, every attempt to think clearly what those relations are, what we really mean, if we talk of a fixed order of events, forces upon us the necessity of thinking also that the different things which stand in relations or the different phases which follow each other cannot be merely externally strung together or moved about by some indefinable external power, in the form of some predestination or inexorable fate. The things themselves which exist and their changing phases must stand in some internal connexion; they themselves must be active or passive, capable of doing or suffering. This would lead to the view of Leibnitz, that the world consists of monads, self-sufficient beings, leading an inner life. But this idea involves the further conception of Leibnitz, that of a pre-established harmony, by which the Creator has cared to arrange the life of each monad, so that it agrees with that of all others. This conception, according to Lotze, is neither necessary nor thoroughly intelligible. Why not interpret at once and render intelligible the conception of everyday life originating in natural science, viz., that of a system of laws which governs the many things? But, in attempting to make this conception quite clear and thinkable, we are forced to represent the connexion of things as a universal substance, the essence of which we conceive as a system of laws which underlies everything and in its own self connects everything, but imperceptible, and known to us merely through the impressions it produces on us, which we call things. A final reflexion then teaches us that the nature of this universal and all-pervading substance can only be imagined by us as something analogous to our own mental life, where alone we experience the unity of a substance (which we call self) preserved in the multitude of its (mental) states. It also becomes clear that only where such mental life really appears need we assign an independent existence, but that the purposes of everyday life as well as those of science are equally served if we deprive the material things outside of us of an independence, and assign to them merely a connected existence through the universal substance by the action of which alone they can appear to us.

The universal substance, which we may call the absolute, is at this stage of our investigations not endowed with the attributes of a personal Deity, and it will remain to be seen by further analysis in how far we are able—without contradiction—to identify it with the object of religious veneration, in how far that which to metaphysics is merely a postulate can be gradually brought nearer to us and become a living power. Much in this direction is said by Lotze in various passages of his writings; anything complete, however, on the subject is wanting. Nor would it seem as if it could be the intention of the author to do much more than point out the lines on which the further treatment of the subject should advance. The actual result of his personal inquiries, the great idea which lies at the foundation of his philosophy, we know. It may be safely stated that Lotze would allow much latitude to individual convictions, as indeed it is evident that the empty notion of an absolute can only become living and significant to us in the same degree as experience and thought have taught us to realize the seriousness of life, the significance of creation, the value of the beautiful and the good, and the supreme worth of personal holiness. To endow the universal substance with moral attributes, to maintain that it is more than the metaphysical ground of everything, to say it is the perfect realization of the holy, the beautiful, and the good, can only have a meaning for him who feels within himself what real not imaginary values are clothed in those expressions.

We have still to mention that æsthetics formed a principal and favourite study of Lotze's, and that he has treated this subject also in the light of the leading ideas of his philosophy. See his essays *Ueber den Begriff der Schönheit*, Gottingen, 1845, and *Ueber Bedingungen der Kunstschönheit*, ibid., 1847 ; and especially his *Geschichte der Æsthetik in Deutschland*, Munich, 1868.

Lotze's historical position is of much interest. Though he disclaims being a follower of Herbart, his formal definition of philosophy and his conception of the object of metaphysics are similar to those of Herbart, who defines philosophy as an attempt to remodel the notions given by experience. In this endeavour he forms with Herbart an opposition to the philosophies of Fichte, Schelling, and Hegel, which aimed at objective and absolute knowledge, and also to the criticism of Kant, which aimed at determining the validity of all human knowledge. But this formal agreement involves material differences, and the spirit which breathes in Lotze's writings is more akin to the objects and aspirations of the idealistic school than to the cold formalism of Herbart. What, however, with the idealists was an object of thought alone, the absolute, is to Lotze only inadequately definable in rigorous philosophical language ; the aspirations of the human heart, the contents of our feelings and desires, the aims of art, and the tenets of religious faith must be grasped in order to fill the empty idea of the absolute with meaning. These manifestations of the divine spirit again cannot be traced and understood by reducing (as Hegel did) the growth of the human mind in the individual, in society, and in history to the monotonous rhythm of a speculative schematism ; the essence and worth which is in them reveals itself only to the student of detail, for reality is larger and wider than philosophy ; the problem, "how the one can be many," is only solved for us in the numberless examples in life and experience which surround us, for which we must retain a lifelong interest, and which constitute the true field of all useful human work. This conviction of the emptiness of terms and abstract notions, and of the fulness of individual life, has enabled Lotze to combine in his writings the two courses into which German philosophical thought had been moving since the death of its great founder, Leibnitz. We may define these courses by the terms esoteric and exoteric,—the former the philosophy of the school, cultivated principally at the universities, trying to systematize everything and reduce all our knowledge to an intelligible principle, losing in this attempt the deeper meaning of Leibnitz's philosophy ; the latter the philosophy of general culture, contained in the literature of the classical period, in the unsystematic writings of Lessing, Winkelmann, Goethe, Schiller, and Herder, who more or less expressed their indebtedness to Leibnitz. Lotze can be said to have brought philosophy out of the schoolroom into the market of life. By understanding and combining what was great and valuable in those divided and scattered endeavours, he has become the true successor of Leibnitz, and his philosophy will no doubt attain that universal celebrity which was attained by the monadology and the system of pre-established harmony.

The age in which Lotze lived and wrote in Germany was not one peculiarly fitted to appreciate the position he took up. Frequently misunderstood, yet rarely criticized, he was nevertheless greatly admired, listened to by devoted hearers, and read by an increasing circle. But no watchword of easy currency, no ready Shibboleth, attracts or helps to combine this increasing circle to the unity of a philosophical school. The real meaning of Lotze's teaching is reached only by patient study, and those who in a larger or narrower sense call themselves his followers will probably feel themselves indebted to him more for the general direction he has given to their thoughts, for the tone he has imparted to their inner life, for the seriousness with which he has taught them to consider even small affairs and practical duties, and for the indestructible confidence with which his philosophy permits them to disregard the materialism of science, the scepticism of shallow culture, the disquieting results of philosophical and historical criticism. It is not unlikely that the present phase of English thought will more easily assimilate the valuable elements of Lotze's philosophy, as indeed fragments and beginnings of a similar view exist already in English literature. Wherever his writings are widely read and appreciated, it will be on account of the great moral influence which his philosophy exerts in common with some systems of the past, but almost alone among the systems of the day. (J. T. M.)

LOUDUN, capital of an arrondissement in the department of Vienne, France, stands on an eminence of 320 feet, overlooking a fertile plain, 45 miles (by rail) south-west from Tours. It was formerly surrounded by walls, of which only two towers and a single gateway now remain. Of the old castle which was destroyed under Richelieu, and of which the site is now turned into a public promenade, a fine old rectangular donjon of the 12th century has been preserved ; at its base traces of Roman constructions have been found, with fragments of porphyry pavement, mosaics, and mural paintings. The Carmelite convent, now occupied by the Brethren of Christian Doctrine, was the scene of the trial of Urban Grandier, who was burnt alive for witchcraft in 1634 (see Bayle's *Dictionnaire*) ; the old Byzantine church of Sainte Croix, of which he was curé, is now used as a market. There are several curious old houses in the town. Lace making and candle making are the chief industries, and there is a considerable trade in grain and flour. Before the revocation of the edict of Nantes the inhabitants numbered, it is said, more than 12,000 ; in 1876 the population was 4522.

LOUGHBOROUGH, the second town in Leicestershire, England, on the Midland Railway, 11 miles from Leicester and 14 from Nottingham. In 1881 its three parishes had a population of 14,733. A large tract of meadow land lies between the town and the river Soar, which is connected with the town by two canals,—the Loughborough canal, formed in 1776, and the Leicester canal, opened in 1791. On the Charnwood Forest side of the town there were once extensive parks. The open fields in the lordship were enclosed in 1762. The town has an excellent market-place, and is in the centre of a rich agricultural district. Its malt was once of special note. The old parish church of All Saints stands on rising ground, and is a conspicuous object for many miles round ; the church itself (restored in 1862) is of the Decorated style, and dates from the 14th century ; the tower is Perpendicular. Emmanuel church was completed in 1837, and Holy Trinity in 1878. The Roman Catholic chapel was built in 1833, and the extensive Early English convent, since enlarged, in 1850. The town-hall and corn exchange, in the market-place, were erected in 1855, and the cemetery and its elegant church date from 1857. The grammar school is a Tudor structure, standing in some 15 acres of ornamental grounds and walks ; it owes its origin to Thomas Burton's charity, in 1495. The present buildings were erected in 1852, and the new scheme was devised under the Grammar School Act of 3 & 4 Vict. The girls' grammar school, in the Early English style, was erected in 1879. The other public buildings comprise a dispensary and infirmary (built at the cost of Mr and Miss Herrick in 1862), local board offices, police station, schools, and nonconformist chapels. There are several large hosiery factories. Lace was a staple trade until 1816 (see HEATHCOAT). Bell-founding was introduced in 1840, and Messrs Taylor cast here in 1881 the great bell for St Paul's, London ($17\frac{1}{2}$ tons). Iron-foundries, dye-works, and horticultural glass-works also provide employment.

The town is mentioned under the name of Lucteburne in Domesday Book. William the Conqueror gave the town and manor to Hugh Lupus, from whom they passed to the more famous Despensers. They were held by the Beaumonts from 1326 to 1464, when they passed into the Hastings family, returning to them, after several changes of ownership, in 1554. Lord Moira sold the manor in 1818, and the major part of the manorial rights have now been purchased by the local board. The title of Baron Hastings of Loughborough was given to Sir Edward Hastings in 1558, and to Colonel Henry Hastings in 1643. Alexander Wedderburn, when made lord chancellor, assumed the title of Lord Loughborough, in 1780.[1] John Cleaveland, the royalist poet, was born here in 1613 ; John Howe, the Puritan divine, in 1630 ; and Richard Pulteney, the botanist, in 1730.

See Thomas Pochin's *Historical Description*, 1770 (vol. viii. of *Bibliotheca Topographica Britannica*); Potter's *Walks Round Loughborough*; Wood's *Plan of Loughborough*, 1857 ; W. G. Dimock Fletcher's *Parish Registers*, 1873, *Rectors of Loughborough*, and *Historical Handbook*, 1881.

LOUIS I., Roman emperor (called "der Fromme," also "le Débonnaire"), was born in 778. He succeeded his father Charlemagne in 814, having in the previous year

[1] The present courtesy title borne by the eldest son of the earl of Rosslyn was taken from Loughborough in Surrey, in 1795.

been declared co-regent. At the beginning of his reign he excited high anticipations by the earnestness with which he attacked the abuses that had accumulated during the later years of Charlemagne's sovereignty. The licentiousness which prevailed at court he sternly suppressed; he punished counts who were proved to have misused their authority; and he sought to reform the manners both of the secular and of the regular clergy. The Saxons and the Frisians, who, although conquered, had never cordially accepted Frankish rule, were conciliated by mild and generous treatment. A period of trouble and confusion, however, was opened in 817, when Louis, anxious to establish the order of succession, declared his eldest son Lothair his successor, and made him co-regent, granting him Austrasia with the greater part of Germany. The younger sons of Louis, Pippin and Louis, received, the former Aquitania, the latter Bavaria, Bohemia, Carinthia, and the subject Slavonic and Avar territories. This arrangement was resented by Bernard, king of Italy, the emperor's nephew, who forthwith rebelled. He was soon captured, and condemned to the loss of his sight, while his kingdom was transferred to Lothair. After the death of Bernard, the emperor, who was a man of a gentle and sensitive temper, bitterly repented the harsh punishment which he had sanctioned, and, being further depressed by the death of his first wife, he proposed to resign the crown and retire to a monastery. He was induced to abandon this intention, and (in 819) to marry Judith, the beautiful daughter of Count Welf of Bavaria. In 829 he made a new division of the empire in favour of Charles (afterwards Charles the Bald), his son by his second wife. The three brothers, deeply dissatisfied, combined to declare war against him, and at Compiègne he was taken prisoner. The empress Judith was condemned to the cloister for alleged infidelity to her husband, and Louis was virtually deposed. Pippin and the younger Louis, suspecting that Lothair meant to usurp exclusive authority, changed their policy, and at a diet in Nimeguen the emperor was restored. Soon afterwards he provoked fresh disturbance by granting Aquitania, the territory of Pippin, to Charles, and in 833 the army of the three brothers confronted that of their father near Colmar. When Louis was negotiating with Pope Gregory IV., who had crossed the Alps in the hope of restoring peace, his troops were persuaded to desert him, and on the Lügenfeld ("the field of lies") he was obliged to surrender to his sons. The empress was sent to Italy, her son to the monastery of Prüm, and at Soissons Louis not only abdicated, but made public confession of his sins, a long list of which he read aloud. Again the arrogance of Lothair awoke the distrust of his brothers, and they succeeded in reasserting the rights of the emperor, whose sufferings had excited general sympathy. He went through the ceremony of coronation a second time, and Lothair found it necessary to confine himself to Italy. After the death of Pippin in 838 Louis proposed a scheme by which the whole empire, with the exception of Bavaria, would have been divided between Charles and Lothair, to whom the empress had been reconciled. The younger Louis prepared to oppose this injustice, and he was supported by the people of Aquitania in the interest of Pippin's sons. A diet was summoned at Worms to settle the dispute, but before it met the emperor died on an island in the Rhine near Mainz, on the 20th of June 840. He had capacities which might have made him a great churchman, but as a secular ruler he lacked prudence and vigour, and his mismanagement prepared the way for the destruction of the empire established by his father. His son Lothair I. succeeded to the imperial title.

See Funck, *Ludwig der Fromme*, 1832; and Simson, *Jahrbücher des Fränkischen Reiches unter Ludwig dem Frommen*, 1874-76.

LOUIS II., Roman emperor, grandson of the preceding, was born about 822 and crowned king of Lombardy in 844. From 849 he shared the imperial title with his father, Lothair I., being crowned at Rome by Leo IV. in 850. He succeeded to the undivided but almost entirely nominal dignity in 855. On the death of his childless brother, Lothair of Lorraine, in 869, the inheritance was seized and shared by his uncles Charles the Bald and Louis the German; the pope, however, espoused the cause of the emperor, crowning him king of Lorraine in 872. Louis II. died in 875, and the imperial crown was forthwith bestowed on Charles the Bald.

LOUIS III., Roman emperor, surnamed "The Blind," was the son of Boso, king of Provence, and, through his mother, grandson of the emperor Louis II. He was born about 880, called to the throne of Provence in 890, and crowned emperor in succession to Berengar I. at Rome in 901. In 905, while residing at Verona, he was surprised by his discrowned rival, blinded, and ultimately sent back to Provence, where he lived in inactivity and comparative obscurity until 929.

LOUIS THE CHILD, though he never actually received the imperial crown, is usually reckoned as the emperor Louis III. or Louis IV. He was the son of the emperor Arnulf, was born in 893, and succeeded to the throne of East Francia or Germany in 900, when he was six years of age. During his brief reign Germany was desolated by the Hungarians, who invaded the country year after year, defeating every force that ventured to oppose them. At the same time the kingdom was weakened by internal strife. The result of the prevailing anarchy was that the imperial constitution established by Charlemagne broke down, and Germany was gradually divided into several great duchies, the rulers of which, while acknowledging the supremacy of the king, sought to become virtually independent. Louis, the last of the Carolingian race in Germany, died in 911.

LOUIS IV. (or V.), "the Bavarian," German king and Roman emperor, was born in 1286. He was the son of the duke of Bavaria, and in 1314, after the death of the emperor Henry VII., was elected to the throne by five of the electors, the others giving their votes for Frederick, duke of Austria. This double election led to a civil war, in which Frederick was supported by the church and by many nobles, while the inhabitants of the great cities rallied round Louis. In 1322 Louis gained the battle of Mühldorf, taking Frederick prisoner; but the war still went on. Pope John XXII. excommunicated Louis in 1324; whereupon, wishing to bring the conflict to an end, Louis offered to liberate Frederick on condition that he would withdraw his claim to the throne, and restore the cities and imperial lands seized by his party in Swabia. Frederick, finding that the obstinacy of his brother, Duke Leopold, would render it impossible to fulfil these terms, returned to captivity; and Louis was so touched by his magnanimity that he proposed that they should share the responsibilities of government. The plan was tried but did not succeed, and was virtually abandoned before Frederick's death in 1330. In 1327 Louis had gone to defend his rights in Italy, where he was crowned emperor by Pope Nicholas V., whom he supported in opposition to Pope John XXII. Returning to Germany in the year of Frederick's death, he made peace with the house of Austria, but John XXII. refused to be conciliated, and his successor Benedict XII., acting in part under the influence of France, continued the struggle. Irritated by the revival of papal pretensions which no longer commanded respect in Germany, the electors met at Rhense, and on the 15th of July 1338, issued an important declaration to the effect that the emperor derived his right to the German and imperial crowns, not from the pope, but from the electors by whom he was appointed. As the representative of national independence, Louis might have made himself one of the most popular of the emperors, but he excited bitter jealousies by his grasping and unscrupulous disposition. By his marriage with Margaret, the sister of Count William of Holland, he secured Holland, Zealand, Friesland, and Hainault; and he obtained the mastery of Tyrol by separating the heiress, Margaret Maultasch, from her husband, a son of John, the powerful king of Bohemia, and making her the wife of his own son Louis, to whom (in 1322) he had granted the march of Brandenburg. The enemies he thus created were reinforced by Pope Clement VI., who not only excommunicated him again, but (in 1346) persuaded a party of the electors to appoint a new king. Their choice fell on Charles, margrave of Moravia, the son of King John of Bohemia, who at once made an unsuccessful attempt to recover Tyrol. The outbreak of a new civil war was prevented by the sudden death of Louis at a bear hunt near Munich, on the 11th of October 1347. The conflict between the papacy and the empire was practically closed during the reign of Louis, and he marked an epoch by his encouragement of the cities in opposition to the princes and nobles.

See Mannert, *Kaiser Ludwig IV.*, 1812; Fr. von Weech, *Kaiser Ludwig der Baier und König Johann von Böhmen*, 1860; and Döbner, *Die Auseinandersetzung zwischen Ludwig IV. dem Baier und Friedrich dem Schönen von Oesterreich*, 1875.

LOUIS THE GERMAN, son of the emperor Louis I., was born in 804. In the first partition of the empire in 817 he received Bavaria, Bohemia, Carinthia, and the subject territories on his eastern frontier. Displeased by later schemes of partition in favour of his half-brother Charles, he associated himself with his brothers Lothair and Pippin against the emperor, and he was in the field in defence of his rights when his father died. After the emperor's death in 840, Louis and Charles united against Lothair, whom they defeated in the battle of Fontenay, and in 843 Louis received by the treaty of Verdun the whole of Germany to the east of the Rhine, with Mainz, Spires, and Worms on the left bank. He was a wise and vigorous ruler, but his forces were inadequate to protect the northern part of his kingdom against the Norsemen, and he was not always successful in his wars with Slavonic tribes. In 858 he invaded West Francia, which he hoped to unite with East Francia, his own state; but Charles the Bald proved to be stronger than Louis had supposed, and he was obliged to retreat. When Lothair of Lorraine died in 869, his kingdom was seized by Charles, who caused himself to be crowned at Metz; but in the following year, by the treaty of Mersen, the eastern half of the country was ceded to Louis. Louis expected to receive the imperial crown after the death of the emperor Louis II. Charles, however, outwitted him, and Louis was attempting to avenge this supposed wrong when he died at Frankfort on August 28, 876. East Francia and West Francia were again united under Charles the Fat; but, as Louis was the first sovereign who ruled over the Germans, and over no other Western people, he is generally considered the founder of the German kingdom.

See Dümmler, *Geschichte des Ostfränkischen Reichs*, 1862.

LOUIS I., king of France, surnamed Le Débonnaire or the Pious. See FRANCE, vol. ix. p. 533; GERMANY, vol. x. p. 480; and LOUIS I., emperor, *supra*.

LOUIS II., surnamed Le Bègue or the Stammerer, the son of Charles I. ("The Bald") by Irmentrud of Orleans, and the grandson of Louis the Pious, was born on November 1, 846. On the death of his elder brother Charles, the second son of Charles the Bald, he was consecrated king of Aquitania in 867, and ten years afterwards he succeeded his father, being crowned by Hincmar of Rheims under the title of "king of the French, by the mercy of God and the election of the people" (December 8, 877). In the following year (September 7) he availed himself of the presence of Pope John VIII. at Troyes to obtain a fresh consecration. He died at Compiègne, after a feeble and ineffectual reign of eighteen months, on April 10, 879.

LOUIS III., son of the preceding by Ansgarde, daughter of Count Hardouin of Brittany, was born about the year 863, and in 879 was designated by his father sole heir to the French throne. It was decided among the nobles, however, that the inheritance should be divided between Louis and his younger brother Carloman, the former receiving Neustria, or all France north of the Loire, and the latter Aquitania and Burgundy. On the Loire and elsewhere the two brothers inflicted several defeats on the Northmen (879–881); but in 882 Louis succumbed to the fatigues of war, leaving his inheritance to Carloman.

LOUIS IV., surnamed D'Outremer (Transmarinus), son of Charles III. ("The Simple") and grandson of Louis II., was born in 921. In consequence of the disasters which befell his father in 922, Louis was taken by his mother Odgiva, sister of Athelstan, to England, where his boyhood was spent,—a circumstance to which he owes his surname. On the death of Raoul or Rodolph of Burgundy, who had been elected king in place of Charles, the choice of Hugh the Great, count of Paris, and the other nobles, fell upon Louis, who was accordingly brought over the Channel and consecrated in 936. His *de facto* sovereignty, however, was confined to the countship of Laon. In 939 he became involved in a struggle with Otto I. ("The Great") of Germany about Lorraine, which had transferred its allegiance to him; the victory remained at last with the emperor, who married his sister Gerberga to Louis. After the death of William Longsword, duke of Normandy, Louis endeavoured to strengthen his influence in the duchy by obtaining possession of the person of Richard the infant heir, but a series of intrigues resulted only in his own captivity at Rouen in 944, from which he was not released in the following year until he had agreed to surrender Laon to his powerful vassal Hugh the Great. By the interposition of Otto, the brother-in-law of Louis, Hugh, who for some years had effectually resisted both the carnal resources of the empire and the spiritual weapons of the church, was at last persuaded to restore Laon. The last years of this reign were marked by repeated Hungarian invasions of France. Louis died in 954, and was succeeded by his son Lothaire.

LOUIS V., Le Fainéant, son of Lothaire and grandson of Louis IV., the last of the Carolingian dynasty, was born in 966, succeeded Lothaire in March 986, and died in May 987. He was succeeded by Hugh Capet.

LOUIS VI., surnamed Le Gros, L'Éveillé, and Le Batailleur, the son of Philip I. of France and Bertha of Holland, was born about 1078, was associated with his father in the government in 1100, and succeeded him in 1108. For some account of his character, and of the events of his reign, see FRANCE, vol. ix. pp. 538, 539. He died on August 1, 1137.

LOUIS VII., Le Jeune and Le Pieux, son of Louis VI., was born in 1120, and was associated with his father on the death of his elder brother Philip in 1131, being crowned at Rheims on October 25 by Pope Innocent II. He succeeded to the undivided sovereignty in 1137, the news of his father's death reaching him as he was engaged at Poitiers in the festivities connected with his unlucky marriage to Eleanor of Aquitania. In 1141 he made an unsuccessful attempt to assert his rights as duke of Aquitania over the countship of Toulouse, and in 1142 he fell into a vehement quarrel with Pope Innocent II., who had presumed too much on the piety of the well brought-up young prince by appointing a nephew of his own to the archbishopric of Bourges. In the course of the contest Louis, who had been excommunicated, pursued the new archbishop into the territory of the count of Champagne, and stormed Vitry, in the sack of which the cathedral was burned, causing the death of three hundred persons who had taken refuge within its walls (1143). Louis, horror-struck, made peace with the pope and his secular adversary, but found that nothing less than a pilgrimage to the Holy Land would suffice to expiate his offence. The capture of Edessa and the massacre of the Christians in 1144 led to the preaching of the second crusade by St Bernard, and in 1147 the king, leaving the regency in the hands of the Abbé Suger and Raoul, count of Vermandois, set out for the East, accompanied by his queen, a large company of nobles, and twenty-four thousand men. The disastrous results of the expedition, personal, domestic, and public, have already been recorded in the article FRANCE (vol. ix. p. 540), where also his long struggle with Henry II. of England, which terminated only in 1178, is briefly described. In 1178 he made a pilgrimage to the tomb of St Thomas of Canterbury on behalf of his eldest son Philip Augustus, then dangerously ill, and in the following year he associated him with himself in the sovereignty. Louis died on September 18, 1180.

LOUIS VIII., surnamed Le Lion, born on September 5, 1187, was the son of Philip Augustus, whom he succeeded in July 1223. In 1200 he had married Blanche of Castile, the granddaughter of Henry II. of England, and in virtue of this connexion he received from the English barons in 1216 an offer of the crown, which he accepted. Landing in England in May, he achieved several military successes, but retired early in 1217; later in the same year he renewed the attempt to make good his claims, but finally quitted English soil in September. He next took charge of the war against the Albigenses with varying success; it continued after his accession to the throne, and ultimately proved fatal to him. He died, most probably of pestilence, shortly after the capture of Avignon, at Montpensier in Auvergne on November 8, 1226, and was succeeded by his son Louis IX.

LOUIS IX., SAINT (1215–1270). See FRANCE, vol. ix. pp. 542, 543. He was canonized by Boniface VIII. in 1297, and is commemorated in the Roman Catholic Church on August 25 or 26. He was succeeded by his son Philip III.

LOUIS X., Le Hutin, was the eldest son of Philip IV. (the Fair) and Joan of Navarre, and was born in 1289. He succeeded his mother in the kingdom of Navarre and countships of Champagne and Brie in 1305. Historians are not agreed as to the origin of the surname ("The Quarreller") by which he is known in France, but it seems with most probability to commemorate the wild and boisterous character of his youth. He succeeded his father in 1314, and died, after a short and unimportant reign of less than two years, in June 1316. He was succeeded by his brother Philip V.

LOUIS XI., son of Charles VII. and Mary of Anjou, was born at Bourges on July 3, 1423. His jealous, ambitious, and restless character early manifested itself in the attitude of opposition he assumed to his father's mistress Agnes Sorel, and in the part he took (1439) as leader of the "Praguerie," as the league formed by the nobles against the introduction of a standing army was called. Though pardoned by his father in 1440 after the failure of the attempt, he never thenceforward enjoyed any of his confidence. He distinguished himself in the years immediately following in several military expeditions, but finally settled (1446) in his apanage of Dauphiné, where he acted with great independence, until in 1456 Charles, irritated by the intrigues of his son, intimated his intention of himself resuming the government of that province. Not waiting the arrival of the army which had been sent to take possession, Louis fled for protection to his uncle the duke of Burgundy, who assigned him a pension and a residence at Nieppe near Brussels. The death of Charles on July 22, 1461, permitted his return to France, where he was crowned at Rheims as Louis XI. in the following month. For the leading events of the three periods of his reign the reader is referred to FRANCE, vol. ix. pp. 552, 553. He died at Plessis-lès-Tours on August 30, 1483, and was succeeded by his son Charles VIII.

LOUIS XII. was born at Blois in 1462. His father was Charles, duke of Orleans, the grandson of Charles V. and the cousin of Charles VII., who spent twenty-five years of captivity in England, and who still holds an honourable place on the roll of French poets. Louis himself was for three years (1487–90) the prisoner of his second cousin, Charles VIII., in the castle of Bourges, but afterwards seconded his ambitious schemes faithfully and well, and on his death (1498) succeeded him, taking the titles of king of France, Jerusalem, and the Two Sicilies, and duke of Milan. For the events of his reign see FRANCE, vol. ix. pp. 554, 555. He died on January 1, 1515, and was succeeded by Francis I.

LOUIS XIII., the son of Henry IV. and Mary de' Medici, was born at Fontainebleau on September 27, 1601, and succeeded his father on May 14, 1610, his mother meanwhile availing herself of the confusion caused by the assassination to seize the regency. For some years the affairs of the kingdom were directed by the council of regency in which the Florentine Concini, created Marquis d'Ancre and a marshal of France, was the most prominent figure. After the assassination of D'Ancre in 1617, Marshal Luynes, the favourite of the weak young king, held the reins of power for about four years; his death of camp fever in the end of 1621, in the course of the Huguenot campaign, left Louis free to assert his own independence, which he did by carrying on the war with some vigour until its termination in the peace of Montpellier (1622). In 1624 Richelieu entered the council of state, and guided the affairs of Louis and of France for the next eighteen years (see FRANCE, vol. ix. pp. 568–571). Louis, who died at St Germain-en-Laye on May 14, 1643, was married at the age of fourteen (December 1615) to Anne of Austria, daughter of Philip III. of Spain; but his eldest son, who succeeded him as Louis XIV., was not born until twenty-three years afterwards.

LOUIS XIV., surnamed Le Grand, the elder son of the preceding, was born at Saint-Germain-en-Laye on September 16, 1638, succeeded to the throne of France in his fifth year, was declared of age in September 1651, and was crowned on June 7, 1654. His marriage with the infanta Maria Theresa of Austria, daughter of the Spanish Philip IV., was solemnized at St Jean-de-Luz on June 9, 1660. On the death of Mazarin in 1661 Louis XIV. began his true reign, the leading events of which will be found recorded in the article FRANCE (vol. ix. p. 574–584). He died at Versailles on September 1, 1715. Of his legitimate children by Maria Theresa, only one, Louis the Dauphin (1661–1711), reached manhood; he was married to a Bavarian princess by whom he had three sons—Louis the Dauphin, duke of Burgundy, who was the father of Louis XV.; Philip, duke of Anjou, afterwards Philip V. of Spain; and Charles, duke of Berri.

LOUIS XV., great-grandson and successor of the preceding, born at Versailles on February 15, 1710, was the third son of Louis, duke of Burgundy. His father became dauphin in 1711, and died in 1712, and he himself succeeded to the throne of France on September 1, 1715. His majority was declared in February 1723, and on September 5, 1725 (his cousin, to whom he had been engaged since 1721, having been sent back to Spain), his marriage to Maria Leczinski of Poland, his senior by seven years, was solemnized at Fontainebleau. This union continued to subsist after a fashion until the queen's death in 1768; but the successive relations of the king with De Châteauroux, De Pompadour, and Du Barry are elements of much greater interest and importance to the student of his reign. His surname of "Le Bien-aimé" is said to date from August 1744, when he was seized with a dangerous illness at Metz; the people of Paris rushed in crowds to the churches to pray for his recovery, nor could they sleep, eat, or enjoy any amusement until the "well-beloved king" was out of danger. He died of small-pox on May 10, 1774, having been predeceased for some years by his only son Louis. His successor was his grandson Louis XVI. For his reign see FRANCE (vol. ix. pp. 584–593).

LOUIS XVI., third son of Louis the Dauphin, and grandson of Louis XV., was born at Versailles on August 23, 1754, was married to Marie Antoinette, archduchess of Austria, at Versailles, on May 16, 1770, succeeded his grandfather on May 10, 1774, and was beheaded on January 21, 1793. See FRANCE (vol. ix. pp. 593–604).

LOUIS XVII., titular king of France, the third son of Louis XVI. and Marie Antoinette, was born at Versailles on March 27, 1785, became dauphin in June 1789, was proclaimed king after the execution of his father, was recognized as such by the Governments of England and Russia, but died in captivity in the Temple, Paris, June 8, 1795.

LOUIS XVIII., brother of Louis XVI., was the fourth grandson of Louis XV., and was born at Versailles on November 17, 1755, receiving at his birth the title of count of Provence. During the earlier stages of the revolutionary struggle he showed considerable sympathy with the popular party, but in June 1791 he found it necessary to withdraw to Coblentz, and subsequently he took some part in the operations of the army of Condé. He was at Hamm in Westphalia when tidings of his brother's murder arrived, and lost no time in proclaiming the succession of his nephew Louis XVII., himself being recognized as regent. In June 1795 he succeeded to the regal title; after several years of involuntary wandering he found an asylum in England from October 1807 till April 1814, when he re-entered France. He only once left it again, during the "Hundred Days" (March to June 1815); his death took place at Paris on September 18, 1824. For his reign, see FRANCE (vol. ix. pp. 617–619). He was succeeded by his brother Charles X.

LOUIS-PHILIPPE, king of the French, was born at the Palais Royal, Paris, on October 6, 1773. His father was Louis-Philippe-Joseph, duke of Orleans, a descendant of the younger brother of Louis XIV., and by his mother he derived his origin from the Comte de Toulouse, the legitimized son of Louis XIV. and Madame de Montespan. At his birth he received the title of duke of Valois; and after 1785, when his father succeeded to the Orleans title, he himself bore that of duke of Chartres. In 1781 Madame de Genlis was appointed his "gouverneur." From 1789 onwards he manifested sincere sympathy with the new ideas then gaining currency, and in June 1791 he joined at Vendôme the regiment of dragoons of which he had been colonel since 1785. In 1792 he took part in the battles of Valmy and Jemmapes, holding high military rank under Kellermann and Dumouriez; in the following year he was present at the bombardment of Venloo and of Maestricht, and showed remarkable courage at Neerwinden. Proscribed along with Dumouriez, he entered upon a period of twenty-one years of exile from France, spent partly in Switzerland and other European countries, partly in the United States and in the Spanish American colonies. By the execution of his father he became duke of Orleans in 1793; and he was married to Marie Amélie, daughter of Ferdinand IV. of Naples, at Palermo, on November 25, 1809. In April 1814 he returned to Paris, where his old military rank and the property of his father were restored to him; the "Hundred Days" in 1815 condemned him to a renewed but much briefer exile; during the reign of Louis XVIII. he was regarded with some jealousy by the court on account of his liberal opinions, but enjoyed greater favour under Charles X.; immediately after the three days of July 1830 he was called to exercise the functions of "lieutenant-general of the kingdom," and on August 9 he accepted the title of king of the French. For his reign see FRANCE (vol. ix. p. 620–622). Escaping in disguise from Paris at the Revolution of 1848, he on March 3 reached England, where Claremont was his home until his death on August 26, 1850.

LOUISA (1776–1810), queen of Prussia, was born March 10, 1776, in Hanover, where her father, Duke Charles of Mecklenburg-Strelitz, was commandant. After the death of her mother, who was by birth a princess of Hesse-Darmstadt, she was entrusted to the care of a Fräulein von Wolzogen, and afterwards to that of her grandmother, the landgravine of Hesse-Darmstadt. During the period of the revolutionary wars, she lived for some time with her sister Charlotte, the wife of Duke Frederick of Saxe-Hildburghausen. In 1793 she met at Frankfort the crown prince of Prussia, afterwards King Frederick William III., who was so fascinated by her beauty, and by the nobleness of her character, that he asked her to become his wife. On April 24 of the same year they were betrothed, and on the 24th of December they were married. As queen of Prussia she commanded universal respect and affection, and nothing in Prussian history is more pathetic than the patience and dignity with which she bore the sufferings inflicted on her and her family during the war between Prussia and France. After the battle of Jena she went with her husband to Königsberg, and when the battles of Eylau and Friedland had placed Prussia absolutely at the mercy of France, she made a personal appeal to Napoleon at his headquarters in Tilsit, but without success. Early in 1808 she accompanied the king from Memel to Königsberg, whence, towards the end of the year, she visited St Petersburg, returning to Berlin on the 23d of December 1809. During the war Napoleon, with incredible brutality, attempted to destroy the queen's reputation, but the only effect of his charges in Prussia was to make her more deeply beloved. On the 19th of July 1810 she died in her husband's arms, while visiting her father in Strelitz. No other queen in modern times has been more sincerely mourned. She was buried in the garden of the palace at Charlottenburg, where a beautiful mausoleum, containing a fine recumbent statue by Rauch, was built over her grave. In 1840 her husband was buried by her side. The Louisa Foundation (Luisenstift) for the education of girls was established in her honour, and in 1814 Frederick William III. instituted the Order of Louisa (Luisenorden). On the 10th of March 1876 the Prussian people celebrated the hundredth anniversary of her birth, and it was then decided to erect a statue of Queen Louisa in the Thiergarten at Berlin.

See Adami, *Luise, Königin von Preussen*, 7th ed., 1875; Engel, *Königin Luise*, 1876; Kluckhohn, *Luise, Königin von Preussen*, 1876; Mommsen and Treitschke, *Königin Luise*, 1876; in English, Hudson, *Life and Times of Louisa, Queen of Prussia*, 1874.

LOUISIANA

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Plate I. LOUISIANA, one of the Southern States of the American Union, situated on the lower course and debouchement of the Mississippi river. It is bounded S. by the Gulf of Mexico, W. by Texas, N. by Arkansas, and E. by Mississippi. Its western boundary is a line through the middle of Sabine lake and river, as far north as the 32d parallel, whence it follows the meridian of the point of intersection of the river with that parallel. The northern boundary is the parallel of 33°. The eastern boundary is the mid-channel of the Mississippi river, as far south as the 31st parallel, whence it follows that parallel eastward to the middle of Pearl river, and passes down that stream to the Gulf. The area of the State, according to a late determination made by the Census Bureau, is 48,720 square miles, of which 1060 consist of land-locked bays, 1700 of inland lakes, and 540 of river surface, leaving 45,420 square miles as the total land area of the State.

Boundaries and extent.

Surface. The average elevation of the State is only 75 feet, and no part of it reaches 500 feet above sea-level. The most elevated portion is near its northern border. The surface is naturally divided into two parts—the upland, and the alluvial and coast swamp regions. Each of the larger streams, as well as a large proportion of the smaller ones, is accompanied by a belt of bottom land, of greater or less width, lying low as regards the stream, and liable to overflow at times of high water. These bottom lands form collectively what is known as the alluvial region. It extends in a broad belt down the Mississippi, from the mouth of the Ohio to the Gulf of Mexico, and up the Ouachita and its branches and the Red River, to and beyond the limits of the State. Its breadth along the Mississippi within this State ranges from 10 to 50 or 60 miles, and that along the Red River and Ouachita has an average breadth of 10 miles. Through its great flood-plain the Mississippi river winds upon the summit of a ridge formed by its own deposits. In each direction the country falls away in a succession of minor undulations, the summits of the ridges being occupied by the streams and bayous. Nearly all of this vast flood-plain lies below the level of high water in the Mississippi, and, were it not for the protection afforded by the levees, with which most of the course of the stream is lined, every considerable rise of its waters would inundate vast areas of fertile and cultivated land.

Stretching along the coast, and extending inland to a varying distance, ranging from 20 to 50 or even 60 miles, is a low, swampy region, the surface of which is diversified only by the slight ridges along the streams and bayous which traverse it, by occasional patches of slightly elevated prairie, and by live oak ridges. It is in and along the borders of this coast swamp region that most of the sugarcane and rice produced in the State are grown.

The low regions of Louisiana, including the alluvial lands and the coast swamps, comprise about 20,100 square miles, or nearly one-half the area of the State. The remainder consists of uplands of prairie and forest. The borders of these uplands are generally defined by lines of bluffs of no great height.

Rivers. The principal rivers are the Mississippi, which flows nearly 600 miles through and along the border of the State, the Red River, the Ouachita or Washita, Sabine, and Pearl, all which, excepting the last, are navigable at all stages of the water. Besides those streams which may properly be called rivers, the State is intersected by "bayous," several of which are of great importance both for navigation and for drainage. They may be characterized as secondary outlets of the rivers. Among them may be mentioned Achafalaya Bayou, Bayou la Fourche, and Bayou Bœuf. The signification of the name has, however, been extended, so that many rivers in this region, particularly if they have sluggish courses, are known as bayous. The alluvial portion of the State, particularly below the mouth of the Red River, is a perfect network of these bayous, which serve, in time of flood, to carry off the invading surplus waters.

The lakes of the State are mainly comprised in three classes. First come the lagoons of the coast, many of which are merely land-locked bays, whose waters are salt, and which rise and fall with the tides. Of this class are Pontchartrain, Borgne, Maurepas, and Sabine, and indeed all or nearly all those situated in the region of the coast swamps. These are simply parts of the sea which have escaped the filling-in process carried on by the great river and the lesser streams. A second class, large in numbers but small in area, is the result of "cut-offs" and other changes of channel in the Mississippi, and, to a small extent, in the Red River. The part of the river left by this change of channel becomes gradually isolated from the stream by the deposit of silt along the borders of the latter, thus changing what were formerly windings of the river into crescent-shaped lakes. A third class may be mentioned, namely, those upon Red River and its branches which are caused by the partial stoppage of the water by the "raft" above Shreveport. These are, of course, much larger at flood season than at other times, and, it may be added, have been much reduced in size by the cutting of a channel through the raft.

The climate of the State is semi-tropical; the mean annual temperature ranges from 60° to 75°, changing approximately with the latitude. The mean temperature of the hottest month is about 85°, while that of the coldest month ranges in different parts of the State from 45° to 60°. The temperature rarely, if ever, falls below 0° Fahr., while the heats of summer reach 105° in some parts. The rainfall is very heavy along the coast, exceeding 60 inches annually, but decreases inland, and is not more than 50 inches in the northern districts.

This large amount of moisture, together with the high temperature and the fertile soil, suffices to cover the greater part of the State, and particularly the alluvial regions and the coast swamps, with the most luxuriant sub-tropical vegetation, both arborescent and herbaceous. Much of the latter region is covered with lofty cypress trees, from which hang festoons of Spanish moss. The most common species of the alluvial regions and the drier portions of the coast swamps are live and other species of oaks, sweet gum, magnolia, the tulip tree, black walnut, pine, and cedar. Along the streams in the alluvial region are found willows, cotton-woods, basket oaks, and other species of similar habitat. For the beauty and fragrance of its flowers Louisiana is justly celebrated. Its bottom lands and its upland prairies are decked with them in tropical profusion. Prominent among them in abundance are roses, magnolias, jasmines, camellias, and oleanders. Most fruits common to a semi-tropical region are to be found here, either native or cultivated, such as oranges, olives, figs, peaches, and plums.

The forests cover a very considerable portion of the area of the State, and are destined in the future to form an important element of its wealth, although up to the present time the lumber interest has not been very extensively developed. The most valuable timber is that of the long-leaved pine (*Pinus australis*) and the short-leaved pine (*Pinus mitis*). These are mainly confined to the upland regions, being nowhere found in the alluvial or coast sections. The north-western part of the State is occupied by the short-leaved pine, while the long-leaved pine is found


Longitude West from Greenwich
94
93
92
91
90
89
33
32
31
30
29
28
ARKANSAS
MISSISSIPPI
TEXAS
GULF OF MEXICO
Redland
Haynesville
Shongaloo
Spearsville
Lind Grove
Pilcher's Pt.
Wilson's Pt.
Homer
Lisbon
CLAIBORNE
Shiloh
Farmers V.
MOREHOUSE
Bonne Idee
WEST
EAST
Lake Providence
Bellevue
Athens
Minden
Arizona
Walnut Cr.
Vienna
Ouachita
Bastrop
Floyd
CARROLL
Goodrich's Landing
Arcadia
LINCOLN
Trenton
Point Jefferson
Greenwood
Shreveport
Bucklhorn
Mount Lebanon
Indian Village
Monroe
Girard
Rayville
Delhi
Milliken's Bend
Bethany
OUACHITA
RICHLAND
Tallulah
Ringgold
Sparta
Vernon
Log Town
MADISON
Vicksburg
JACKSON
Spring Ridge
BIENVILLE
L. Bistineau
JACKSON
Alto
Warsaw
Delta
Kellogg's Landing
Keatchie
Wood's Mills
Winnsboro
FRANKLIN
Point Pleasant
RED RIVER
East Point
Columbia
Gansville
CALDWELL
Mansfield
Coushatta Chute
Copenhagen
Hogan's Ldg.
Oakley
Hard Times Landing
WINN
St. Joseph
Pleasant Hill
Campti
Winfield
Saline L.
Enterprise
Rosefield
Harrisonburgh
Waterproof
San Patricio
Bellmount
St. Maurice
Black Cr.
Manifest
Trinity
Troy
Bullitt's Bayou
Fort Jesup
Natchitoches
GRANT
Colfax
Vidalia
Natchez
Many
E. Pendleton
Fairmount
Pineville
Alexandria
Mound
Anacoco
Leesville
Collins
Marksville
Black Hawk
Burr's Ferry
VERNON
RAPIDES
Cheneyville
AVOYELLES
Mansura
Bordelonville
Woodland
Liverpool
Palestine
Shady Grove
Babb's Bridge
Merrick's Store
WEST
EAST
Clinton
Greensburgh
WASHINGTON
Evergreen
FELICIANA
HELENA
Arcola
Franklinton
Sabine River
Sugartown
Big Cane
POINTE
Jackson
Bayou Sara
Amite City
Ville Platte
New Roads
Pine Grove
Live Oak Store
Hammond
Washington
COUPEE
Port Hudson
ST. LANDRY
Livonia
EAST
ROUGE
LIVINGSTON
ST. Covington
Opelousas
Leon
WEST BATON
BATON ROUGE
TAMMANY
Madisonville
CALCASIEU
Fabacher
Arnaud V.
Grand Coteau
Port Allen
Manchac
Port Vincent
Mandeville
Church Pt.
La Place
Bayou Lacomb
Carencro
Breaux Br.
Plaquemine
Pass Manchac
Rose Bluff
Vermillion V.
LAFAYETTE
ST. MARTINS
ASCENSION
Lake Pontchartrain
Pearl River
Orange
Niblett's Bluff
Lake Charles
Mermenton
St. Martins V.
Donaldsonville
SHIP I.
ISLE AU PIED
Youngsville
Convent
Ft. Pike
L. Borgne
Sabine Lake
Calcasieu Lake
Abbeville
New Iberia
Kenner
New Orleans
St. Bernard
CAMERON
VERMILLION
Napoleon V.
Gretna
Chandeleur Sound
Mud L.
Cameron
Grand Chenier
White L.
Franklin
Thibodeaux
Johnson's Bayou
Centre
LAFOURCHE
Isle au Breton Sound
Sabine Pass
Calcasieu Pass
Vermillion Bay
Cote Blanche Bay
ST. MARY'S
Washa
Barataria
Point a la Hache
CHANDELEUR IS.
Pattersonville
Morgan City
Houma
Grand Prairie
Big Constance B.
Little Constance B.
Bay St. Bernard
Atchafalaya Bay
TERREBONNE
ISLE AU BRETON
Point au Fer
Live Oak
The Forts
L. Caillou
Tiger Pt.
Bayou de Large
Caillou Bay
Raccoon Pt.
I. DERNIERE
Pilot Town
Terre Bonne Bay
Timbalier Bay
Grand Isle
Marchand B.
Delta of the Mississippi
Scale of Miles
0 5 10 20 30 40 50
County Towns
Railroads
16
15
14
13
12
Longitude West from Washington

mainly in large masses north and south of the Red River, and also in the east of the State.[1]

'auna. The native fauna of the State resembles in its general features that of the other Gulf States. Large quadrupeds are comparatively rarely met with, although occasionally there are seen black bears and wolves, and in the swamps an occasional panther. Smaller quadrupeds, such as raccoons, squirrels, wild cats, opossums, &c., are still common. Every bayou contains alligators; and reptiles of various species, such as turtles, lizards, horned toads, rattlesnakes, and moccasin snakes, are abundant. The avifauna of the State is varied and abundant, comprising eagles, vultures, hawks, owls, pelicans, cranes, turkeys, geese, partridges, ducks, &c., besides numberless smaller species, many of these, as in other parts of the world in the same latitude, being brilliant of plumage, but harsh of voice.

Jeology. The surface geology in its general outlines is very simple. The whole alluvial region and the coast swamps, besides a considerable portion of the prairie and pine flats bordering upon the lowlands, are of the most recent or Quarternary formations, while the remainder of the State, comprised mainly in the region west of the Ouachita and Calcasieu rivers, is Tertiary, with the exception of a few very small islands of the Cretaceous formation in the north-western part of the State.

Iinerals. In the Tertiary region are found small quantities of iron ore, and an indifferent brown coal. But the only important mineral product of the State is rock salt; the deposit upon Petite Anse Island, in the coast swamp region, has been extensively worked, and produces a very high quality of salt. In 1880 its production was 312,000 bushels.

Agriculture. The principal industry of the State is agriculture, and in that cotton takes the first place. Out of a total area of tilled land of two and a half million acres, more than one-third was planted in 1879 with cotton. The total production was 508,569 bales, an average of ·59 of a bale per acre. Louisiana stood seventh in the list of cotton-producing States, being exceeded by Mississippi, Georgia, Texas, Alabama, Arkansas, and South Carolina. The cotton crop is cultivated both in the alluvial and the upland regions. In the former there were raised in 1879 282,390 bales, on 364,790 acres, an average yield per acre of ·77 of a bale. In the latter region 498,080 acres were planted, giving a total yield of 225,385 bales, an average of ·45 of a bale per acre. The great depth and fertility of the alluvial soils are strikingly illustrated by these average yields. In the coast swamp region but little cotton is cultivated,—the total yield in these parishes, as reported by the census, being but 794 bales.

The production of other agricultural products, as given by the census of 1880, is as follows:—

Indian corn		Bush.	9,906,189
Oats		,,	229,840
Wheat		,,	5,034
Rye		,,	1,013
Sugar cane	Sugar	Hhds.	171,706
	Molasses	Gals.	11,696,248
Sweet potatoes		Bush.	1,318,110
Rice		lb	23,189,038
Tobacco		,,	55,954

Rice is cultivated almost entirely in the lower coast region, on the margin of the swamps, upon their prairie islands, and in the alluvial region south of Red River.

Communication. With the exception of its navigable streams, the State is not well supplied with the means of transportation. The only railroads of importance are—the Chicago, St Louis, and New Orleans, which connects New Orleans with Cairo, Illinois; the Louisiana and Texas Railroad (Morgans), which runs from New Orleans westward to Vermillionville, and thence northward to Cheneyville; the Louisiana Western Railroad, from Vermillionville to Orange in Texas; the New Orleans and Pacific Railroad, from New Orleans to Shreveport; and the Vicksburg, Shreveport, and Pacific Railroad, running from Delta to Monroe. Besides these there are several minor lines. The total length of railroad is 632½ miles, and the cost of construction $44,869,342. The gross returns for 1880 were $3,238,318, and the net returns $984,497.

Manufactures. Louisiana, like the other Southern States, has latterly made great advances in the manufacture of home products. In 1880 there were 120 looms and 6096 spindles, which used 1354 bales of raw cotton.

Banking. The banking interest is not extensive, as will be seen from the following statement, from the report of the comptroller of the currency in 1880:—

	Number.	Capital.
National banks	7	$2,875,000
State banks	3	2,723,698
Private bankers	8	53,333
Total	18	5,652,031

The number and circulation of newspapers and periodicals for 1880 are as follows:—

	Number.	Circulation.
Dailies	13	38,765
Weeklies, semi-weeklies, &c.	97	95,115
Monthlies	2	950

Population. According to the census of 1880, the population of the State was 939,946. This was divided nearly equally between the sexes, females being but slightly in excess. The proportion of the population which was of foreign birth was very small, being but 5·5 per cent., while in respect of race, the negro element outnumbered the whites, being 51·5 per cent. of the total population. The following table gives the number in each of the above classes:—

Male	468,754	White	454,954
Female	471,192	Coloured	483,655
Native	885,800	Chinese	489
Foreign	54,146	Indian	848

The following table exhibits the growth of the State in population since it became a portion of the United States:—

	Population.	Per Cent. of Increase.	Density of Population.		Population.	Per Cent. of Increase.	Density of Population.
1810	76,556	...	1·7	1850	517,762	46·9	11·4
1820	152,923	99·7	3·4	1860	708,002	36·7	15·6
1830	215,739	41·0	4·7	1870	726,915	2·6	16·0
1840	352,411	63·3	7·8	1880	939,946	29·3	20·6

The principal cities are New Orleans, with a population of 216,090; Shreveport, in the north-western corner, population 8009; and Baton Rouge, the State capital, 7197.[2]

Education. The State is fairly well provided with the means of education. School attendance, however, is not very general. Out of a population of 330,930 between the ages of six and sixteen, 78,528 were enrolled in public schools, and the estimated average attendance was 50,248, or less than one-sixth. There are in the State seven colleges, with 49 instructors and 786 students.

Administration. As in the other States of the Union, the government is distributed among the executive, legislative, and judicial departments. The executive is represented by the governor, lieutenant-governor, secretary of state, State treasurer, auditor of public accounts, attorney-general, and superintendent of instruction—all these offices being elective, and the period of incumbency four years. The legislative power is vested in a general assembly consisting of two branches, the lower one being the house of representatives and the upper one the senate. The members of the former body are elected every two years, and the number is by law never to exceed 120 nor be less than 90. The members of the senate are elected for four years. The number of senators is fixed at 36, and the senatorial districts are apportioned according to the population. The judicial power is vested in a supreme court, district and parish courts, and justices of the peace. The supreme court, except in cases specially provided for by law, has appellate jurisdiction only. It is composed of one chief justice and four associate justices. These are appointed by the governor, by and with the advice and consent of the senate, and hold office for a term of eight years. The State is divided by the legislature into judicial districts, in each of which there is a district court. The number of districts in the State cannot by law be less than twelve nor more than twenty. The district judges are elected by the voters of the district, and hold office for four years. Each parish has its own court. The parish judge is elected by the voters of the parish, and holds his office for two years. In addition to this each parish elects a certain number of justices of the peace with power to try minor cases. The State is divided into fifty-eight parishes (equivalent to counties), and each of these into a certain number of police jury wards which are designated by their numbers.

[1] Of these two species of trees, Professor Sargent, of the United States Census Bureau, estimates that there were standing on June 1, 1880, 26,558,000,000 feet of the long-leaved and 21,625,000,000 feet of the short-leaved species. The cut of the former for the census year was 61,882,000, and of the latter 22,709,000 feet, the total cut being but ·2 per cent. of the amount standing. There is every probability, however, that the rate of destruction will increase greatly in the future.

[2] The capital was removed from New Orleans to Baton Rouge in 1880.

Louisiana is represented in the National Congress by two senators who are chosen by the legislature of the State for a term of six years, and by six representatives who are chosen for a term of two years by the voters of the several representative districts.

Finance. The following table, compiled from the returns of wealth, debt, and taxation of the tenth United States census, shows the financial condition of the State in 1880.

Valuation (Assessed)—	
Real estate	$122,362,297
Personal property	37,800.142
Debt—	
State	23,437,640
Parish	1,107,951
Municipal	18,320,361
Taxation—	
State	1,171,084
Parish	710,573
Municipal	1,914,219

History. *History.*—The early history of the exploration of Louisiana forms one of the most interesting chapters in the annals of the country. It was first visited in 1541 by De Soto, of the Spanish Government service. This daring explorer, landing on the coast of Florida, made his way through the pathless forests and almost impassable swamps to the Mississippi, and even penetrated many leagues west of it, finally leaving his bones upon its shores. In 1673 Marquette and Joliet, starting from the settlements in Canada, descended the great river from northern Illinois to the mouth of the Arkansas. In 1682 La Salle descended the Mississippi, also starting from the French settlements in the Canadas. He navigated the river from the mouth of the Illinois to the Gulf. Returning to France, he originated a scheme for colonizing the country, and succeeded in obtaining from France the desired concessions, and in collecting a company of colonists, which set sail from Rochelle on the 24th of July 1684. Owing to the difficulty of obtaining correct longitudes at sea, the vessel missed the mouth of the Mississippi, and finally landed on the shore of Matagorda Bay, in Texas, where they established a colony. From this point La Salle started to make his way overland to Canada, but was treacherously murdered by his companions. Shortly after his death the colony disappeared.

The first successful attempt at settlement within the State was made by the French under the leadership of Iberville in 1700. The colony was located at a point on the Mississippi about 38 miles below the present site of New Orleans, now known as "Poverty Point." At first it was by no means prosperous, and it was only after the treaty of Utrecht that it appears to have gained ground. At that time there were not over five hundred Europeans in the whole territory of Louisiana as then constituted; the greater part were in what is now the State of Louisiana, the others being scattered at a few little posts along the Mississippi and Illinois rivers. Immediately after the treaty of Utrecht the king of France granted the whole territory of Louisiana to Antoine Crozat, ceding to him all the territories watered by the Mississippi and its tributaries below the mouth of the Illinois, with all the privileges of hunting, fishing, commerce, mining, &c., which might arise in this new territory. Crozat appointed Cadillac governor of the colony. Affairs, however, went badly under the new administration, and after a succession of governors, the whole district fell into the hands of John Law, the originator of the famous "Mississippi scheme." Desiring to control, among other commercial monopolies, the colony of Louisiana, Law found it an easy matter to obtain the charter and privileges from Crozat, who was only too glad to relinquish them in his favour. A company was formed under the name of the "Western Company." Grants made to it were for twenty-five years. Subscribers to the stock were allowed to pay three-fourths of the purchase money in the depreciated bonds of France, one-fourth only of the subscription being asked for in coin. Bienville, brother of Iberville, and a man possessing great influence in the colony, was appointed governor. One of his first acts was to found the city of New Orleans on its present site. During the year 1718 7 vessels were sent out with stores and emigrants, numbering in all about 1500 persons. The following year 11 ships were despatched, and 500 negroes from the Guinea coast were imported. In 1721 1000 white emigrants arrived, and 1367 slaves.

In the meantime the Western Company had obtained from the regent power to join with it the East India Company grants, and its name was changed to that of the India Company. This inflated scheme burst in due time, but the misfortunes of the company did not check the prosperity of the colony. The year 1721, which was that following the financial ruin of the former, witnessed the greatest immigration to the colony which it had ever received. The company retained its organization and its grant of Louisiana until 1732, when the province reverted to the crown. At that time the population of the colony was said to have been 5000 whites and 2000 slaves; but a census taken fifteen years later shows a population of only 4000 whites.

In 1762, by a secret treaty, the province was transferred from France to Spain. This treaty was not made public till a year and a half after it was signed, and Spain did not obtain possession until 1769. Meanwhile, in February 1763, by a treaty made between France and Spain on the one hand and Great Britain and Portugal on the other, the portion of Louisiana lying east of the Mississippi from its source to the river Iberville, and thence along the middle of the Iberville and the lakes Maurepas and Pontchartrain to the sea, was ceded to Great Britain. In this treaty, by implication, Louisiana was made to extend to the sources of the Mississippi, and this is the view commonly held. The province was governed by Spain till the year 1800, in the meantime making little or no progress owing to the narrow and oppressive policy pursued towards it by the home government. By the treaty of 1783 with Great Britain, the United States were placed in possession of the eastern bank of the Mississippi river, as far down as the 31st degree of latitude, while Spain held possession of the other bank, and had complete possession of the river below the 31st parallel.

From the time of the first settlement in the valley of the Mississippi and its tributaries, the importance of the river as a means of transportation to the seaboard, and the almost absolute necessity of possessing the country about its mouths, were recognized by the United States. As settlements increased in the valley and spread down the river, and as the hostile policy of Spain became more and more plainly developed, the feeling of the settlers became stronger against the restrictions of the Spanish Government. In 1800, however, Spain ceded the territory back to France, and in 1803 it was sold to the United States by Napoleon, in order to prevent it from falling into the hands of Great Britain. The price was 60,000,000 francs, with a stipulation that the United States should assume the claims of its citizens against France (French spoliation claims), which were estimated to amount to $3,750,000. The province which thus came into the possession of the United States was of vast though ill-defined territorial extent.

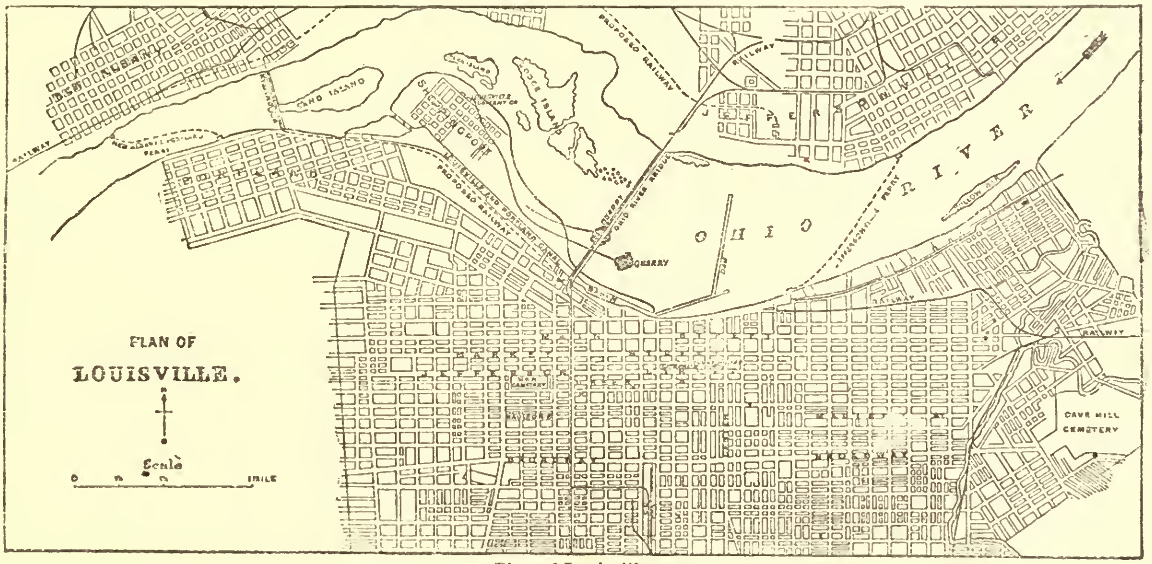
In 1804 nearly all of what is now the State of Louisiana was erected into a territory, under the name of Orleans. In 1810 this was increased by the addition of the south-eastern portion, east of the Mississippi river, and in 1812 it was admitted as a State under its present name, and with its present boundaries. During the war with Great Britain, which followed shortly after, a battle was fought for the possession of New Orleans, between the British forces under Pakenham and the American army under Jackson, in which the former were signally defeated. Up to 1860 the development of the State was very rapid, especially in the direction of agriculture and commerce.

Upon the outbreak of the civil war the State promptly joined its fortunes with the Southern Confederacy. Its act of secession from the Union was passed December 23, 1860, and from that time until the final suppression of the rebellion the State government was in the hands of the Confederates, although for the last two years of the war its territory was held in the main by the Federal forces. In the early part of the war the State suffered but little, but in April 1862 Admiral Farragut with a powerful fleet succeeded in passing Forts Jackson and St Philip, which defended the approaches to New Orleans, and captured the city, thus compelling the evacuation of the forts. The navigation of the Mississippi being secured by this means and by operations from the north, the State was at the mercy of the Federal Government. At the close of the war, on the reorganization of the State government, the administration fell into the hands of the ignorant negro classes led by unscrupulous whites, and an unfortunate state of affairs ensued, which was brought to an end only by the arbitrary and forcible assumption of power by the better elements of society. This occurred in 1877, and since that time the State has prospered markedly in all material respects. (H. G.)

LOUISVILLE, the sixteenth city of the United States in population, and the most important place in the State of Kentucky, is situated on the south bank of the Ohio river, in 38° 3′ N. lat. and 85° 30′ W. long. The river is here interrupted by a series of rapids which, except at high water, oblige the steamboat traffic to make use of the Louisville and Portland Canal (2½ miles long, constructed in 1833). The city, which has an area of 13 square miles, and a water front of 8 miles, occupies an almost level site about 70 feet above low-water mark. Its plan is regular and spacious, and, in the residential portions the houses, for the most part, have lawns and gardens in front. Among the public buildings of importance may be mentioned the city-hall, the court-house, the public library, the female high school, the industrial exhibition building, the Roman Catholic cathedral, and the State school for the blind.

From the time of the introduction of steam navigation upon the Ohio by Fulton in 1812, Louisville rapidly gained in importance as a centre of river trade. Owing to its position at the "falls of the Ohio," which obstruction long made necessary the transfer of goods at this point, the city became an important depôt of supplies for the cotton-growing States lying immediately to the south. The owners of plantations in those States devoted themselves wholly to the culture of cotton, and relied upon Kentucky for supplies of wheat, Indian corn, oats, and the like cereals, for the hempen bagging and rope used in baling the cotton, and for mules and horses, large droves of which were annually driven south from Louisville. The city was also for many years one of the principal points in the United States for pork-packing.

After the close of the civil war, the development of Kentucky, as of the South generally, entered new channels. Largely increased facilities of railway transportation, while bringing Louisville into more direct competition with Cincinnati, St Louis, and Chicago, resulted in a marked increase of both its commercial and manufacturing interests, notwithstanding the decline of the river trade. The extensive tobacco crop of Kentucky, with much of that grown in neighbouring States, now finds a market at Louisville, instead of at New Orleans as formerly; and it has become probably the largest market in the world for leaf tobacco, 68,300 hogsheads of which, of an aggregate value exceeding $5,000,000, were sold here during 1881. The manufacture of whisky is also important, this, with that of tobacco, paying to the Federal Government nearly $3,000,000 annually in revenue taxes, in the Louisville district. Pork-packing employs a capital of $2,520,000, and the tanning of leather $1,704,000, this industry being twenty times larger than before the war, and the product, especially of sole-leather, being in high demand. The manufacture of agricultural and mechanical implements employs $1,915,000 capital, the plough factories, which produce 125,000 ploughs annually, being among the largest in the United States. Steam-power is chiefly employed, the available water-power of the rapids having been neglected. The greater part of the coal consumed by the factories is brought down the Ohio from Pittsburg. The mountainous eastern portion of the State, rich in vast



Plan of Louisville.

deposits of both coal and iron, is now penetrated by several railroads, and others are being constructed, whose influence in developing this mineral wealth will add largely to the prosperity of the city.

The reports of the United States census of 1880 give the following summary of the industries of the city:—

	1860.	1870.	1880.
Number of establishments	436	801	1,191
Number of hands employed	7,396	11,589	21,937
Capital invested	$5,023,491	$11,129,291	$20,864,449
Wages paid	2,120,179	4,464,040	5,765,387
Value of material	7,896,891	10,369,556	22,362,704
Value of product	14,135,517	20,364,650	35,908,338

The Louisville and Nashville Railway, opened in 1859, controls, under one management, nearly 4000 miles of connected lines, reaching New Orleans, Pensacola, and Savannah. Various other lines contribute to make Louisville an important railway centre.

A bridge across the river, 5218⅔ feet long between abutments, with twenty-seven spans, and admitting the free passage of steamboats at high water, affords continuous railway transit, and connects the city with the thriving towns of New Albany (population 16,423) and Jeffersonville (population 9357), situated on the opposite bank of the Ohio, in the State of Indiana. A second railway bridge, having waggon-ways and foot-ways in addition, is now (1882) building.

Louisville is provided with adequate water-works, gas-works, &c. The famous Dupont artesian well, 2066 feet deep, has a flow of 330,000 gallons per day, with a force of ten horse-power, its water resembling slightly that of the Kissengen and Blue Lick (Ky.) springs. Although once regarded as unhealthy, the city has now an effective system of sewerage, and is in good sanitary condition.

The public school system is sustained at an annual expense of over $300,000, abundant separate provision being made for coloured children. There are four medical colleges, having a large attendance and reputation, and numerous private seminaries and schools. Among the newspapers published at Louisville the *Courier Journal* deserves mention both for its early connexion with George D. Prentice, and as a leading representative of the best order of American journalism. There are four other dailies (two English and two German), besides thirteen weekly sheets.

Louisville is a port of entry for foreign imports, which aggregate annually about $125,000. The city is governed by a mayor, elected every third year, with a board of aldermen and a common council, the former containing one, and the latter two representatives of each of the twelve wards. The population in 1830 was 10,341; in 1840, 21,210; in 1850, 43,196; in 1860, 68,033; in 1870, 100,753;

and in 1880 it was 123,758. This last total includes 20,905 persons of colour and 23,156 foreigners, the larger proportion of the latter being Germans.

It was in 1778 that Colonel George Rogers Clarke, on his way down the Ohio, left a company of settlers who took possession of Corn Island (no longer existing), near the Kentucky shore above the falls; and in the following year the first rude cluster of cabins appeared on the site of the present city. An Act of the Virginian legislature in 1780 gave the little settlement the rank of a town, and called it Louisville in honour of Louis XVI. of France, then assisting the American colonies in their struggle for independence. The rank of city was conferred by the Kentucky legislature in 1828.

LOULÉ, an old town of Portugal, in the district of Faro and province of Algarve, is beautifully situated in an inland hilly district about 5 miles to the north-west of the port of Faro. It is surrounded by walls and towers dating from the Moorish period, and the principal church is large and fine. The special industry of the place is basket-making. The population in 1878 was 14,862. The neighbouring church of Nuestra Senhora da Pietade is a favourite resort of pilgrims.

LOURDES, capital of a canton, and seat of the civil court of the arrondissement of Argelès, in the department of Hautes-Pyrénées, France, lies 12 miles by rail south-south-west of Tarbes, on the right bank of the Gave de Pau, and at the mouth of the valley of Argelès. It has grown up around what was originally a Roman castellum, and subsequently a feudal castle, picturesquely situated on the summit of a bare scarped rock. Near the town are marble quarries employing six hundred workpeople; and forty slate quarries give occupation to two hundred and sixty more. The pastures of the highly picturesque neighbourhood support the race of milch cows which is most highly valued in south-western France. The present fame of Lourdes is entirely associated with the grotto of Massavielle, where the Virgin Mary is believed in the Catholic world to have revealed herself repeatedly to a peasant girl in 1858; the spot, which is resorted to by multitudes of pilgrims from all quarters of the world, is now marked by a large church above the grotto, consecrated in 1876 in presence of thirty-five cardinals and other high ecclesiastical dignitaries. There is a considerable trade in rosaries and other "objets de piété," as well as in the wonder-working water of the fountain, for which a miraculous origin is claimed. Not far from the grotto of Massavielle are several other caves where prehistoric remains, going back to the Stone Age and the period of the reindeer, have been found. The population of Lourdes in 1876 was 5470.

LOUSE, a term applied indiscriminately in its broad sense to all epizoic parasites on the bodies of other animals. From a more particular point of view, however, it is strictly applicable only to certain of these creatures that affect the bodies of mammals and birds. The former may be considered as lice proper, the latter are commonly known as bird-lice (although a few of their number infest mammalia). Scientifically they are now generally separated into *Anoplura* and *Mallophaga*, although some authors would include all under the former term. In the article INSECTS it has been shown that modern ideas tend towards placing the *Anoplura* as degraded members of the order *Hemiptera*, and *Mallophaga* as equally degraded *Pseudo-Neuroptera*, according to the different formation of the mouth parts. Both agree in having nothing that can be termed a metamorphosis; they are active from the time of their exit from the egg to their death, gradually increasing in size, and undergoing several moults or changes of skin; but it should be remembered that many insects of the hemimetabolic division would scarcely present any stronger indications of metamorphoses were it not for the usual outgrowth of wings, which are totally wanting in the lice.

The true lice (or *Anoplura*) are found on the bodies of many mammalia, and, as is too well known, occasion by their presence intolerable irritation. The number of genera is few. Two species of *Pediculus* are found on the human body, and are known ordinarily as the head-louse (*P. capitis*) and the body-louse (*P. vestimenti*); some appear to recognize a third (*P. tabescentium*), particularly affecting persons suffering from disease, burrowing (at any rate when young) beneath the skin, and setting up what is termed "phthiriasis" in such a terrible form that the unhappy victims at length succumb to its attacks; to this several historical personages both ancient and modern are said to have fallen victims, but it is open to very grave doubts whether this frightful condition of things was due to other than the attacks of myriads of the ordinary body-louse. *P. capitis* is found on the head, especially of children. The eggs, laid on the hairs, hatch in about eight days, and the lice are full grown in about a month. Such is the fecundity of lice that it is asserted by Leeuwenhoek that one female (probably of *P. vestimenti*) may in the course of eight weeks witness the birth of five thousand descendants. Want of cleanliness undoubtedly favours their multiplication in a high degree, but it is scarcely necessary here to allude to the idea once existing, and probably still held by the very ignorant, to the effect that they are directly engendered from dirt. The irritation is caused by the rostrum of the insect being inserted into the skin, from which the blood is rapidly pumped up. Attempts have been made to prove that the head-louse (and, in a smaller degree, the body-louse) is liable to slight variation in structure, and also in colour, according to the races of men infested. This was probably first enunciated by Pouchet in 1841, and the subject received more extended examination by Andrew Murray in a paper published in the *Transactions of the Royal Society of Edinburgh* in 1861 (vol. xxii. pp. 567–577), who apparently shows that some amount of variation does exist, but there is yet need for further investigation. That lice are considered *bonnes bouches* by certain uncivilized tribes is well known. It would be out of place to discuss here the possible interpretation of the Biblical reference to "lice" (*cf.* Exodus viii. 16, 17). A third human louse is known as the crab-louse (*Phthirius pubis*); this disgusting creature is found amongst the hairs on other parts of the body, particularly those of the pubic region, but probably never on the head; although its presence may generally be looked upon as indicating dissolute association, it should not be regarded as always resulting therefrom, as it may be accidentally acquired by the most innocent. The louse of monkeys is now generally considered as forming a separate genus (*Pedicinus*), but the greater part of those infesting domestic and wild quadrupeds are mostly grouped in the large genus *Hæmatopinus*, and very rarely is the same species found on different kinds of animals; one species is found on the seal, and even the walrus does not escape, a new species (*H. trichechi*) having been recently discovered affecting the axillæ (and other parts where the skin is comparatively soft) of that animal.

The bird-lice (or *Mallophaga*) are far more numerous in species, although the number of genera is comparatively small. With the exception of the genus *Trichodectes*, the various species of which are found on mammalia, all infest birds (as their English name implies). As the mouth parts of these creatures are not capable of being extended into a sucking tube, but are clearly mandibulate, it appears probable that they feed more particularly on the scurf of the skin and feathers; nevertheless great irritation must be caused by their presence, for it is notorious that cage-birds, much infested, will peck themselves to such an extent as to cause death in their endeavours to get rid of the parasites. Several hundred species are already known. Sometimes two or three species (ordinarily of different genera) infest the same species of bird, and the same species of louse is not often found in different birds, unless those latter happen to be closely allied. But in aviaries and zoological gardens such cases do occasionally occur, as is natural under the circumstances. These are analogous to the occasional presence of the flea of the cat, dog, domestic fowl, &c., on man; temporary annoyance is caused thereby, but the conditions are not favourable for the permanent location of the parasites. Notwithstanding the marked preference shown by a special kind of bird-lice for a special host, there is also a marked preference shown by the individual species of certain genera or groups of lice for allied species of birds, which bears upon the question of the possible variation of human lice according to the race infested.

Literature.—The following works are the most important:—Denny, *Monographia Anoplurorum Britanniæ*, London, 1843; Giebel, *Insecta Epizoa* (which contains the working-up of Nitzsch's posthumous materials), Leipsic, 1874; Van Beneden, *Animal Parasites*, London, 1876; Piaget, *Les Pédiculines*, Leyden, 1880; Mégnin, *Les Parasites et les Maladies Parasitaires*, Paris, 1880.

LOUTH, a maritime county in the province of Leinster, Ireland, is bounded on the N.E. by Carlingford Bay and the county of Down, E. by the Irish Sea, S.W. by Meath, and N.W. by Monaghan and Armagh. It is the smallest county in Ireland, the area comprising 202,124 acres, or 316 square miles.

The greater part of the surface is undulating, with occasionally lofty hills; and in the north-east, on the borders of Carlingford Bay, there is a range of mountains approaching 2000 feet in height. Many of the hills are finely wooded, and towards the sea-coast the scenery, in the more elevated districts, is strikingly picturesque. The northern mountains are composed of felspathic and pyroxenic rocks. The lower districts rest chiefly on clay-slate and limestone. With the exception of the promontory of Clogher Head, which rises abruptly to a height of 180 feet, the sea-coast is for the most part low and sandy. The narrow and picturesque bay of Carlingford is navigable beyond the limits of the county, and the bay of Dundalk stretches to the town of that name and affords convenient shelter for a harbour. The principal rivers are the Fane, the Lagan, the Glyde, and the Dee, which all flow eastwards. None of these are navigable, but the Boyne, which forms the southern boundary of the county, is navigable for large vessels as far as Drogheda.

Agriculture.—In the lower regions the soil is a very rich deep mould, admirably adapted both for cereals and green crops. The higher mountain regions are covered principally with heath. Agriculture generally is in an advanced condition, and the farms are for the most part well drained.

In 1880 there were 97,954 acres, or nearly one-half of the total area, under tillage, while 74,944 were pasture, 4585 plantations, and 24,135 waste. The total number of holdings in 1880 was 8216, of which 1294 were less than 1 acre in extent. No less than 5340 were below 15 acres in extent, and of these 2486 were between 5 and 15 acres. The following table shows the areas under the principal crops in 1855 and 1881:—

	Wheat.	Oats.	Other Cereals.	Potatoes.	Turnips.	Other Green Crops.	Flax.	Meadow and Clover.	Total.
1855	9,674	38,530	22,028	12,010	9,235	2,548	190	17,286	111,501
1881	3,382	26,543	20,620	11,356	9,906	1,696	1,307	22,581	97,391

Between 1855 and 1881 horses have diminished from 12,133 to 10,810, of which 7394 are used for agricultural purposes. The number of cattle has increased only slightly, from 32,107 to 34,739, of which 8728 are milch cows. Sheep in 1855 numbered 31,712, and 33,362 in 1881. Pigs in 1881 numbered 10,471, and poultry 241,446. According to the last return the land was divided among 1279 proprietors, who possessed 200,287 acres, with an annual rateable value of £209,090, or 20s. 10d. per acre. Of the owners, 45 per cent. possessed less than 1 acre, and the average size of the properties was 156 acres. The largest proprietors were Lord Clermont, 20,369 acres; Viscount Masserene, 7193; A. H. Smith Barry, 6239; Colonel J. C. W. Fortescue, 5262; and Lord Bellew, 5109.

Manufactures and Trade.—Sheetings and coarse linen cloth are manufactured in some places. Many of the inhabitants are engaged in deep-sea fishing, and there is a very valuable oyster fishery in Carlingford Bay. At Newry, Drogheda, and Dundalk a considerable coasting trade is carried on.

Railways.—The county is intersected from north to south by the Dundalk and Belfast line, and the Irish North-Western line passes westwards from Dundalk to Enniskillen.

Administration and Population.—The county includes 6 baronies, 64 parishes, and 674 townlands. It is in the north-eastern circuit. Assizes are held at Dundalk, and quarter sessions at Ardee, Drogheda, and Dundalk. There are ten petty sessions districts within the county and a portion of one. It includes portions of the three poor-law unions of Ardee, Drogheda, and Dundalk. With the exception of Drogheda, which is in the Dublin military district, the county is in the Belfast military district; and there are barracks at Dundalk. Besides the two members at present returned by the county, and one member by each of the boroughs of Drogheda and Dundalk, Louth in the Irish parliament was represented by an additional member for each of the boroughs of Drogheda and Dundalk, and by two members for each of the boroughs of Ardee, Carlingford, and Dunleer. The principal towns are Drogheda (14,662) and Dundalk (12,294). In 1760 the population was estimated at 67,572, which in 1841 had increased to 128,347, but in 1851 had diminished to 108,018, in 1871 to 84,021, and in 1881 to 78,228, of whom 38,241 were males and 39,987 females. From 1st May 1851 to 31st December 1881, the number of emigrants was 33,521, a percentage of 37·2 of the average population during that period. The marriage rate to every 1000 of estimated population in 1880 was 3·4, the birth rate 23·5, and the death rate 21·4.

History and Antiquities.—In the time of Ptolemy, Louth was inhabited by the Voluntii. Subsequently it was included in the principality of Orgial or Argial, which comprehended also the greater part of Meath, Monaghan, and Armagh. A subordinate territory which included Louth was known as *Hy-Conal* and *Machuire-Conal.* The chieftain of the district was conquered by John de Courcy in 1183, and in 1210 that part of the territory now known as Louth was made shire ground by King John, and peopled by English settlers. Until the time of Elizabeth it was included in Ulster.

In the county there are a large number of antiquarian remains of special interest. There are ruins of Druidical altars at Balrighan and Carrick Edmond, and of a Druidical temple at Ballinahatrey near Dundalk. The round tower at Monasterboice is in very good preservation, and there are remains of another at Dromiskin. The most remarkable cromlechs are those on Killin Hill and at Ballymascanlan. At Killin Hill there is an extraordinary fort called *Faghs-na-ain-eighe*, or "the one night's work"; and near Ballymascanlan is Castle Rath, surrounded by lesser raths, and having a remarkable tumulus in its vicinity. About 2 miles from Dundalk there is a very ancient structure, the origin of which has been much discussed. Near Balrighan there is a curious artificial cave. A large number of spears, swords, axes of bronze, gold ornaments, and other relics of antiquity have been discovered. There are a great number of Danish and other old forts. Originally there are said to have been no fewer than twenty religious houses within the county. Of these there are interesting remains at Carlingford; at Faughart, where is also to be seen St Bridget's stone and pillar; at Mellifont, the architecture of which is specially beautiful and elaborate; and at Monasterboice, where there are two crosses, one of which, St Boyne's, is the most ancient and most finely decorated in Ireland.

LOUTH, a municipal borough and market-town of Lincolnshire, England, is pleasantly situated on the river Lud, and on a branch of the Great Northern Railway, 25 miles east-north-east of Lincoln. By means of a canal, completed in 1763, at a cost of £28,000, there is water communication with Hull. The town is about a mile in length, and is well built and paved. The church of St James, completed about 1516, in the Later English style, with a spire 288 feet in height, is one of the finest ecclesiastical buildings in the county. There are an Edward VI. grammar school, which is richly endowed, a commercial school founded in 1676, and a national school. The other public buildings include a town-hall, a corn exchange, and a market-hall. In the vicinity are the ruins of a Cistercian abbey, founded in 1139. The industries include the manufacture of carpets, tanning, iron-founding, brewing, malting, lime burning, and rope and brickmaking.

The population, which in 1851 was 10,467, had increased in 1871 to 10,500, and in 1881 to 10,690.

Louth is a corruption of *Ludd*, the ancient name of the river Lud. It received a charter of incorporation from Edward VI. In 1536 the town took part in the "Pilgrimage of Grace," on which account the vicar was executed at Tyburn. Alfred and Charles Tennyson were educated at the grammar school, and their little volume entitled *Poems by Two Brothers* was published by a Louth bookseller, whose shop still exists.

LOUVAIN, a town of Belgium in the province of Brabant, 18 miles east of Brussels, on the Liége and Cologne Railway, and on the river Dyle. The population in 1880 was 34,700. Louvain possesses some fine specimens of Gothic art,—the town-hall, which displays a wealth of decorative architecture almost unequalled on the Continent, and the collegiate church of St Pierre, with some fine sculptures and panels by Quentin Matsys. The general aspect of the town to the casual observer is dull and cheerless; the newer portions, extending between the town-hall and station, consist of broad streets of monotonous regularity, while the old mediæval quarter, despite its historic interest, is somewhat dingy and lifeless. Louvain has a market for corn and cattle as well as for cloth wares; wood carving is also carried on; but the chief industry of the locality is brewing, the Louvain beer, a lemon-coloured frothy beverage, being held in high repute in the country. In the world of science Louvain holds honourable rank, having a celebrated university, an academy of painting, a school of music, extensive bibliographic collections, a museum of natural history, and a botanical garden. The university, a stronghold of the Roman Catholic faith, was first instituted in 1425, and soon grew famous among the learned of all nations. In the 15th and 16th centuries not less than six thousand students flocked thither yearly, and it became the nursery of many illustrious men. Swept away for a time by the first French Revolution, it was re-established in 1835; and, though less conspicuous than in bygone ages, and more generally confined to the instruction of the youth of Belgium, it is yet of considerable importance in the country as the only Catholic university, and one of the main supports of the Conservative party.

Like Bruges and many other Flemish towns, Louvain was at one time a great and flourishing city, with a population of 200,000 souls, and one of the principal markets of the Continent. The turbulent spirit of the people, their frequent outbreaks against their rulers, and in particular the massacre of the patricians in 1378, were the chief causes of its decline. Duke Wenceslaus of Brabant, in a spirit of revenge after the last-mentioned rising, imposed so heavy taxes upon the people that they emigrated in large numbers. A hundred thousand weavers left the country, carrying abroad, mainly to England, the secrets of their trade; and from that period the material prosperity of Louvain has steadily diminished.

LOUVIERS, capital of an arrondissement in the department of Eure, France, is pleasantly situated, in a green valley surrounded by wooded hills, on the Eure (here divided into many branches), 71 miles west-north-west from Paris, and some 13 miles from Rouen and Evreux. The old part of the town, built of wood, stands on the left bank of the river; the more modern portions, in brick and hewn stone, on the right. There are several good squares, and the place is surrounded by boulevards. The Gothic church of Notre Dame has a fine square tower, recently restored, and a portal which ranks among the richest and most beautiful works of the kind produced in the 15th century; it contains several interesting works of art. The chief industry of Louviers is the cloth and flannel manufacture. There are also nineteen wool-spinning mills, five fulling mills, and important thread factories; and paper-making, tanning, currying and tawing, dyeing, and bleaching are also carried on. The town has a court of first instance, a tribunal of commerce, chambers of manufactures and agriculture, and a council of prudhommes. The population in 1876 was 10,973.

Louviers was originally a villa of the dukes of Normandy; its cloth-making industry first arose in the beginning of the 13th century. It changed hands once and again during the Hundred Years' War, and from Charles VII. it received extensive privileges, and the title of Louviers le Franc for the bravery of its inhabitants in driving the English from Pont de l'Arche, Verneuil, and Harcourt. It passed through various troubles successively at the period of the "ligue du bien public" under Louis XI., in the religious wars (when the parliament of Rouen sat for a time at Louviers), and in the wars of the Fronde. Its industries nevertheless developed steadily; before the Revolution its production of cloth amounted to 3000 pieces annually, in 1837 the number had risen to 15,000, and it is still greater now.

LOUVOIS, François Michel le Tellier, Marquis de (1641–1691), the great war minister of Louis XIV., was born at Paris on January 18, 1641. His father, Michel le Tellier, sprung from a bourgeois family of Paris, but had attached himself to the parlement of Paris, and married the niece of the chancellor Aligre. He won the favour of De Bullion, the superintendent of finances, and through him obtained the intendancy of Piedmont, where he made the acquaintance of Mazarin. He was Mazarin's right hand through the troublous times of the Fronde, and was the medium of communication between him and the queen, when the cardinal was in nominal disgrace at Brühl. He had been made secretary of state in 1643, and on the death of Mazarin was continued in his office. Like Colbert and unlike Fouquet he recognized the fact that Louis intended to govern, and by humouring his master's passion for knowing every detail of personnel and administration he gained great favour with him. He married his son to a rich heiress, the Marquise de Courtenvaux, and soon began to instruct him in the management of state business. The young man speedily won the king's confidence, and in 1666 was made secretary of state for war in his father's room. His talents were perceived by the great Turenne in the short war of the Devolution (1667–68), who gave him instruction not so much in the art of war as in the art of providing armies. The peace of Aix-la-Chapelle signed, Louvois devoted himself to the great work of organizing the French army. The years between 1668 and 1672, says Camille Rousset, "were years of preparation, when Lionne was labouring with all his might to find allies, Colbert to find money, and Louvois soldiers for Louis." Louvois's work was not the least important of the three. Till then armies were either bodies of free lances collected round a particular general and looking to him for pay, or a sort of armed militia, who looked on soldiering as an interlude, not a profession. Louvois understood the new condition of things, and organized a national standing army. In his organization, which lasted almost without a change till the period of the French Revolution, the leading points must be noted. First among them was the almost forcible enrolment of the nobility and gentry of France, which St Simon so bitterly complains of, and in which Louvois carried out part of Louis's measures for curbing the spirit of independence by service in the army or at court. Then must be mentioned his elaborate hierarchy of officers, the grades of which with their respective duties he established for the first time, and his new system of drill, perfected by Martinet. Besides the army itself, he organized for its support a system of payment and commissariat, and a hospital system, which made it more like a machine, less dependent on the weather, and far superior to the old German system. Further, with the help of Vauban he formed a corps of engineers, and lastly, to provide the deserving with suitable reward, and encourage the daring, he reorganized the military orders of merit, and founded the Hôtel des Invalides at Paris. The success of his measures is to be seen in the victories of the great war of 1672–1678, in which his old instructor Turenne was killed. After the peace of Nimeguen in 1678, Louvois was high in favour, his father Michel le Tellier had been made chancellor, and his only opponent Colbert was in growing disfavour. The ten years of peace between 1678 and 1688 were distinguished in French history by the rise of Madame de Maintenon, the capture of Strasburg, and the revocation of the edict of Nantes, in all of which Louvois bore a prominent part. The surprise of Strasburg in 1681 in time of peace, in pursuance of an order of the chamber of reunion, was not only planned but executed by Louvois and Monclar, and after the revocation of the Edict of Nantes he claims the credit of inventing the dragonnades. Colbert died in 1683, and had been replaced by Le Pelletier, an adherent of Louvois, in the controller-generalship of finances, and by Louvois himself in his ministry for public buildings, which he took that he might be the minister able to gratify the king's two favourite pastimes, war and buildings. Louvois was able to superintend the successes of the first years of the war of 1688, but died suddenly of apoplexy after leaving the king's cabinet on July 16, 1691. His sudden death caused a suspicion of poison, and struck everybody with surprise. "He is dead," writes Madame de Sevigné, "that great minister, that important man, who held so grand a position, and whose *Moi* spread so far, who was the centre of so much." "Tell the king of England," said Louis the next day, "that I have lost a good minister, but that his affairs and mine will go none the worse for that." He was very wrong; with Louvois the organizer of victory was gone. Great war ministers are far rarer than great generals. French history can only point to Carnot as his equal, English history only to the elder Pitt. The comparison with Carnot is an instructive one: both had to organize armies out of old material on a new system, both had to reform the principle of appointing officers, both were admirable contrivers of campaigns, and both devoted themselves to the material well-being of the soldiers. But in private life the comparison will not hold; Carnot was a good husband, an upright man, and a broad minded thinker and politician, while Louvois married for money and lived openly with various mistresses, most notoriously with the beautiful Madame de Courcelles, used all means to overthrow his rivals, and boasted of having revived persecution in his horrible system of the dragonnades.

The principal authority for Louvois's life and times is Camille Rousset's *Histoire de Louvois*, 4 vols., 1862–63, a gr at work founded on the 900 volumes of his despatches at the Depôt de la Guerre. Saint Simon from his class prejudices is hardly to be trusted, but Madame de Sevigné throws many bright side-lights on his times. *Testament Politique de Louvois* (1695) is spurious.

LOVAT, Simon Fraser, Baron, a famous Jacobite intriguer, executed for the part which he took in the rebellion of 1745, was born about the year 1676, and was the second son of Thomas, afterwards twelfth Lord Lovat. He was educated at King's College, Aberdeen, and there seems reason to believe that he was there no negligent student, as his correspondence afterwards gives abundant proof, not only of a thorough command of good English and idiomatic French, but of such an acquaintance with the Latin classics as to leave him never at a loss for an apt quotation from Virgil or Horace. Whether Lovat ever felt any real principle of loyalty to the Stuarts or was actuated throughout merely by what he supposed to be self-interest it is difficult to determine, but that he was a born traitor and deceiver there can be no doubt. One of his first acts on leaving college was to recruit three hundred men from his clan to form part of a regiment in the service of William and Mary, in which he himself was to hold a command,—his object being, as he unhesitatingly avows, to have a body of well-trained soldiers under his influence, whom at a moment's notice he might carry over to the interest of King James. Among other wild outrages in which he was engaged about this time was a rape and forced marriage committed on the widow of a previous Lord Lovat with the view apparently of securing his own succession to the estates; and it is a curious instance of his plausibility and power of influencing others that, after being subjected by him to the most horrible ill-usage, the woman is said to have ultimately become seriously attached to him. A prosecution for his violence, however, having been instituted against him by Lady Lovat's family, Simon found it prudent to retire first to his native strongholds in the Highlands, and afterwards to France, where he at length found his way in July 1702 to the court of St Germains. One of his first steps towards gaining influence there seems to have been to announce his conversion to the Catholic faith. He then proceeded to put the great project of restoring the exiled family into a practical shape. Hitherto nothing seems to have been known among the Jacobite exiles of the efficiency of the Highlanders as a military force. But Lovat, who was of course well acquainted with their capabilities, saw that, as they were the only part of the British population accustomed to the independent use of arms, they could be at once put in action against the reigning power. His plan therefore was to land five thousand French troops at Dundee, where they might reach the north-eastern passes of the Highlands in a day's march, and be in a position to divert the British troops till the Highlands should have time to rise. Immediately afterwards five hundred men were to land on the west coast, seize Fort William or Inverlochy, and thus prevent the access of any military force from the south to the central Highlands. The whole scheme affords strong indication of Lovat's sagacity as a military strategist, and it is observable that his plan is that which was continuously kept in view in all the future attempts of the Jacobites, and finally acted on in the last outbreak of 1745. The advisers of the Pretender seem to have been either slow to trust their astute coadjutor or slow to comprehend his project. At last, however, he was despatched on a secret mission to the Highlands to sound those of the chiefs who were likely to rise, and to ascertain what forces they could bring into the field. He very soon found, however, that there was little disposition to join the rebellion, and he then made up his mind to secure his own safety by revealing all that he knew to the Government of Queen Anne. Having by this means obtained a pardon for all his previous crimes, he was sent back to France to act as a spy on the Jacobites. On returning to Paris suspicions soon got afloat as to his proceedings, and in the end he was committed close prisoner in the castle of Angoulême, where he remained for nearly ten years, or till November 1714, when he made his escape to England. For some twenty-five years after this he was chiefly occupied in lawsuits for the recovery of his estates and the re-establishment of his fortune, in both of which objects he was successful. The intervals of his leisure were filled up by Jacobite and Anti-Jacobite intrigues, in which he seems to have alternately, as suited his interests, acted the traitor to both parties. But he so far obtained the confidence of the Government as to have secured the appointments of sheriff of Inverness and of colonel of an independent company. His disloyal practices, however, soon led to his being suspected; and he was deprived of both his appointments. When the rebellion of 1745 broke out, Lovat acted with his characteristic duplicity. He represented to the Jacobites—what was probably in the main true—that though eager for their success his weak health and advanced years prevented him from joining the standard of the prince in person, while to the Lord President Forbes he professed his cordial attachment to the existing state of things, but lamented that his headstrong son, in spite of all his remonstrances, had insisted on joining the Pretender, and succeeded in taking with him a strong force from the clan of the Frasers. The truth was that the poor lad was most unwilling to go out, but was compelled by his father to do so. Lovat's false professions of fidelity did not of course long deceive the Government, and after the battle of Culloden he was obliged to retreat to some of the wildest recesses of the Highlands, after seeing from a distant height his proud castle of Dounie delivered to the flames by the royal army. Even then, however, broken down by disease and old age, carried about on a litter and unable to move without assistance, his mental resources did not fail him; and in a conference with several of the Jacobite leaders he proposed that they should raise a body of three thousand men, which would be enough to make their mountains impregnable, and at length force the Government to give them advantageous terms. The project, though by no means a chimerical one, was not carried out, and Lovat, after enduring incredible hardships in his wanderings, was at last arrested on an island in Loch Morar close upon the west coast. He was conveyed in a litter to London, and after a trial of five days sentence of death in "the ordinary brutal form peculiar to England" was pronounced upon him on the 19th of March 1747. His execution took place on the 9th of April following. His conduct to the last was dignified and even cheerful,—his humour, his power of sarcasm, and his calm defiance of fate never deserting him. Just before submitting his head to the block he repeated the line from Horace—

"Dulce et decorum est pro patria mori."

LOVE-BIRD, a name somewhat indefinitely bestowed, chiefly by dealers in live animals and their customers, on some of the smaller short-tailed Parrots, from the remarkable affection which examples of opposite sexes exhibit towards each other, an affection popularly believed to be so great that of a pair that have been kept together in captivity neither can long survive the loss of its partner. By many systematic ornithologists the little birds thus named, brought almost entirely from Africa and South America, have been retained in a single genus, *Psittacula*, though those belonging to the former country were by others separated as *Agapornis*. This separation, however, was by no means generally approved, and indeed it was not easily justified, until Garrod (*Proc. Zool. Society*, 1874, p. 593) assigned good anatomical ground, afforded by the structure of the carotid artery, for regarding the two groups as distinct, and thus removed what had seemed to be the almost unintelligible puzzle presented by the geographical distribution of the species of *Psittacula* in a large sense, though Professor Huxley (*op. cit.*, 1868, p. 319) had indeed already suggested one way of meeting the difficulty. As the genus is now restricted, only one of the six species of *Psittacula* enumerated in the *Nomenclator Avium* of Messrs Sclater and Salvin is known to be found outside of the Neotropical Region, the exceptional instance being the Mexican *P. cyanopygia*, and not one of the seven recognized by the same authors as forming the very nearly allied genus *Urochroma*. On the other hand, of *Agapornis*, from which the so-called genus *Poliopsitta* can scarcely be separated, five if not six species are known, all belonging to the Ethiopian Region, and all but one, *A. cana* (which is indigenous to Madagascar, and thence has been widely disseminated), are natives of Africa. In this group probably comes also *Psittinus*, with a single species from the Malayan Subregion. These Old-World forms are the "Love-birds" proper; the others scarcely deserve that designation, and still less do certain even smaller Parrots, the very smallest indeed of the Order *Psittaci*, included in the genera *Cyclopsitta* and *Nasiterna*, which are peculiar to the Australian Region, though on account of their diminutive size they may here be just mentioned by name, but their real affinity remains to be determined. (A. N.)

LOVELACE, Richard (1618–1658), English poet, was born in 1618. On the father's side he was a scion of a Kentish family, and inherited a tradition of military distinction, maintained by successive generations from the time of Edward III. His mother's family was legal; her grandfather had been chief baron of the exchequer. Lovelace's fame has been kept alive by a few songs and the romance of his career, and his poems are commonly spoken of as careless improvisations, and merely the amusements of an active soldier. But the unhappy course of his life gave him more leisure for verse-making than opportunity of soldiering. Before the outbreak of the civil war in 1642 his only active service was in the bloodless expedition which ended in the Pacification of Berwick in 1640. By that time he was one of the most distinguished of the company of courtly poets gathered round Queen Henrietta, and influenced as a school by contemporary French writers of *vers de société*. Lovelace had probably a more serious and sustained poetical ambition than any of them. He wrote a comedy, *The Scholar*, when he was sixteen, and a tragedy, *The Soldier*, when he was one and twenty. From what he says of Fletcher, it would seem that this dramatist was his model, but only the spirited prologue and epilogue to his comedy have been preserved. When the rupture between king and parliament took place, Lovelace was committed to the Gatehouse at Westminster for presenting to the Commons a petition from Kentish royalists in the king's favour. It was then that he wrote his most famous song, "To Althæa from Prison." He was liberated on bail of £40,000,—a sign of his importance in the eyes of the parliament,—and throughout the civil war was a prisoner on parole, with this security in the hands of his enemies. His only active service was after 1646, when he raised a regiment for the French king, and took part in the siege of Dunkirk. Returning to England in 1648, he was again thrown into prison. During this second imprisonment, he collected and revised for the press a volume of occasional poems, many if not most of which had previously appeared in various publications. The volume was published in 1649 under the title of *Lucasta*, his poetical name—contracted from *Lux Casta*—for Lucy Sacheverell, a lady who married another during his absence in France, on a report that he had died of his wounds at Dunkirk. The last ten years of Lovelace's life were passed in obscurity. His fortune had been exhausted in the king's interest, and he is said to have been supported by the generosity of more fortunate friends. He died, according to Aubrey, "in a cellar in Longacre." A volume of Lovelace's *Posthume Poems* was published in 1659 by one of his brothers. They are of very inferior merit to his own collection.

The world has done no injustice to Lovelace in neglecting all but a few of his modest offerings to literature. But critics often do him injustice in dismissing him as a gay cavalier, who dashed off his verses hastily and cared little what became of them. It is a mistake to class him with Suckling; he has neither Suckling's easy grace nor his reckless spontaneity. We have only to compare the version of any of his poems in *Lucasta* with the form in which it originally appeared to see how fastidious was his revision. In many places it takes time to decipher his meaning. The expression is often elliptical, the syntax inverted and tortuous, the train of thought intricate and discontinuous. These faults—they are not of course to be found in his two or three popular lyrics, "Going to the Wars," "To Althæa from Prison," "The Scrutiny"—are, however, as in the case of his poetical master, Donne, the faults not of haste but of over-elaboration. His thoughts are not the first thoughts of an improvisatore, but thoughts ten or twenty stages removed from the first, and they are generally as closely packed as they are far-fetched. Lovelace is not named by Johnson among the "metaphysical poets," but in elaboration of workmanship as well as in intellectual force he comes nearer than any other disciple to the founder of the school. His most far-fetched conceits are worth the carriage, and there is genuine warmth in them. The wine of his poetry is a dry wine, but it is wine, and not an artificial imitation. His career as a dramatist was checked by the suppression of the stage; if he had been born thirty years earlier or thirty years later, Fletcher or Congreve would have had in him a powerful rival. The most recent edition of his poems is that by W. C. Hazlitt, in 1864.

LOVER, SAMUEL (1797–1868), novelist, artist, song-writer, and musician, was born in Dublin in 1797. His father was a member of the stock exchange. Lover began life as an artist, and was elected an academician of the Royal Hibernian Society of Arts—a body of which he afterwards became secretary. He acquired repute as a miniature painter; and a number of the local aristocracy sat to him for their portraits. His love for music showed itself at a very early age. At a dinner given to the poet Moore in 1818 Lover sang one of his own songs, which elicited special praise from Moore. One of his best known portraits was that of Paganini, which was exhibited at the Royal Academy. He attracted attention as an author by his *Legends and Stories of Ireland* (1832), and was one of the first writers for the *Dublin University Magazine*. He went to London about 1835, where, among others, he painted Lord Brougham in his robes as lord chancellor. His varied gifts rendered him very popular in society; and he appeared often at Lady Blessington's evening receptions. There he sang several of his songs, which were so well received that he published them (*Songs and Ballads*, 1839). Some of them illustrated Irish superstitions, among these being "Rory O'More," "The Angel's Whisper," "The May Dew," and "The Four-leaved Shamrock." In 1837 appeared *Rory O'More, a National Romance*, which at once made him a great reputation as a novelist; he afterwards dramatized it for the Adelphi Theatre, London. In 1842 was published his best known work, *Handy Andy, an Irish Tale*. Meanwhile his multifarious pursuits had seriously affected his health; and in 1844 he gave up writing for some time, substituting instead public entertainments, called by him "Irish Evenings," illustrative of his own works and his powers as a musician and composer. These were very successful both in Great Britain and in America. In addition to publishing numerous songs of his own, Lover edited a collection entitled *The Lyrics of Ireland*, which appeared in 1858. He died on July 6, 1868. Lover was remarkable for his versatility; but his fame rests mainly on his songs and novels; the latter are full of sunny Irish humour, and teem with felicitous pictures of national life. Besides those already mentioned he wrote *Treasure Trove* (1844), and *Metrical Tales and Other Poems* (1860).

LOWELL, the twenty-seventh city in population of the United States, in Middlesex county, Massachusetts, at the junction of the Concord and Merrimack rivers, 26 miles north-west from Boston. It is often called the "Spindle City," and the "Manchester of America," because of the extent of its cotton manufacture. The principal source of its water-power is Pawtucket Falls in the Merrimack, and steam is employed as an auxiliary to the amount of 19,793 horse-power. The first cotton-mill was started in 1823, when the place was the village of East Chelmsford. In 1826 it was made a town, and named Lowell in memory of Francis Cabot Lowell, from whose plans it had been developed, but who died in 1817. It was incorporated as a city in 1836. It originally comprised 2885 acres, but by annexation from neighbouring towns its area has been increased to 7615 acres, or 11·8 square miles. The population, which in 1836 was 17,633, was 40,928 in 1870, and 59,485 in 1880 (males, 26,855; females, 32,630), and in 1882 was estimated at 64,000.

The following table shows the extent of the principal manufacturing companies in 1882:—

Company.	Established.	Looms.	Spindles.	Operatives.	Yards per Week.
Merrimack	1823	4,267	153,552	3,300	947,000
Hamilton	1825	1,597	59,816	1,387	364,000
Appleton	1828	1,228	45,000	820	285,000
Lowell	1828	392	24,750	1,700	48,000
Middlesex	1830	250	18,640	836	25,000
Tremont and Suffolk	1832	2,700	94,000	1,500	550,000
Lawrence	1833	2,360	100,000	2,130	425,000
Booth	1836	3,600	127,000	1,875	650,000
Massachusetts	1840	3,658	119,528	1,717	907,000

The capital invested is $17,300,000; number of mills, 153; spindles, 806,000; looms, 20,521; females employed, 12,809; males, 9750; yards per year, cotton 209,056,000, woollen 8,335,000, carpetings 2,700,000; shawls, 350,000; hosiery per year, 13,695,520 pairs; cotton consumed annually, 34,087 tons; clean wool, 11,750,000 ℔; yards cotton dyed and printed, 97,240,000; coal consumed, 80,000 tons. There are many secondary industries connected with the cotton manufacture, including the making of machinery, elastic and leather goods, tools, boilers, &c., and also a number of small factories for the production of cartridges, chemicals, wire cloth, paper, doors, sashes, blinds, and carriages. The Lowell machine-shop employs 1400 men in the manufacture of machinery, and consumes 9800 tons of iron and steel annually. Lowell has 90 public day schools, 6 evening and 4 technical schools, a reform school, and 2 parochial schools. The principal public buildings are the city-hall, court-house, Middlesex county jail, Green school-house, and St John's Hospital. There are 7 national banks with a total capital of $2,500,000, and 6 savings banks with deposits of $11,000,000. The religious congregations number 35, all but three of which own their places of worship. The two largest Roman Catholic churches, St Patrick's and the Church of the Immaculate Conception, are among the finest in the State. Seven railroads connect Lowell with the railroad system of the country. The benevolent institutions include a home for young women and children, and one for aged women, 2 orphanages, and 3 hospitals. There are 2 reading-rooms, 5 daily newspapers (one French), 6 weeklies, and 4 public libraries. Lowell was early famed for the high character of its operatives, who for some years published a periodical of considerable literary merit called *The Lowell Offering*, which was, it is believed, the only publication of the kind ever sustained by workpeople. Many of the young women rose to positions of prominence in American society, and at least one, Miss Lucy Larcom, is known to readers on both sides of the Atlantic by her contributions to leading magazines.

In 1843 Charles Dickens visited the place, and devoted a chapter of his *American Notes* to its praise. The manufacturers have from the first provided for the moral and social as well as the physical wellbeing of their operatives, so that labour troubles have been exceedingly rare in Lowell. The corporation boarding-houses are model dwellings for the workpeople. The first blood shed in the American civil war was that of two Lowell young men, Luther C. Ladd and A. O. Whitney, who were killed by a mob while their regiment was passing through the streets of Baltimore, on the way to the defence of Washington, April 19, 1861. In their honour a granite monument has been erected in Merrimack Street, and in the same enclosure is a bronze statue of Victory by the German sculptor Rauch to commemorate the triumph of the Northern cause.

The assessed valuation in May 1881 was $42,785,434 an increase of $3,108,035 since 1879); the net debt December 31, 1881, was $1,992,868, of which $1,565,539 was on account of the introduction of water in 1873.

Lowell is divided into six wards, and is governed by a mayor, a board of eight aldermen, and a common council of twenty-four members.

LOWESTOFT, a watering-place, seaport, and market-town of Suffolk, England, is picturesquely situated on a lofty declivity, which includes the most easterly point of land in England, 23 miles south-west of Norwich by rail. Previous to the opening of a railway, it was only a small fishing village, but since then it has risen to some importance as a seaport, while its picturesque situation, and its facilities for sea-bathing, have rendered it a favourite watering-place. The church of St Margaret, in the Later English style, with tower and spire, possesses a very ancient font. There are a town-hall, a county-hall, two foundation schools, a large general hospital, and a number of charities. Along the shore there is a fine esplanade, and a new park was opened in 1874. Two piers 1300 feet in length enclose a harbour of 20 acres, which is much used as a harbour of refuge. For the last five years the average value of the foreign and colonial imports has been over £100,000, and the exports have been valued at about £5000. The fisheries of Lowestoft are of some importance, and there are shipbuilding yards, oil and flour mills, and rope-works. The population of the urban sanitary district in 1871 was 15,246, and in 1881 it had increased to 19,597.

LOWICZ, a town of Russian Poland, on the Bzura river, in the government of Warsaw, 54 miles by rail west from the capital, on the line between Skiernewice and Bromberg. It has lately become a centre of manufacture and trade, and the population (6650 in 1872) is rapidly increasing. Its fairs are important as regards the trade in horses and cattle. In the immediate neighbourhood are situated the hamlet Liczcowice, which has a beetroot sugar factory, and the rich estates Nieboron and Villa Arcadia of the Radziwill family.

LOWTH, Robert (1710–1787), bishop of London, was born at Buriton, Hampshire, or, according to other authorities, in the Close of Winchester, on November 27, 1710. He was the younger son of Dr William Lowth (1661–1732), rector of Buriton, a man of considerable learning, author of *A Vindication of the Divine Authority and Inspiration of the Old and New Testaments* (1692), *Directions for the Profitable Reading of the Holy Scriptures* (1708–26), and *A Commentary on the Prophets* (4 vols., 1714). Robert was educated on the foundation of Winchester College, and in 1730 was elected to a scholarship at New College, Oxford, where he took his degree of M.A. in 1737. In 1741 he was appointed professor of poetry, and it was in this capacity that he delivered the *Prælectiones Academicæ de Sacra Poesi Hebræorum*, afterwards published in 1753. Bishop Hoadly appointed him in 1744 to the rectory of Ovington, Hampshire, in 1750 to the archdeaconry of Winchester, and in 1753 to the rectory of East Woodhay, also in Hampshire. In 1754 he received the degree of doctor of divinity from his university, and in the following year he went to Ireland along with the duke of Devonshire, then lord-lieutenant, as first chaplain. Soon afterwards he declined a presentation to the see of Limerick, but accepted a prebendal stall at Durham and the rectory of Sedgfield. In 1758 he published his *Life of William of Wykeham*, which was followed in 1762 by *A Short Introduction to English Grammar*. In 1765, the year of his election into the Royal Societies of London and Göttingen, he engaged in a hot war of pamphlets with Warburton on a now obsolete question about the relations between the book of Job and the Mosaic economy; and (Gibbon being judge), "whatsoever might be the merits of an insignificant controversy, his victory was clearly established by the silent confession of Warburton and his slaves." In June 1766 Lowth was promoted to the see of St David's, whence about four months afterwards he was translated to that of Oxford, where he remained till 1777, when he became bishop of London. This last appointment he continued to hold until his death, having declined the archbishopric of Canterbury in 1783. In 1778 appeared his last work, *Isaiah, a new Translation, with a Preliminary Dissertation, and Notes, Critical, Philological, and Explanatory.* He died at Fulham on November 1787.

The *Prælectiones* exercised a great influence both in England and on the Continent. Their chief importance lay in the idea of looking at the sacred poetry as poetry, and examining it by the standards applied to profane literature. Lowth's æsthetic criticism was that of the age, and is now in great part obsolete, a more natural method having been soon after introduced by Herder. The principal point in which Lowth's influence has been lasting is his doctrine of poetic parallelism, and even here his somewhat mechanical classification of the forms of Hebrew sense-rhythm, as it should rather be called, is open to serious objections. The *Prælectiones* reached a second edition in 1763, and were republished with notes by J. D. Michaelis in 1770; both text and notes were translated by G. Gregory (1787; 4th ed., 1839). The Oxford edition of the original (1821) contains additions by Rosenmüller, Richter, and Weiss. The editions of Lowth's *Isaiah* have been numerous (13th ed., 1842), but the book is now much less read than the *Prælectiones*. A volume of *Sermons and other Remains*, with memoir by Hall, was published in 1834, and there is a comparatively recent edition of the *Popular Works* of Robert Lowth, 3 vols., 1843.

LOYALTY ISLANDS, a group in the South Pacific, about 60 miles east of New Caledonia, consisting of Uvea or Uea (the northmost), Lifu, Toka and several small islands, and Mare or Nengone. They are coral islands of comparatively recent elevation, and in no place rise more than 250 feet above the level of the sea. Lifu, the largest, is about 50 miles in length by 25 in breadth. Enough of its rocky surface is covered with a thin coating of soil to enable the natives to grow yams, taro, bananas, &c., for their support; cotton thrives well, and has even been exported in small quantities, but there is no space available for its cultivation on any considerable scale. Fresh water, rising and falling with the tide, is found in certain large caverns, and, in fact, by sinking to the sea-level a supply may be obtained in any part of the island. The population, about 7000, is on the decrease. The island called Nengone by the natives and Mare by the inhabitants of the Isle of Pines is about 80 miles in circumference, and contains about 6000 souls. Uvea, the most recent part of the group, consists of a circle of about twenty islets enclosing a lagoon 20 miles in width; the largest is about 30 miles in length, and in some places 3 miles wide, and the next largest is about 12 miles in length. The inhabitants, numbering about 2500, export considerable quantities of cocoa-nut oil.

The Loyalty islanders are classed as Melanesian; the several islands have each its separate language, and in Uvea the one tribe uses a Samoan and the other a New Hebridean form of speech. Captain Cook passed to the east of New Caledonia without observing the Loyalty group; but it was discovered soon afterwards, and Dumont D'Urville laid down the several islands in his chart. For many years after their discovery the natives had a bad repute as dangerous cannibals. Christianity was introduced into Mare by native teachers from Rarotonga and Samoa; missionaries were settled by the London Missionary Society at Mare in 1854, at Lifu in 1859, and at Uvea in 1865; Roman Catholic missionaries also arrived from New Caledonia; and in 1864 the French, considering the islands a dependency of that colony, formally instituted a commandant. An attempt was made by this official to put a stop to the English missions by violence; but the report of his conduct led to so much indignation in Australia and in England that the emperor Napoleon, on receipt of a protest from Lord Shaftesbury and others, caused a commission of inquiry to be appointed, and free liberty of worship to be secured to the Protestant missions. A new persecution of the Christians in Uvea, during 1875, called forth a protest on the part of the English Government, and matters appear to have since improved.

See W. Gill, *Gems from the Coral Islands*, new edition, 1871; S. Macfarlane, *Story of the Lifu Mission*, 1873.

LOYOLA, Ignatius de, St. Inigo, the youngest son of Beltran de Loyola, was born in 1491 at the castle of Loyola, the family seat, situated on the river Urola, about a mile from the town of Azpeitia, in the province of Guipuzcoa, Spain. He died at Rome on July 31, 1556, was beatified by Paul V. in 1609, and canonized along with Francis Xavier by Gregory XV. on March 13, 1623, the bull being published by Urban VIII. on August 6. His festival (duplex) is observed on July 31. See Jesuits.

LOZÈRE, a department of south-eastern France, but belonging to the great central plateau, is composed of almost the whole of Gévaudan and of some parishes of the old dioceses of Alais and Uzès, districts all formerly included in the province of Languedoc. It lies between 44° 6′ and 44° 58′ N. lat., and between 2° 58′ and 4° E. long., and is bounded on the N.W. by Cantal, on the N.E. by Haute-Loire, on the E. by Ardèche, on the S.E. by Gard, and on the S.W. by Aveyron, having an extreme length of 65 miles, an extreme breadth of 50, and an area of 1996 square miles. Lozère is mountainous throughout, and its average elevation makes it the highest of all the French departments. It has three distinct regions—the Cevennes to the south-east, the "causses" to the south-west, and the mountain tracts which occupy the rest. The Cevennes, forming the watershed between the Garonne and Loire basins to the west and that of the Rhone to the east, begin (within Lozère) with Mount Aigoual, which rises to a height of more than 5100 feet; parallel to this are the mountains of Bougès, a range between the rivers Tarn and Tarnon, bold and bare on its southern face, but falling gently away with wooded slopes toward the north. To the north of the Tarn is the range of Lozère, including the peak of Finiels, the highest point of the department (5584 feet). Further on occurs the broad marshy plateau of Montbel, from which the water drains southward to the Lot, northwards to the Allier, eastward by the Chassezac to the Ardèche. From this plateau extend the mountains of La Margeride, a long series of undulating granitic table-lands partly clothed with woods of oak, beech, and fir, and partly covered with pastures, to which the flocks are brought up from lower Languedoc in summer. The highest point (Mount de Randon) is 5098 feet. Adjoining the Margeride hills on the west is the volcanic range of Aubrac, an extensive pastoral district where horned cattle take the place of sheep; the highest point is 4826 feet. The "causses" of Lozère, having an area of about 483 square miles, consist of extensive calcareous tracts, fissured and arid, but separated from each other by deep and well-watered gorges, whose freshness and beauty are in pleasant contrast with the desolate aspect of the plateaus. The "causse" of Sauveterre, between the Lot and the Tarn, ranges from 3000 to 3300 feet in height; that of Méjean has nearly the same average altitude, but has peaks some 1000 feet higher. Between these two "causses" the Tarn flows through a series of landscapes which are among the most picturesque and grand in France. The Lot and the Tarn, the two most important tributaries of the Garonne, both have their sources in this department, as also have the Allier, the two Gardons, which unite to form the Gard, the Cèze, and the Chassezac with its affluent the Altier. The climate of Lozère varies greatly with the locality. The mean temperature of Mende, the capital, is below that of Paris; that of the mountains is always low, but in the "causses" the summer is scorching and the winter severe; in the Cevennes the climate becomes mild enough at their base (656 feet) to permit the growth of the olive. Rain falls in violent storms, causing disastrous floods. On the Mediterranean versant there are 78·7 inches, in the Garonne basin 45·5, and in that of the Loire only 27·95. The general character of the department is pastoral; only one-fourth of the area is occupied by arable land; 91,500 acres are meadow, 155,700 wood, and 90,000 chestnut plantation. The number of sheep (which is doubled in summer) is 300,000; there are 50,000 head of cattle; and pigs, goats, horses, asses, and mules are also reared. Bees are also kept, and, among the Cevennes, silkworms. The export of chestnuts from the Cevennes is considerable. Rye is the chief cereal; but oats, wheat, meslin, barley, and many potatoes are also grown. Great care is bestowed on cultivation in the valleys adjoining the Ardèche; fruit trees and leguminous plants are irrigated by small canals ("béals") on terraces which have been made or are maintained with much labour. The department yields argentiferous lead (Villefort), slates, and mineral waters, among which those of Bagnols are most frequented. The exportation of its antimony, manganese, marble, and lithographic stones is undeveloped as yet. The tufa of Mende is well adapted for building purposes. The manufactures are unimportant. The population in 1876 was 138,319, having decreased by 5000 since 1801, and by a still greater number since the end of the 17th century. There are about 20,000 Protestants. The arrondissements are three (Mende, Florac, and Marvejols), the cantons twenty-four, and the communes one hundred and ninety-six.

LÜBECK, a free city of Germany, situated in 53° 52′ N. lat. and 10° 41′ E. long., on a gentle ridge between the rivers Trave and Wakenitz, 10 miles S.W. of the mouth of the former, and 40 miles by rail N.E. of Hamburg. Old Lübeck, the chief emporium of the Slav inhabitants of Wagria (East Holstein), stood on the left bank of the Trave, where it is joined by the river Schwartau, and was ultimately destro ed in 1138. Five years later Count Adolphus II. of Holstein founded new Lübeck, a few miles farther up, on the peninsula Buku, where the deep current of the Trave is joined on the right by the Wakenitz, the broad emissary of the Lake of Ratzeburg. A most excellent harbour, well sheltered against pirates, it became almost at once a successful competitor for the commerce of

Plan of Lübeck.

1. Pitching Yard.
2. Citadel.
3. Tivoli.
4. "Chimborasso" Tower.
5. Custom House.
6. St James's Church.
7. Hospital zum Heiligen Geist.
8. St Catharine's Church.
9. St Mary's Church.
10. Exchange.
11. Town-Hall.
12. St Peter's Church.
13. Church of St Ægidius.
14. Church of St Anne.
15. Orphanage.
16. Cathedral.

the Baltic. Its foundation coincided with the beginning of the general advance of the Low German tribes of Flanders, Friesland, and Westphalia along the southern shores of the great inland sea,—the second great emigration of the colonizing Saxon element. In 1140 Wagria, in 1142 the country of the Polabes (Ratzeburg and Lauenburg), had been annexed by the Holtsætas (the Transalbingian Saxons). From 1166 onwards there was a Saxon count at Schwerin. Frisian and Saxon merchants from Soest, Bardewieck, and other localities in Lower Germany, who already navigated the Baltic and had their factory in the distant isle of Gothland, settled in the new town, where Wendish speech and customs never entered. About 1157 Henry the Lion, duke of Saxony, forced his vassal, the count of Holstein, to give up Lübeck; and in 1163 he removed thither the tottering episcopal see of Oldenburg (Stargard), founding at the same time the dioceses of Ratzeburg and Schwerin. He issued the first charter to the citizens, and deliberately constituted them a free Saxon community having its own magistrate, an inestimable advantage over all other towns of his dominions. He invited the traders of the towns and realms of the north to visit his new market free of toll and custom, provided his subjects were promised similar privileges in return. From the very beginning the king of Denmark granted them a settlement for their herring fishery on the coast of Schoonen. Adopting the statutes of Soest in Westphalia as their code, Saxon merchants exclusively ruled the city. In concurrence with the duke's reeve they recognized only one right of judicature within the town, to which nobles as well as artisans had to submit. Under these circumstances the population grew rapidly in wealth and influence by land and sea, so that, when Henry was attainted by the emperor, who had come in person to besiege Lübeck, Barbarossa, "in consideration of its revenues and its situation on the frontier of the empire," fixed by charter, dated September 19, 1188, the limits, and enlarged the liberties, of the free town. Evil times, however, were in store when the Hohenstaufen dynasty became more and more involved in its Italian projects. In the year 1201 Lübeck was conquered by Waldemar II. of Denmark, who prided himself on the possession of such a city. But in 1223 it regained its liberty, after the king had been taken captive by the count of Schwerin. In 1226 it was incorporated as an independent city of the empire by Frederick II., and took an active part with the enemies of the Danish king in the victory of Yornhövd, 1227. The citizens, distinguished by the firmness and wisdom with which they pursued their objects, and fully conscious that they were the pioneers of civilization in the barbarian regions of the north-east, repelled the persistent encroachments of their dynastic neighbours alike in Holstein and in Mecklenburg. On the other hand their town, being the principal emporium of the Baltic by the middle of the 13th century, acted as the firm ally of the Teutonic knights in Livonia. Generation after generation of crusaders embarked to found new cities and new sees of Low German speech among alien and pagan races; and thus in the course of a century the commerce of Lübeck had fully supplanted that of Westphalia. In close connexion with the Germans at Wisby, the capital of Gothland, and at Riga, where they had a house from 1231, the people of Lübeck with their armed vessels scoured the sea between the Trave and the Neva. They were encouraged by papal bulls in their brave contest for the rights of property in wrecks, and for the protection of shipping against pirates and slave-hunters. Before the close of the century the statutes of Lübeck were adopted by most Baltic towns having a German population, and Wisby raised her protest in vain that the city on the Trave had become the acknowledged court of appeal for nearly all these cities, and even for the German settlement in Russian Novgorod. In course of time more than a hundred places were embraced in this relation, the last vestiges of which did not disappear until the beginning of the 18th century. Hitherto only independent merchants, individual Westphalian and Saxon citizens, had flocked together at so many out-lying posts. From about 1299 Lübeck presided over a league of cities, Wismar, Rostock, Stralsund, Greifswald, and some smaller ones, commonly called the Wendish towns. A Hansa of towns became heir to a Hansa of traders simultaneously on the eastern and the western sea, after Lübeck and her confederates had been admitted to the same privileges with Cologne, Dortmund, and Soest at Bruges and in the Steelyards of London, Lynn, and Boston. Such progress of civic liberty and federal union held its own, chiefly along the maritime outskirts of the empire, rather against the will of king and emperor. Nevertheless Rudolf of Hapsburg and several of his successors issued new charters to Lübeck. Charles IV., who, like his son after him, deliberately opposed all confederacies of the Franconian and Swabian towns in Upper Germany, surrendered to the municipal government of Lübeck the little that remained of imperial jurisdiction by transferring to them the chief responsibility for preserving the public peace within the surrounding territories. Under these circumstances the citizens, like independent members of the empire, stood valiantly together with their sister towns against encroaching princes, or joined the princes against the lawless freebooters of the nobility. As early as 1241 Lübeck, Hamburg, and Soest had combined to secure their common highways against robber knights. Solemn treaties to enforce the public peace were concluded in 1291 and 1338 with the dukes of Brunswick, Mecklenburg, and Pomerania, and the counts of Holstein. From Lübeck families, the descendants of Low German immigrants with a certain admixture of patrician and even junker blood, arose a number of wise councillors, keen diplomatists, and brave warriors to attend almost incessantly the many diets of the league, to decide squabbles, petty or grave, of its members, to interfere with shrewd consistency when the authorities in Flanders, or king and parliament in England, touched their ancient commercial privileges, to take the command of a fleet against the kings of Norway or Denmark. Though the great federal armament against Waldemar IV., the destroyer of Wisby, was decreed by the city representatives assembled at Cologne in 1367, Lübeck was the leading spirit in the war which ended with the surrender of Copenhagen and the glorious peace concluded at Stralsund on 24th May 1370. Her burgomaster, Brun Warendorp, who commanded in person the combined naval and land forces, died bravely in harness. In 1368 the seal of the city, a double-headed imperial eagle (which in the 14th century took the place of the more ancient ship), was expressly adopted as the common seal of the confederated towns (*civitates maritimæ*), some seventy of which had united to bear the brunt of the strife. By and by, however, towards the end of the 15th century, the power of the Hanseatic League began slowly to decline, owing to the rise of Burgundy in the west, of Poland and Russia in the east, and the emancipation of the Scandinavian kingdom from the fetters of the union of Calmar. Still Lübeck, even when nearly isolated, strove manfully to preserve its predominance in a war with Denmark (1501–12), supporting Gustavus Vasa in Sweden, lording it over the north of Europe during the years 1534 and 1535 in the person of Jürgen Wullenwever, the democratic burgomaster, who professed the most advanced principles of the Reformation, and engaging with Sweden in a severe naval war (1563–70). Before the end of the century the old privileges of the London Steelyard were definitely suppressed by Elizabeth. As early as 1425 the regular shoals of herring, a constant source of early wealth, began to forsake the Baltic waters. Later on, by the discovery of a new continent, general commerce was diverted into new directions. Finally, with the Thirty Years' War, misfortunes and ruin came thick. The last Hanseatic diet met at Lübeck in 1630, shortly after Wallenstein's unsuccessful attack on Stralsund; and from that time merciless sovereign powers stopped free intercourse on all sides. Danes and Swedes battled for the possession of the Sound and its heavy dues. The often changing masters of Holstein and Lauenburg abstracted much of the valuable landed property of the city and of the chapter of Lübeck. Still, towards the end of the 18th century, there were signs of improvement. Though the Danes temporarily occupied the town in 1801, it preserved its freedom and gained some of the chapter lands when the imperial constitution of Germany was broken up by the Act of February 25, 1803. Trade and commerce prospered marvellously for a few years. But in November 1806, when General Blücher, retiring from the catastrophe of Jena, had to capitulate in the vicinity of Lübeck, the town was taken and sacked by the enemy. Napoleon annexed it to the empire in December 1810. But it rose against the French, March 19, 1813, was reoccupied by them till the 5th December, and was ultimately declared a free and Hanse town of the German Confederation by the Act of Vienna, June 9, 1815. The Hanseatic League, however, having never been officially dissolved, Lübeck still enjoyed its traditional connexion with Bremen and Hamburg. In 1853 they sold their common property, the London Steelyard. Till 1866 they enlisted by special contract their military contingents for the German Confederation. Down to the year 1879 they had their own court of appeal at Lübeck. The town, however, joined the Prussian Customs Union as well as the North German Union in 1866, profiting by the final retirement from Holstein and Lauenburg of the Danes, whose interference had prevented as long as possible a direct railroad between Lübeck and Hamburg.

Lübeck through many changes in the course of eight centuries has preserved its republican government. At the first rise of the town, justice was administered to the inhabitants by the *vogt* (reeve) of the count. Simultaneously with the incorporation by Henry the Lion, who presented the citizens with the privileges of mint, toll, and market of their own, there appears a magistracy of six persons, elected probably by the reeve from the *schöffen* (*scabini*, *probi homines*). The members of the town council had to be freemen, born in lawful wedlock, in the enjoyment of free property, and of unstained repute. Vassals or servants of any lord and tradespeople were excluded. A third of the number had annually to retire for a year, so that two-thirds formed the sitting, the other third the reposing council. By the middle of the 13th century there were two burgomasters (*magistri burgensium*, *magistri civium*, *proconsules*). Meanwhile the number of magistrates (*consules*) had largely increased, but was indefinite, ranging from twenty to forty and upwards. The council appointed its own officers in the various branches of the administration,—chancellor, chaplain, surgeon, *stadesscrivere* (recorders), notaries, secretaries, marshal, constable, keeper of the ordnance, messengers, watchmen. In the face of so much self-government the *vogt* by and by vanished completely. He is by no means to be confounded with the *rector*, a neighbouring prince, whom the Lübeckers occasionally adopted as their honorary guardian. There were three classes of inhabitants—full freemen, half freemen, guests or foreigners. People of Slav origin being considered unfree, all intermarriage with them tainted the blood. Hence nearly all surnames point to Saxon, especially Westphalian, and even Flemish descent.

Since the end of the 13th century the city has been entered by the same gates and traversed by the same streets as at the present day. Stately churches of the Gothic order in glazed brick rose slowly,—last not least St Mary's or *Die Rathskirche* close to the *Rathhaus* (town-hall) and the spacious market-place with its long rows of booths and the pillory. Within its precincts is the *Dom* (cathedral) dedicated to St Nicholas, the patron saint of navigators; in Protestant times down to 1803 the secularized chapter was generally presided over by a prince of the ducal house of Gottorp. There were magnificent convents of the Dominicans, the Franciscans, and the nuns of St Clara. The population, when the city and the Hansa were in full power about 1400, can scarcely have been under 80,000. But such prosperity was not obtained by foreign commerce alone, though this was the principal occupation of the upper classes:—the *Junker* or *Zirkel* company, a sort of patriciate (since 1379); the merchant company, also patricians, but mostly "rentiers"; the "nations" of the *Bergenfahrer*, *Schonenfahrer*, *Novgorodfahrer*, *Rigafahrer*, *Stockholmfahrer*. From the very beginning various tradespeople and handicraftsmen had settled in the town, all of them freemen, of German parentage, and with property and houses of their own. Though not eligible for the council, they shared to a certain extent in the self-government through the aldermen of each corporation (*amt*, officium, guild), of which some appear as early as the statutes of 1240, and many more arise and disappear in course of time under authority of the council and the guidance of certain police magistrates (*wetteherren*). A number still exist, and own their old picturesque gable houses. The rolls of nearly all have been kept most carefully. Naturally there arose much jealousy between the guilds and the aristocratic companies, which exclusively ruled the republic. After an attempt to upset the merchants had been suppressed in 1384, the guilds succeeded under more favourable circumstances in 1408. The old patrician council left the city to appeal to the Hansa and to the imperial authorities, while a new council, elected chiefly from the guilds, with democratic tendencies, took their place. In 1416, however, there was a complete restoration, owing to the interference of the confederated cities and of two kings of the Romans, Rupert and Sigismund. The aristocratic government was expelled a second time when democracy and religious sectarianism got the upper hand under the dictatorship of Wullenwever, till the old order of things was once more re-established in 1535. Nevertheless the mediæval church had been finally supplanted by the Lutheran Reformation, and the tendency to increase the political privileges of the commonalty appeared again and again. In the constitution of 1669, under the pressure of a great public debt, the seven upper companies yielded to (8) the *Gewandschneider* (merchant tailors), (9) the grocers, (10) the brewers, (11) the mariners, and (12) the combined four great guilds, viz., the smiths, bakers, tailors, and shoemakers, a specified share in the financial administration. Nevertheless they continued to choose the magistrates by co-optation among themselves. Three of the four burgomasters and two of the senators, however, henceforth had to be graduates in law. Their constitution, set aside only during the French ascendency, has subsequently been slowly reformed. From 1813 senatorial and civic deputies joined in the administration of an annual budget of income, expenditure, and public debt. But the reform committee of 1814, of which the object was to substitute for the rule of the old companies a wider participation of the citizens in their common affairs (most of the learned professions, many proprietors, and the suburban population being without any representation), had made very little progress, when under the pressure of the events of the year 1848 a representative assembly of one hundred and twenty members, elected by universal suffrage, obtained a place beside the senatorial government. By the constitution of the 29th December 1851 the senate, for which all citizens above thirty years of age are eligible, has at present fourteen members. Eight must be taken from the learned professions, of whom six have to be lawyers, while of the rest five ought to be merchants. Every second year the offices and departments are redistributed, to be in most cases administered conjointly with deputies of the assembly. The president of the senate, chosen for two years, retains the old title of burgomaster. The members of the assembly, which participates in all public affairs, are elected for six years, and must be summoned at least six times a year, while a committee of thirty members meets every fortnight simultaneously with the periodical sessions of the senate. These truly democratic institutions have been scarcely at all modified by the resuscitation of the German empire under the king of Prussia. But evidently the ancient republic has lost some important attributes of a sovereign state by giving up its own military contingent, its right of levying customs, its coinage, its postal dues, its judicature, to the new national empire. On the other hand, it has preserved its municipal self-government and its own territory, the inhabitants of which now enjoy equal political privileges with the citizens. The territory, of about 5½ German square miles (116 Eng. sq. m.), partly extends towards the mouth of the river Trave, where the borough of Travemünde has been the property of Lübeck since 1329, and partly consists of numerous villages, manors, farms, and corn, pasture, and forest lands scattered over the adjoining portions of the duchies of Holstein and Lauenburg. The manor and borough of Bergedorf on the Elbe, 1½ German square miles, long held by Lübeck in common with Hamburg, was ceded to the latter by treaty of 1st July 1867. The lands which remain to Lübeck are thinly peopled, for, according to the census of 1875, of the total of 56,912 inhabitants 44,799 lived in Lübeck itself. The vast majority, 55,693, are Lutheran Protestants, whose service continues in the magnificent city churches, the cathedral, two parishes at Travemünde, and the four country parishes. A celebrated high school (gymnasium) is situated in the spacious buildings of St Catharine, formerly the house of the Franciscans. The charitable institutions enjoy a large, well-administered property, chiefly the lands of the monastery of St John and the hospital of the Holy Ghost. Since 1789 there has existed a "Gesellschaft zur Beförderung Gemeinnütziger Thätigkeit," with a branch union for the history and the antiquities of Lübeck, which has collected a valuable museum and promotes important historical publications, the materials of which are kept in the most unique municipal archives in existence. The income and expenditure of the Lübeck budget of 1881 balance with 2,739,382 marks; the public debt amounts to 23,804,913 marks.

The manufactures of the town are numerous, but not large or important (woollen, linen, cotton, and silk goods, leather wares, hardware, tobacco, and preserves). The commerce, on the other hand, is considerable, the chief exports being corn, cattle, wool, timber, and iron; while wines, silks, cottons, hardware, colonial products, and dye-stuffs are imported. There is regular steamship communication with Copenhagen and the Baltic ports, and four lines of railway converge in Lübeck. Since the deepening of the Trave (1850-54) sea-going ships can come up to Lübeck itself; formerly they required to unload at Travemünde. In 1878 the local shipping of Lübeck amounted to 46 vessels of 10,223 aggregate tonnage (27 steamers, 1504 horse-power, 6463 tons). In 1877 2302 vessels (981 steamers) with a tonnage of 301,910 entered, and 2332 vessels (979 steamers) with a tonnage of 307,567 cleared the port.

See *Codex Diplomaticus Lubecensis*, 6 vols., 1843-81; C. W. Pauli, *Lübeckische Zustände zum Anfang des vierzehnten Jahrhunderts*, 1847; Waitz, *Lübeck unter Jürgen Wullenwever*, 3 vols., 1855, 1856; W. Mansel's "Lübeck," in Bluntschli und Prater, *Deutsches Staatswörterbuch*, iv. p. 731; Wehrmann, *Die älteren Lübeck'schen Zunftrollen*, 1872; D. Schäfer, *Die Hansestädte und König Waldemar von Dänemark*, 1879. (R. P.)

LUBLIN, a town of Russian Poland, capital of the province of same name, 60 miles south-east of Warsaw, on the Bistrzyca, a tributary of the Wieprz. It is the most important town of Poland after Warsaw and Lodz. It has an old citadel, many churches, and several educational and charitable institutions, and it is the see of a bishop. Lublin is one of the chief centres of the manufacture of thread-yarn and of linen and hemp goods (to the value of more than £250,000), as well as of woollen stuffs; there is also an active trade in corn and cattle. The three annual fairs have a certain importance for the neighbouring district. The population in 1873 was 28,900, and is rapidly increasing.

The date of the foundation of Lublin is unknown, but it was in existence in the 10th century, and has a church which is said to have been built in 986. During the time of the Jagellons it was the most important city between the Vistula and the Dnieper, having 40,000 inhabitants (70,000 according to other authorities), and keeping in its hands all the trade with Podolia, Volhynia, and Red Russia. Indeed, the present town is surrounded with heaps of ruins, which prove that it formerly covered a much larger area. But it was frequently destroyed by the inroads of Tartars and Cossacks. In 1568 and 1569 it was the seat of the stormy convention at which the union between Poland and Lithuania was decided. In 1702 another convention was held in Lublin, in favour of Augustus II. and against Charles XII., who carried the town by assault, giving it over to his army to be plundered, and stayed for six weeks at Jacobowice, the estate of Prince Lubomirsky, in the immediate neighbourhood. In 1831 Lublin was taken by the Russians after a battle. The whole surrounding country is rich in historical reminiscences of the struggle of Poland for independence.

LUBRICANTS are fluids which are interposed between solid machine surfaces that are required to slide on each other. The object is to lessen the friction, which is injurious both in wearing away the surfaces, and thus destroying the fit between them, and in dissipating and rendering useless part of the energy transmitted through the machine. The difference between the wear on unlubricated and that on lubricated surfaces is so serious that a comparison between the cost of lubrication and the money saving in avoidance of repairs is superfluous. But the difference in wear when two different lubricants are used is not very great, and the proper choice between the two lubricants depends on a comparison of their cost with the amount of working power they save from dissipation. If the price of oil per gallon, inclusive of wages for its application to the journals, &c., be p; if, in order to lubricate as well as can be done with this oil any one working surface or set of such surfaces, it is necessary to use the fraction g of a gallon of oil per hour; if, with the use of this quantity of the oil, there is still wasted in friction at these surfaces H horse-power; and if the cost in fuel, water, wages, repairs, &c., of the working energy is P per hour per horse-power; then the money loss per hour caused by the friction is $pg + \text{PH}$. By comparing the values of this quantity for two oils, it can be determined which it is more advantageous to use. Of the commonly used oils, the higher priced are much more efficient as lubricants. If two oils of which the same amount requires to be used have the prices p_1 and p_2, and allow H_1 and H_2 horse-power to be wasted, then the money advantage to be gained per hour by using the first (the higher priced) rather than the second is $\text{P}(\text{H}_2 - \text{H}_1) - (p_1 - p_2)g$. This is positive if

$$\frac{\text{H}_2 - \text{H}_1}{g} > \frac{p_1 - p_2}{\text{P}}.$$

If this inequality is found *not* to be true in any special comparison, then the cheaper oil should be used. P varies from $\frac{3}{4}$d. to over $1\frac{1}{2}$d., according to the class of engine and boiler and to the good or bad management of the works, while $p_1 - p_2$, in comparing the extremes of cheap and expensive commercial lubricants, amounts to 2s. 6d. or more.

To compare the advantages of using a larger or smaller amount of the same oil, let g_1 and g_2 be the quantities used, and the resulting wastes of horse-power be H_1 and H_2. Then the use of the larger quantity g_1 will be economical if

$$\text{P}(\text{H}_2 - \text{H}_1) - p(g_1 - g_2) > 0\,; \quad \text{or} \quad \frac{\text{H}_2 - \text{H}_1}{g_1 - g_2} > \frac{p}{\text{P}}.$$

Considering the meaning of this inequality in the two cases of a high-priced and of a low-priced oil, in the former case $\frac{p}{\text{P}}$ has a larger value, while $\frac{\text{H}_2 - \text{H}_1}{g_1 - g_2}$ has also a larger value than in the latter case. In both cases this latter fraction decreases with increase of g_1; but it decreases more rapidly in the case of a high-priced than in that of a low-priced oil, because the former is a better lubricator. Thus with the dearer oil the limit beyond which it is uneconomical to increase the consumption of oil is reached sooner than with the cheaper, and it follows that of the cheaper oils it is best to use a large quantity, while of the dearer a smaller amount is what is most usefully employed. If the law according to which H varies with g be found for any oil, by experiment or otherwise, then the exact most economical quantity can be found by differentiating $pg + \text{PH}$ with respect to g, and equating the differential coefficient to zero; thus

$$\frac{d\text{H}}{dg} = -\frac{p}{\text{P}},$$

when $\frac{d\text{H}}{dg}$ is expressed in terms of g, gives this most economical value of g. An example of the actual values of the quantities involved in these formulas is given by an experiment by Van Cleve on a journal 6 inches in diameter by 7 inches long, in which the coefficient of friction was found to be about ·077, and there was wasted 3·4 horse-power when ·023 of a gallon was used per hour.

Of the animal oils and fats suitable for lubrication those commonly used are sperm, lard, neats-foot, tallow, and common whale oil. Of vegetable oils olive, cotton-seed, and rape-seed are extensively employed, the first mostly in those countries where the olive is grown, and generally in the pure condition, while the last two are more used for mixing with higher class and more expensive oils. Various fish oils are also much used, and mineral oils now form a large proportion of the many lubricating compositions that are in use. For machinery where considerable pressure is exerted between the bearing surfaces the mineral oils are too thin, or, as it is termed, are too wanting in "body" to be quite suitable without being mixed with an animal or vegetable oil. Unless a lubricant has considerable "body" it is quickly pressed out of the bearing, and an unnecessarily rapid supply has to be provided. The same oil may be used several times over, and several ingenious designs of bearings for rotating shafts, such as Player Brothers' or Taylor & Challen's, whereby the shaft itself as it runs round continually pumps up again to the top of the bearing the oil that has once been used, have been very successful in practice. If an automatic arrangement of this sort is not employed, the oil dripping from the bearing should be collected in a pan and used again to fill the oil-cups. The oil gets gradually worn out as a lubricant by becoming filled with dirt, partly the dust of the atmosphere and partly the minute iron and brass dust that is continually rubbed off the bearing surfaces. Oils that have been used two or three times can be to a certain extent repurified by washing in a solution of carbonate of soda or potash and chloride of calcium in boiling water. But it must not be supposed that with repurification an oil may be used an indefinite time as a lubricant. A large portion of it is actually evaporated by the heat caused by the friction at the journal, and the unevaporated portion seems to undergo some chemical change injurious to its lubricating properties. Vegetable oils are peculiarly rich in volatile constituents, and it is this fact probably, even more than the greater cheapness of mineral oils, that has led to the largely increased use of the latter in the lubrication of machinery.

The quality of an oil may be tested by chemical analysis; by measurement of density and viscosity; by observation of the temperature necessary for ignition in the atmosphere, or, as it is called, the "flashing" temperature; by observation of the succession of figured patterns produced when a single drop of the oil is let fall upon the surface of pure water in a clean dish; by the measurement of the temperatures to which a journal rises when running at different speeds and under different pressures, and when supplied with a given amount of the lubricant per minute; and by the measurement of the coefficient of friction at the same journal with varying speeds of rotation and pressures. The last two methods of test are the most interesting and directly useful from a mechanical point of view, *i.e.*, considering the oil as a lubricant simply.

The machine designed and used by Professor Thurston of the Stevens Institute of technology is the best that has yet been constructed to carry out these tests. In it a spindle is revolved in horizontal bearings by a belt from the main shaft of the workshop of the Institute. On the overhanging end of this spindle is formed a journal from which is hung a heavily-weighted rod. The bearings in this rod by which it hangs on the journal are of brass, and the two halves are pressed down upon the journal with any desired pressure by means of a spiral spring placed in the centre of the rod. The weight of this pendulum prevents it revolving along with the spindle, but the friction at the journal deflects the pendulum from the vertical through an angle whose sine is a measure of the frictional effort. There is also inserted in the bearings a thermometer by which the effect of the friction in increasing the temperature is observed. With this machine Professor Thurston has obtained extremely interesting results regarding the variation of the coefficient of friction with temperature, pressure, and velocity of rubbing. These are summarized as follows. With great intensity of pressure and low velocity, the friction increases as the temperature is raised; but for each low velocity the rate of increase of friction with temperature becomes slower as the pressure diminishes, and becomes zero at a certain limit of pressure which is higher the higher the velocity is. With high velocities the variation of friction with temperature is in the opposite direction within the limits of pressure commonly used. Again at a given temperature and a given pressure the friction first decreases very rapidly with increase of velocity, and then above a certain limit of velocity increases again slowly with further increase of velocity. The limit of velocity at which the direction of variation changes from negative to positive does not appear to depend on the intensity of pressure, but the change occurs at much lower velocity-limits with low than with high temperatures. Thirdly, with a given temperature and a given velocity the coefficient of friction, *i.e.*, the ratio of friction to normal pressure, at first decreases rapidly with increase of pressure at low pressures, and then at higher pressures increases again with the pressure. This law seems to hold for all temperatures and all velocities; but how the limit of pressure at which the variation changes in direction is altered by alteration of temperature and velocity is not as yet certainly determined.

It is thus seen that the variation of friction at lubricated journals is extremely complicated, and has no resemblance to the simple law of constant proportionality between the friction and the normal pressure which until lately was commonly believed to hold good for unlubricated flat surfaces. This simple law is really true for many unlubricated surfaces and through a tolerably wide range of conditions, but is not true for all such surfaces, or under all, and especially extreme, conditions of pressure, velocity, and temperature.

Professor Thurston has endeavoured to represent these results in algebraic formulæ, but the number of his experiments seems hardly sufficient to establish any general mathematical law which will be true under all circumstances, and the particular formulæ which he has adopted give values differing very considerably from those given by some of his experiments.

The friction at a lubricated journal depends really much more on the viscosity of the lubricant than on the frictional properties of either of the solids, which never come in contact when the lubrication is carefully attended to. The layer of oil immediately in contact with either solid probably does not move at all relatively to the solid. The rubbing, therefore, in all probability takes place between two surfaces, or rather between an indefinitely large number of pairs of surfaces, of oil. The viscosity of the oil, which hinders this relative motion, is, however, very likely affected by the adhesive force between the solid and liquid surfaces, because, especially if the intensity of bearing pressure be great and the film of lubricant consequently very thin, some at least of the liquid motion will take place within the sphere of action of the cohesive forces.

It is of the greatest importance in order to secure economy in the use of lubricants to maintain the supply to each journal at a constant uniform rate. To effect this, numberless "automatic lubricators" have been invented. The common syphon oil-cup is very efficient so long as the rate of working is steady; but the supply does not automatically vary with the requirements. The "needle" lubricator allows the oil to flow down to the journal through a small straight tube in which is placed a wire which nearly blocks up the tube. When the wire is motionless the dimensions of the space between the wire and the tube are capillary, and no oil flows. When the shaft runs, however, its surface scraping on the end of the wire throws it into continual vibration, and this allows a slow stream of oil to pass downwards which is automatically regulated in accordance with the speed of revolution. The necessity of very perfect lubrication of the cylinders of gas engines, which run at a high speed and at a high temperature, has led to the adoption by Messrs Crossley Brothers of an extremely neat and perfect arrangement. A small crank on the end of a spindle, driven at a rate proportional to that of the engine, has suspended from the crank pin a short wire pendulum. At the lower part of the revolution this pendulum dips into a basin of oil and lifts a drop from it. In the upper half of the circular motion, the wire is dragged over a little scraper extending over the open mouth of a pipe. This scrapes the drop off the pendulum, and the drop falls from the scraper into the tube, along which it flows to the surface to be lubricated. The number of drops is thus accurately proportioned to the speed of the engine, and the size of drop can be varied by using smaller or larger wire for the pendulum.

Table of Coefficients of Friction on Cast-Iron Journals at Temperature 70° F. and Velocity 750 Feet per Minute (from Thurston).

Name of Oil.	Pressure in lb per sq. in.			
	8.	16.	32.	48.
Natural Summer Sperm	·17	·16	·10	·12
" Winter "	·25	·14	·09	·08
Bleached " "	·19	·16	·12	·10
Natural Summer Whale	·20	·14	·11	·09
Winter Lard	·24	·16	·14	·10
Extra Neatsfoot	·22	·16	·12	·11
Tallow	·18	·15	·09	·12
Olive	·17	·16	·17	·09
Refined Cotton Seed	·21	·14	·12	·11
Rape Seed	·18	·16	·12	·11
Menhaden	·25	·12	·10	·12
Kerosine	·23	·17	·13	·17
Paraffin	·26	·18	·13	·22

Other mineral oils than the kerosine and paraffin give a smaller coefficient. For mineral oils generally the lowest coefficient appears to occur at from 30 to 40 lb pressure per square inch. The supply of oil in the experiments was intermittent, and must have been insufficient for the best lubrication.

Table of Coefficients of Friction between Steel Journals and Bronze Bearings lubricated with Sperm Oil, and run at different Pressures, Velocities, and Temperatures (from Thurston).

Temperature, Degrees Fahr.	Velocity in feet per minute.													
	30.				100.				250.		500.		1200.	
	Press. lb per sq. in.				Press. lb per sq. in.				Press. lb per sq. in.		Press. lb per sq. in.		Press. lb per sq. in.	
	200.	100.	50.	4.	200.	100.	50.	4.	200.	100.	200.	100.	200.	100.
150	·050	·025	·012	·125	·014	·002	·003	·063	·005	·003	·005	·004	·006	·006
130	·016	·005	·007	·125	·008	·002	·003	·063	·005	·003	·005	·004	·006	·007
110	·010	·004	·006	·094	·004	·002	·003	·063	·005	004	·006	·005	·007	·009
90	005	·003	·004	·094	·004	·002	·003	·063	·007	·005	·007	·006	010	·015

The journal upon which the above results were obtained was $1\frac{1}{4}$ inches in diameter and $1\frac{1}{2}$ inches long. With a larger journal the results would probably not be exactly the same. (R. H. S.*)

LUCAN. Marcus Annæus Lucanus, the most eminent Roman poet of the silver age, grandson of the rhetorician Seneca and nephew of the philosopher, was born at Corduba, November 3, 39 A.D. His father, Lucius Annæus Mela, had amassed great wealth as imperial procurator for the province. In a memoir by an anonymous grammarian, who may have abridged Suetonius, Lucan is said to have been taken to Rome at the age of eight months, to have displayed remarkable precocity, and to have incurred the displeasure of Nero by overcoming him in a poetical contest. The latter statement seems to be founded upon a misapprehension of a passage in Statius's *Genethliacon Lucani*; but it is certain that Nero, whether from jealousy, as Tacitus affirms, or on account of the republican spirit of Lucan's poetry, forbade him to recite in public, and that his indignation made him an accomplice in the conspiracy of Piso, 65 A.D. Upon the discovery of the plot he is alleged to have endeavoured to purchase safety by impeaching his own mother ("hoping," says his translator Gorges quaintly, "that this impiety might be a means to procure pardon at the hands of an impious prince"). The statement, however, of Tacitus, that letters were forged in his name to implicate his father, warrants the suspicion that the evidence against his mother may also have been fabricated. Failing to obtain a reprieve, he caused his veins to be opened, and expired with great courage, repeating a passage from his *Pharsalia* descriptive of the death of a wounded soldier ("Lucan by his death approved," Shelley's *Adonais*). His father was involved in the proscription, his mother escaped, and his widow Polla Argentaria survived to receive the homage of Statius under Domitian.

Besides his principal performance, Lucan's works included juvenile poems on the descent of Orpheus and the ransom of Hector, an unfinished tragedy on the subject of Medea, and numerous miscellaneous pieces. The *Carmen ad Pisonem* sometimes attributed to him is now more commonly ascribed to Saleius Bassus. His minor works have perished, but all that the author wrote of the *Pharsalia* has come down to us. It would probably have concluded with the battle of Philippi, but breaks off abruptly as Cæsar, beset by foes, is about to plunge into the harbour of Alexandria. This incompleteness should not be left out of account in the estimate of its merits, for, with two capital exceptions, the faults of the *Pharsalia* are such as revision might have mitigated or removed. No such pains, certainly, could have amended the deficiency of unity of action, or supplied the want of a legitimate protagonist. The *Pharsalia* follows history with inevitable servility, and is rather a metrical chronicle than a true epic. If it had been completed according to the author's design, Pompey, Cato, and Brutus must have successively enacted the part of nominal hero, while the real hero is the arch enemy of liberty and Lucan, Cæsar. Yet these defects, though glaring, are not fatal or peculiar to Lucan. The real hero of *Paradise Lost*, it has been repeatedly observed, is no other than Satan; and Shakespeare himself succeeded no better than Lucan in preserving unity of action when he wrote his *Julius Cæsar*. The false taste, the strained rhetoric, the ostentatious erudition, the tedious harangues and far-fetched or commonplace reflexions so frequent in this singularly unequal poem, are faults much more irritating, but they are also faults capable of amendment, and which the writer might not improbably have removed. As pointed out by Dean Merivale, the bombastic style of composition which prevailed under Nero yielded to a more sober taste under the Flavian dynasty; and the lapse of time would have contributed to mellow the poet's immaturity and chasten the ardour of temperament which made him essay great themes "ante annos Culicis Maroniani." Great allowance should also be made for the difficulties the highest genius must encounter when emulating predecessors who have already carried art to its last perfection, and thus necessitated to choose between mere imitation and a conscious effort after originality. Lucan's temper could never have brooked the former course; his versification, no less than his subject, is entirely his own; he avoids all resemblance to his great predecessor with a persistency which can only have resulted from deliberate purpose, while largely influenced by the declamatory school of his grandfather and uncle. Hence his partiality for finished antithesis, contrasting strongly with his generally breathless style and turbid diction. Quintilian sums up both aspects of his genius with pregnant brevity, "Ardens et concitatus et sententiis clarissimus," adding with equal justice, "Magis oratoribus quam poetis annumerandus." Lucan's oratory, however, frequently rises into the region of poetry, especially where it sets forth ideas essentially sublime, and impressive in the mere statement. Such are the apotheosis of Pompey at the beginning of the ninth book, and the passage in the same book where Cato, in the truest spirit of the Stoic philosophy, refuses to consult the oracle of Jupiter Ammon. The exordium of the poem, and the portraits of Cæsar and Pompey, are examples of oratory blazing up into poetry, as a wheel takes fire by friction. In some cases Lucan's rhetoric is frigid, hyperbolical, and out of keeping with the character of the speaker, as in Cæsar's address to his legions before Pharsalia; in general, however, it may be said that the more he is of an orator or a moralist the more he is of a poet. If this denotes that his genius was not essentially and in the truest sense poetical, the same may be said of Dryden and Pope; and it at least proves him to have been in harmony with the living forces of his age, in which rhetoric was a note of culture and philosophical humanitarianism a growing idea, while poetry, though widely cultivated, was becoming more and more a mere ornamental accomplishment. This is not the case with Lucan; his theme has a genuine hold upon him; in the age of Nero he celebrates the republic as a poet with the same energy with which in the age of Cicero he might have defended it as an orator. But for him it might almost have been said that the Roman republic never inspired a Roman poet.

Lucan never speaks of himself, but his epic speaks for him. The author of the *Pharsalia* must have been endowed with no common ambition, industry, and self-reliance, an enthusiastic though narrow and aristocratic patriotism, and a faculty for appreciating magnanimity in others which is at least some presumption that he possessed it himself. He probably bore a strong family resemblance to his uncle Seneca; but the only personal trait positively known to us is his conjugal affection, a characteristic of Seneca also.

Lucan, together with Statius, was preferred even to Virgil in the Middle Ages. So late as 1493 his commentator Sulpitius writes:—"Magnus profecto est Maro, magnus Lucanus; adeoque prope par, ut quis sit major possis ambigere." Shelley and Southey, in the first transport of admiration, thought Lucan superior to Virgil; Pope, with more judgment, says that the fire which burns in Virgil with an equable glow breaks forth in Lucan with sudden, brief, and interrupted flashes. In general, notwithstanding the enthusiasm of isolated admirers, Lucan has been unduly neglected, but he has exercised an important influence upon one great department of modern literature by his effect upon Corneille, and through him upon the classical French drama.

The most celebrated editions of Lucan are those by Oudendorp (1728), Burmann (1740), and Weber (1829). Bentley's emendations are brilliant, but unsafe. The most elaborate criticism is that in Nisard's *Études sur les Poëtes Latins de la Décadence*, stern to the poet's defects and unkind to his deserts. Dean Merivale has some excellent observations in his *History of Imperial Rome*, chaps. liv. and lxiv. Brebeuf's French version is celebrated. Christopher Marlowe, a kindred spirit, translated the first book of the *Pharsalia* into English, and there are other old versions by Sir Ferdinand Gorges and Thomas May. The latter's supplement is one of the best examples of modern Latin versification. Gorges's translation is in octosyllabic verse, and very curious. The standard English version, by Rowe, is one of the most successful translations in our language. It is somewhat too diffuse, but as a whole reproduces the vehemence and animation of the original with a spirit that leaves little to be desired. (R. G.)

LUCANIA, in ancient geography, was the name given to a province of Southern Italy, extending from the Tyrrhenian Sea on the west to the Gulf of Tarentum on the east, while to the north it adjoined Campania, Samnium, and Apulia, and to the south was separated by a comparatively narrow isthmus from the province of Bruttium, which forms the southern extremity of Italy. It thus comprised the modern province of the Basilicata, together with the greater part of the Principato Citeriore and a small portion of Calabria. The precise limits were the river Silarus on the north-west, which separated it from Campania, and the Bradanus, which flows into the Gulf of Tarentum, on the north-east; while the two little rivers Laus and Crathis, flowing from the ridge of the Apennines to the sea on the west and east, marked the limits of the province on the side of Bruttium.

Almost the whole of the province thus limited is occupied by the rugged masses of the Apennines, which in this part of Italy can hardly be said to constitute a range of mountains so much as a group of lofty masses, huddled together in a very irregular manner. The main ridge, however (if it be taken as determined by the watershed), approaches much more nearly to the western sea than to the Gulf of Tarentum, and is continued from the lofty knot of mountains immediately on the frontiers of Samnium, nearly due south, till it approaches within a few miles of the Gulf of Policastro, and thenceforward is separated from the sea by only a narrow interval till it enters the province of Bruttium. Just within the frontier of Lucania rises the very lofty group of Monte Pollino, the highest summit of which attains to an elevation of above 7000 feet, the greatest that is found in the southern Apennines. Towards the east the mountains descend by a much more gradual slope to the Gulf of Tarentum, constituting long ridges of hills which subside by degrees to the strip of plain that immediately adjoins the shores of the gulf. This narrow strip is somewhat wider from the mouth of the Bradanus to that of the Siris, and again expands to a considerable extent at the mouth of the Crathis, but between the two a group of rugged hills descends quite to the sea, and forms the headland of Roseto. The consequence of this constitution is that while the rivers which flow to the Tyrrhenian Sea are of comparatively little importance, those that descend towards the Gulf of Tarentum have much longer courses, and attain to a considerable magnitude. Of these the most important are—the Bradanus (still called Bradano), which rises near Potentia, and enters the gulf just to the north of the ruins of Metapontum; the Casuentus (Basiento), which has a course almost exactly parallel with the preceding; the Aciris or Agri; and the Siris or Sinno. The Crathis, which forms at its mouth the southern limit of the province, belongs almost wholly to Bruttium, but it receives a tributary, the Sybaris (Coscile), which flows from the mountains of Lucania. The only considerable stream on the western side of Lucania is the Silarus or Sele, which constitutes its northern boundary, and has two important tributaries in the Calor or Calore, and the Tanagrus, which joins it from the south, after flowing through one of those trough-like upland valleys so characteristic of the Apennines.

The province of Lucania was so called from the people of that name, by whom it was conquered about the middle of the 5th century B.C. Previous to that period it was included under the general name of Œnotria, which was applied by the Greeks to the whole of the southernmost portion of Italy. The mountainous regions of the interior were occupied by the tribes known as Œnotrians and Chones, while the coasts on both sides were occupied by Greek colonies, which attained to great power and prosperity, and doubtless exercised a kind of protectorate over the interior also. (See GRÆCIA MAGNA.) The Lucanians were a Sabellian race, an offshoot of the Samnites of Central Italy, who pressed downwards towards the south until they gradually conquered the whole country (with the exception of the Greek towns on the coast) from the borders of Samnium and Campania to the southern extremity of Italy. Subsequently, however, the inhabitants of the peninsula which forms the extreme south (now known as Calabria) broke out into insurrection, and under the name of Bruttians succeeded in establishing their independence, after which the Lucanians became confined within the limits already described. After this time we find them engaged in hostilities with the Tarentines, and with Alexander, king of Epirus, who was called in by that people to their assistance, 326 B.C. It was immediately after this that they first entered into relations with Rome, with which they were sometimes in alliance, but more frequently engaged in hostilities, during the long-continued wars of the Romans with the Samnites. On the landing of Pyrrhus in Italy (281 B.C.) they were among the first to declare in his favour, and in consequence found themselves exposed to the full brunt of the resentment of Rome when the departure of Pyrrhus left his allies at the mercy of the victorious Romans. It was not, however, till after several campaigns that they were reduced to complete subjection (272 B.C.). Notwithstanding this lesson, the Lucanians again espoused the cause of Hannibal during the Second Punic War (216 B.C.), and their territory became the theatre of war during several successive campaigns, and was ravaged in turn by both contending armies. It is clear that the country never recovered the effects of these disasters, and under the Roman government Lucania fell into a state of complete decay, to which the Social War (90–88 B.C.) appears to have given the finishing stroke. In the time of Strabo the Greek cities on the coast, once so rich and flourishing, had fallen into utter insignificance, and the few towns of the interior were poor places of no importance. A large part of the province was given up to pasture, and the mountains of the interior were covered with vast forests, which abounded in wild boars, bears, and wolves.

The towns on the east coast, adjoining the Gulf of Tarentum, were—Metapontum, a few miles south of the Bradanus; Heraclea, at the mouth of the Aciris; and Siris, on the river of the same name. Close to its southern frontier stood Sybaris, which was destroyed in 510 B.C., but subsequently replaced by Thurii, founded within a few miles of the same site. On the west coast stood Posidonia, known under the Roman government as Pæstum, immediately south of the Silarus; below that came Elea or Velia, Pyxus, called by the Romans Buxentum, and Laus, near the frontier of the province towards Bruttium. Of the towns of the interior, none of which ever attained to any importance, the most considerable was Potentia, still called Potenza, and now the capital of the Basilicata. To the north, near the frontier of Apulia, were Acheruntia and Bantia; while due south from Potentia was Grumentum, and still farther in that direction were Nerulum and Muranum. In the upland valley of the Tanagrus were Atina, Forum Popilii, and Consilinum; Eburi (Eboli) and Volceii (Buccino), though to the north of the Silarus, were also included in Lucania.

For administrative purposes under the Roman empire, Lucania was always united with Bruttium. The two together constituted the third region of Augustus. (E. H. B.)

LUCARIS, CYRILLUS (*c.* 1572-1638). See GREEK CHURCH, vol. xi. p. 158.

LUCAS OF LEYDEN (*c.* 1494–1533) was born at Leyden, where his father Hugh Jacobsz gave him the first lessons in art. He then entered the painting-room of Cornelis Engelbrechtszen of Leyden, and soon became known for his capacity in making designs for glass, engraving copper-plates, painting pictures, portraits, and landscapes in oil and distemper. According to Van Mander he was born in 1494, and painted at the age of twelve a Legend of St Hubert, for which as many florins were paid to him as he numbered years. He was only fourteen when he finished a plate representing Mohammed taking the life of a friar, and at fifteen he produced a series of nine plates for a Passion, a Temptation of St Anthony, and a Conversion of St Paul. The list of his engravings in 1510, when, according to Van Mander, he was only sixteen, includes a celebrated Ecce Homo, Adam and Eve expelled from Paradise, a herdsman and a milkmaid with three cows, and a little naked girl running away from a barking dog. It will be seen to what a variety of tastes the youthful artist was asked to cater. Whatever may be thought of the tradition embodied in Van Mander's pages as to the true age of Lucas of Leyden, there is no doubt that, as early as 1508, he was a master of name as a copper-plate engraver, and had launched his boat in the current which in those days led to wealth and to fame. The period of the great masters of etching, which had not yet come for Holland, was being preceded by the period of the great masters in the use of the graver. It was the time when art readily found its patrons amongst the large public that could ill afford to buy pictures, yet had enough interest in culture to wish to educate itself by means of prints. Lucas of Leyden became the representative man for the great public of Holland as Dürer became the representative man for the great public of Germany; and a rivalry grew up between the two engravers, which came to be so close that on the neutral market of Italy the products of each were all but evenly quoted. Vasari devoted almost equal attention to both, affirming indeed that Dürer surpassed Lucas as a designer, but that in the use of the graver they were both unsurpassed, a sentence which has not been reversed by the criticism of our day. But the rivalry of the two artists was friendly. About the time when Dürer visited the Netherlands Lucas came to Antwerp, which then flourished greatly as an international mart for productions of the pencil and the graver, and it is thought, not without reason, that he was the master who took the freedom of the Antwerp guild in 1521 under the name of Lucas the Hollander. In the diary which Dürer faithfully kept during his travels in the Low Countries, we find that at Antwerp he met Lucas, who asked him to dinner, and that Dürer accepted the invitation, and was much surprised at the smallness of the Dutchman's stature. But he valued the art of Lucas at its true figure, and exchanged the Dutchman's prints for eight florins' worth of his own. In course of time Lucas rose to more than a competence. In 1527 he made a tour of the Netherlands, giving dinners to the painters of the guilds of Middleburg, Ghent, Malines, and Antwerp. He was accompanied during the trip by Mabuse, whom he imitated in his style as well as in his love of rich costume. But festive cheer and banquets disagreed with Lucas. On his return home he fell sick and remained ailing till his death in 1533, and when he died he did so with the firm belief that poison had been administered to him by some envious comrade.

As an engraver Lucas of Leyden deserves his reputation. He has not the genius, nor had he the tact, of Dürer; and he displays more cleverness of expression than skill in distribution or refinement in details. But his power in handling the graver is very great, and some of his portraits, especially his own, are equal to anything that was done by the master of Nuremberg. Much that he accomplished as a painter has been lost, because he worked a good deal upon cloth in distemper. But some pictures have been preserved which fairly manifest the influences under which he became productive. In 1522 he painted the Virgin and Child with the Magdalen and a kneeling donor, now preserved in the gallery of Munich. His manner was then very much akin to that of Mabuse. The Last Judgment in the town-hall, now the town-gallery of Leyden, is composed on the traditional lines of Cristus and Memling, furnished with monsters in the style of Jerome Bosch, and figures in the stilted attitudes of the South German school; the scale of colours in yellow, white, and grey is at once pale and gaudy; the quaintest contrasts are produced by the juxtaposition of alabaster flesh in females and bronzed skin in males, or black hair by the side of yellow, or rose-coloured drapery set sharply against apple-green or black, yet some of the heads are painted with great delicacy and modelled with exquisite feeling. Dr Waagen gave a most favourable opinion of a triptych now at the Hermitage at St Petersburg, executed, according to Van Mander, in 1531, representing the blind man of Jericho healed by Jesus Christ in the presence of the apostles. Here too the great German critic observed the union of faulty composition with great finish and warm flesh-tints with a gaudy scale of harmonies. The same defects and qualities will be found in such specimens of the master's art as are still preserved in public collections, amongst which may be mentioned the Card Party at Wilton House, the Penitent St Jerome in the gallery of Berlin, and the hermits Paul and Anthony in the Lichtenstein collection at Vienna.

A few days before his death Lucas van Leyden was informed of the birth of a grandson, firstborn of his only daughter Gretchen. Gretchen's fourth son Jean de Hoey followed the profession of his grandfather, and became well known at the Parisian court as painter and chamberlain to the king of France, Henry IV.

LUCCA, a city of Northern Italy, the chief town of a province, an archiepiscopal see, and the seat of a court of assize, lies 13 miles by rail north-east of Pisa, in 43° 50' N. lat. and 10° 28' E. long. Situated 50 feet above the level of the sea, in the valley of the Serchio, the city looks out for the most part on a horizon of hills and mountains. The fortifications—pierced by four gates—were commenced in 1504 and completed in 1645, and long ranked among the most remarkable in the peninsula. The city has a well-built and substantial appearance, its chief attraction lying in the numerous churches, which belong in the main to a well-marked basilican type, and present richly decorated exteriors, fine apsidal ends, and quadrangular campaniles. The cathedral or church of St Martin was begun in 1063 by Bishop Anselm; but the great apse with its tall columnar arcades is probably the only remnant of the early edifice. The west front, "built during the first forty years of the 13th century, consists of a vast portico of three magnificent arches, and above them three ranges of open galleries covered with all the devices of an exuberant fancy." The ground plan is a Latin cross, the nave being 273 feet in length and 84 feet in width, and the transepts 117 feet in length. In the nave is a little octagonal temple or chapel built (1484) by Matteo Civitali, which serves as a shrine for the most precious of the Lucchese relics, a cedar-wood crucifix, carved, according to the legend, by Nicodemus, and miraculously conveyed to Lucca in 782. The Sacred

Countenance (*Volto Santo*), as it is generally called, because the face of the Saviour is considered a true likeness, is only shown thrice a year. The beautiful tomb of Maria Guinigi is described by Ruskin, *Modern Painters*, ii. The church of Saint Michael, founded in the 8th century, and built of marble within and without, has a lofty and magnificent western façade (1188)—an architectural screen rising much above the roof of the church. St Frediano or Frigidian dates originally from the 7th century; the front (of the 13th century) occupies the site of the ancient apse; in one of its chapels is the tomb of Santa Zita, patroness of servants and of Lucca itself. San Giovanni (originally of the 12th century), San Romano (rebuilt in the 17th century, by Vincenzo Buonamici), and Santa Maria Forisportam (of the 13th century) also deserve to be mentioned. Among the secular buildings are the old ducal palace, begun in 1578 by Ammanati, and now the residence of the prefect and seat of the provincial officers and the public picture gallery; the Palazzo Pretorio, or former residence of the podestà, now the seat of the civil and correctional courts; the palace, erected in the 15th century by a member of the great Guinigi family, and now serving as a poor-house; and the 16th century palace of the Marquis Guidiccioni, now used as a depository for the archives. The principal market-place in the city (*Piazza del Mercato*) has taken possession of the arena of the ancient amphitheatre, the arches of which can still be seen in the surrounding buildings. Besides the academy of sciences just mentioned, which dates from 1584, there are several institutions of the same kind—a royal philomathic academy, a royal academy of arts, and a public library of 50,000 volumes. The silk manufacture, which was introduced at Lucca about the close of the 11th century, and in the early part of the 16th became for a time the means of subsistence for 30,000 of its inhabitants, now gives employment (in reeling and throwing) to only about 1500. The bulk of the population is engaged in agriculture. In 1871 the city had 21,286 inhabitants. The commune has increased from 61,175 in 1834 to 68,063 in 1881.

Lucca (Latin, *Luca*) is probably a place of Ligurian origin. First mentioned as the place to which Sempronius retired (218 B.C.) before the victorious Hannibal, it passes out of sight again till 177, when it became the seat of a Roman colony. In the time of Julius Cæsar it is frequently heard of as a town in his province of Cisalpine Gaul and Liguria, to which he repaired for consultation with his political associates. By Augustus it was transferred to Etruria. Though plundered and deprived of part of its territory by Odoacer, Lucca appears as an important city and fortress at the time of Narses, and under the Lombards it was the residence of a duke or marquis and had the privilege of a mint. The dukes gradually extended their power over all Tuscany, but after the death of the famous Matilda the city began to constitute itself an independent community, and in 1160 it obtained from Welf VI., duke of Bavaria and marquis of Tuscany, the lordship of all the country for 5 miles round. Internal discord afforded an opportunity to Uguccione della Faggiola to make himself master of Lucca in 1314; but the Lucchese expelled him two years afterwards, and handed over their city to Castruccio, under whose masterly tyranny it became "for a moment the leading state of Italy." Occupied by the troops of Louis of Bavaria, sold to a rich Genovese Gherardo Spinola, seized by John, king of Bohemia, pawned to the Rossi of Parma, sold to the Florentines, surrendered to the Pisans, nominally liberated by the emperor Charles IV., and governed by his vicar, Lucca was subjected to endless vicissitudes, but managed, at first as a democracy, and after 1628 as an oligarchy, to maintain "its independence alongside of Venice and Genoa, and painted the word Libertas on its banner till the French Revolution." In the beginning of the 16th century one of its leading citizens, Francesco Burlamacchi, made a noble attempt to give political cohesion to Italy, but perished on the scaffold (1548); his statue by Ulisse Cambi was erected on the Piazza San Michele in 1863. As a principality formed in 1805 by Napoleon in favour of his sister Elisa and her husband Baciocchi, Lucca was for a few years wonderfully prosperous. It was occupied by the Neapolitans in 1814; from 1816 to 1847 it was governed as a duchy by Maria Luisa, queen of Etruria, and her son Charles Louis; and it afterwards formed one of the divisions of Tuscany.

The bishops of Lucca, who can be traced back to 347, gradually acquired a variety of exceptional marks of distinction, such as the pallium in 1120, and the archiepiscopal cross from Alexander II.; and at length in 1726 Benedict XIII. raised their see to the rank of an archbishopric, without suffragans.

See *Memorie per servi. e alla storia del ducato di Lucca*, published by the Lucca Academy; Mazzarosa, *Storia di Lucca*, Lucca, 1833; Repetti, *Dizionario della Toscana*, Florence, 1835; Freeman, *Hist. and Arch. Sketches*, London, 1876.

LUCCA, BATHS OF (BAGNI DI LUCCA, formerly BAGNO A CORSENA), a commune of Italy in the province of Lucca, containing a number of famous watering-places. They are situated in the valley of the Lima, a tributary of the Serchio; and the district is known in the early history of Lucca as the Vicaria di Val di Lima. Ponte Serraglio (16 miles to the north of Lucca) is the principal village; but there are warm springs and baths also at Villa, Docce Bassi, Bagno Caldo, &c. Bagno a Corsena is mentioned in 1284 by Guidone da Corvaia, a Pisan historian (Muratori, vol. xxii.); and by the 16th century the waters had attained great celebrity. Fallopius, who gave them credit for the cure of his own deafness, sounded their praises in 1569; and they have been more or less in fashion since. The temperature of the water varies from 96° to 133° Fahr.; in all cases it gives off carbonic acid gas, and contains lime, magnesium, and sodium products. In the village of Bagno Caldo there is a considerable hospital, constructed largely at the expense of Nicholas Demidoff in 1826. The population of the commune was 11,000 in 1881.

LUCENA, a town of Spain, in the province of Cordova, 37 miles south-south-east from that city, and 11 miles by road south-east from the Aguilar station of the Cordova-Malaga Railway. It is pleasantly situated on the Cascajar, a minor tributary of the Genil, in a district that produces oil, wine, and cereals in great abundance, and affords excellent pasture. The parish church, which is large but not otherwise remarkable, dates from the beginning of the 16th century. The chief industries are the manufacture of hardware and pottery, bronze lamps being a specialty of Lucena, and also the large earthenware jars (*tinajas*) used throughout Spain for the storage of oil and wine. There is considerable trade in the produce of the neighbourhood, and the horse mart is famous throughout Andalusia. The population in 1877 was 19,540. Lucena was taken from the Moors early in the 14th century; it was in the attempt to recapture it that King Abu 'Abdallah (Boabdil) of Granada was taken prisoner in 1483.

LUCERA, a city of Italy, in the province of Foggia, on a hill in the midst of the Apulian plain, lies 10 miles west-north-west of Foggia. Although a busy and flourishing place, with 14,014 inhabitants in 1871, Lucera is mainly of historical interest. The cathedral, erected on the ruins of the magnificent mosque, is a fine Romanesque building with Gothic features; and the castle, whose imposing ruins still crown the hill to the north of the town, was formerly the grandest of all the strongholds possessed by the Hohenstaufen emperors to the south of the Alps.

By a Greek tradition the foundation of Luceria was assigned to Diomede, and the statue in its temple of Minerva passed as the authentic Palladium; but the place would seem to be really of Oscan rather than Daunian origin. The Romans were marching to the relief of Luceria when they suffered the defeat at the Caudine Forks; they effected its capture in 320 B.C.; and when they recovered it in 314 they slew a great part of the inhabitants, and introduced a powerful body of colonists. During the Second Punic War the city was the headquarters of the Apulian campaigns. It continued to exist as a place of some mark down through the empire, and is mentioned by Pliny as a colony. Destroyed (663 A.D.) by the emperor Constans, who had recovered it from the Lombards, it was shortly after restored, and in 1227 it was raised to more than its former prosperity by Frederick II., who settled there a great body of his Saracen followers from Sicily, and thus increased its population to about 77,000. The Mohammedan colony, however, was brought to ruin by the hostility of Charles I. and II. of Anjou. Previous to 1806 Lucera was the administrative centre of the two provinces Basilicata and Molise. See W. Lang, in *Im Neuen Reich*, Dec. 1877.

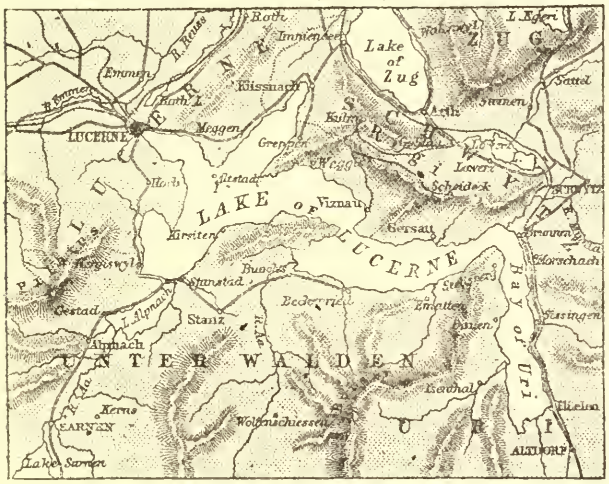
LUCERNE (German, *Luzern*), a canton of Switzerland lying north-west of the central mass of the Swiss Alps, having the canton of Aargau to the north, Bern to the west and south, and the small cantons of Zug, Schwyz, and Unterwalden on the east and south-east sides. Like most of the Swiss cantons its form is very irregular, and it includes, besides a part of the Lake of Lucerne, the Lakes of Sempach and Baldegg, and several smaller sheets of water. To this circumstance is probably due the discrepancy in the various estimates of the area, which range from 498 to 585 square miles. The greater part of its territory lies in the low hilly region of north-western Switzerland, most of which is under cultivation; but it has one considerable valley, the Entlebuch, enclosed by mountains, several of which exceed 5000 feet in height, which is devoted to pasturage. The only considerable mountain in the canton is the Pilatus, a steep jagged ridge with numerous peaks, the highest of which is 7290 feet above the sea, forming the boundary between this and the canton of Unterwalden. The only river is the Reuss, which issues from the lake at the town of Lucerne, but soon turns abruptly to the north-east, and passes the boundary of the canton. Of many smaller streams that water its surface, the most important is the Little Emme, which drains the Entlebuch and its tributary valleys. The soil is moderately fertile, and produces good crops of cereals, but the vine is grown only in a few exceptionally favourable situations. Some of the higher valleys, especially the Entlebuch, are mainly devoted to pasture, and furnish cheese and butter in considerable quantities, of which the surplus is exported. The population in December 1880 was 134,806, of whom all but 5634 were Roman Catholics. The language is exclusively German, and the people belong to the Teutonic stock. Excepting the inhabitants of the town of Lucerne, they are mainly employed in agriculture. The men of the Entlebuch, leading a pastoral life and little exposed to intercourse with strangers, have preserved more of the original simplicity of manners and costume than is now often found elsewhere in Switzerland. They are famed for their strength and skill in wrestling and other athletic exercises, as may be seen at the *Schwingfeste*, still frequently held in that district.

Like the rest of northern Switzerland, Lucerne was subject to the house of Austria until 1332, when its people joined the league of the forest cantons, Uri, Schwyz, and Unterwalden, thus forming the fourth in date of the confederation. They bore their share in the brilliant victory of Sempach, fought in 1386 near the village of that name, and in 1402 acquired the Entlebuch by purchase from the Austrian duke. The government was until the end of the 18th century an oligarchy in the hands of a few families, but in 1798 the French invasion substituted democratic institutions. These, with several changes all tending to give more complete power to the people, have continued to the present time. The constitution now in force dates from the 17th February 1869, and is based on the principle which prevails throughout the whole of Switzerland, that the sovereign power is vested exclusively in the people, but may be exercised either directly or through delegates elected by universal suffrage. Lucerne formerly sent a contingent of 1734 men to the federal army, but according to the latest return the number of men belonging to the canton on the rolls (in 1879) was 5176. In 1846 Lucerne took a leading part in the formation of the *Sonderbund*, a league of several of the Catholic cantons to oppose forcible resistance to the decree of the federal government for the expulsion of the Jesuits from Switzerland. In the brief campaign that ensued in the following year, the forces of the Sonderbund were utterly routed, and after a few days the conflict ceased. Since that date the canton seems to have enjoyed complete internal tranquillity. Lucerne has produced a fair proportion of men who have distinguished themselves in science, literature, philosophy, and art. Among many others whose reputation is confined to their own country, the names of the naturalists Cappeler and Lange, the historians Etterlin and Balthasar, and the philosopher Troxler have acquired more permanent reputation.

LUCERNE, the chief town of the Swiss canton of that name, stands on both banks of the Reuss, where that river issues from the north-west end of the chief arm of the lake of Lucerne. The position of the town is singularly beautiful. Beyond the lower hills, rich with planting and cultivation, which slope towards the shores of the lake and the river, loftier summits of very varied form rise in the background. Most prominent of these is the many-peaked Pilatus, only about 7 miles distant, while the double summit of the Mythen, at the opposite end of the lake, is flanked by other less imposing summits, amongst which the Righi draws attention, owing to the fame of its panoramic view. The picturesque aspect of the town is much enhanced by the ancient walls, now partly removed, and the circular or octagonal towers which surround it. One of these, called the Wasserthurm, rising from the water's edge, is said to have served as a lighthouse (*lucerna*), and to have originated the name of the town and canton. The town appears to owe its origin to a Benedictine monastery which stood on the site of the present Hofkirche. The buildings which clustered round gradually increased, until, early in the 14th century, the walls were erected for protection, and bridges were carried across the river. The Rathhaus, which is the seat of the cantonal Government, is an ancient building adorned with wood carving and quaint pictures. In a large hall are preserved the portraits of the chief magistrates (*Schultheissen*) from the earliest times to the year 1814. The libraries of Lucerne are said to possess the most complete and important collection of documents connected with the history of Switzerland during the Middle Ages. The town library, now in the museum, contains about 12,000 volumes, and is especially rich in manuscript chronicles. The cantonal library, reckoned at over 80,000 volumes, with many incunabula, was chiefly formed from the libraries of suppressed monasteries. Other curious books are to be found in the library of the Capuchins at Wesemlin outside the town.

Besides two modern bridges which span the river, there are two wooden causeways, roofed over, and passable only on foot, which anciently served the wants of the inhabitants; a third, the longest of all, was removed in the progress of modern improvements. Of those remaining, the more ancient, called the Mühlbrücke, was adorned with illustrations of the "Dance of Death," a favourite subject with German and Swiss mediæval artists; though much injured by time, they are still visible. The other wooden bridge—the Kapellbrücke—is decorated with numerous paintings representing events in Swiss history and in the lives of Saints Leodegar and Mauritius, the patrons of the city. The principal church, which has little architectural merit, possesses a fine organ. Along with various religious and charitable institutions which seem fully adequate to the wants of the population, a museum has been opened of late years which, among various other objects, contains an interesting archæological collection, going back to the prehistoric period, and including relics of historical interest, such as trophies taken on the field of Sempach, formerly preserved in the arsenal. The town contains one object of genuine artistic interest—the colossal lion designed to commemorate the men of the Swiss guard who fell in the defence of the Tuileries in Paris on the 10th August 1792. The idea, which might easily have led an inferior artist into extravagance and vulgarity, was well suited for the simple and manly genius of Thorwaldsen, who supplied the model; and, although the execution is necessarily somewhat rude, the effect is touching and impressive. In an architectural point of view the most notable part of the town is the wide quay formed on land reclaimed from the lake in 1852, planted on one side with trees, and on the other showing a succession of those great hotels which everywhere in Switzerland have been built to accommodate and to tempt the strangers who annually resort to the country. This constant flow of visitors has led to a large increase of population; that of Lucerne, which twenty years before was little over 10,000, was 17,850 at the census of 1880. (J. B.)

LUCERNE, Lake of, the name given by foreigners to the Vierwaldstättersee, or lake of the four forest cantons of Switzerland. Only a small portion of its shores lie within the canton of Lucerne, but the name has been taken from the most considerable town which it approaches. Lying on the north-west side of the Alps of central Switzerland, this lake has extraordinary interest for the physical geographer, for the lover of natural scenery, and for all who feel sympathy with the story of Swiss independence. Like most of the other Alpine lakes, it lies altogether among the *Voralpen*, or outer ranges of the Alps, but is remarkable for the extreme irregularity of its form, which suggests problems of much difficulty to the orographer. The great majority of the Alpine lakes occupy depressions or excavations in a single line of valley; and, so far as their form is concerned, the facts appear to be equally reconcilable with the views of those geologists who believe the lake basins to have been hollowed out by great glaciers as with those



Plan of Lake of Lucerne.

which refer their origin to disturbances of relative level, and restrict the action of the ancient glaciers to a secondary part in the result. The Lake of Lucerne, however, appears to occupy portions of four different valleys, orographically distinct, and connected only by narrow and tortuous channels. Commencing at its eastern extremity, we have the portion called the Bay of Uri, which at its southern end receives the considerable stream of the Reuss, bearing down the drainage of the Alps adjoining the pass of St Gotthard. This extends from south to north about 8 miles, with an average breadth of less than 2 miles, enclosed between steep limestone mountains rising from 4000 to 5000 feet above its surface. At the north end of the Bay of Uri a low tract, only a few miles in width, divides the shore of the lake from the little Lake of Lowerz, and another similar tract divides the latter from the Lake of Zug, so that it seems natural to conclude that if the Bay of Uri had been excavated by ice action it would have retained its original direction and carried the waters of the Reuss to the Lake of Zug. In point of fact the channel of the lake is bent abruptly westward round the promontory of Treib, and extends in the same direction nearly 10 miles, with the local designation of Buochsersee. But this channel is closed at its western end by a low neck of land, and the passage for navigation is through a narrow strait, less than half a mile wide, which connects the Buochsersee, lying south of the Bürgenstein and the Vitznauerstock, with a third basin occupying the bottom of the valley which lies north of those ridges. Proceeding westward along this latter portion of the lake, we find two deep bays, several miles in length, opening on either hand, while a third extends somewhat north of west to the town of Lucerne. The bay on the left hand, opening towards the south-west, is called the Alpnachersee, while that on the opposite or north-east side is the Bay of Küssnacht. At the central point where these meet it is seen that they lie in a continuous line of valley extending from the Brünig Pass to the Lake of Zug, as the Bay of Küssnacht is separated from the latter only by a low isthmus. Those who refuse to regard glaciers as the chief agents in the excavation of lake basins ask how it can be supposed that a glacier from the valley of the Reuss could have accomplished the hollowing out of the middle portions of the lake, and further inquire whether the glacier from the valley of Sarnen, which is supposed to have excavated the bays of Alpnach and Küssnacht, should not have also cleared away the isthmus between the latter and the Lake of Zug, leading the drainage of the lake in that direction. The question as to the true origin of lake basins in the Alps cannot be satisfactorily discussed until their forms have been determined by numerous and accurate soundings, and this has as yet been done for the Lake of Como alone. The greatest depth hitherto measured in the Lake of Lucerne is 1040 feet, but no connected series of soundings appear to have as yet been made. The mean height of the surface above the sea-level is 1437 feet, or 68 feet higher than the Lake of Zug.

The irregularity of its form is the chief cause of the unequalled variety which characterizes the scenery of the Lake of Lucerne, but the geological structure of the mountains that enclose it much enhances the effect. Its eastern portion lies amid the Secondary limestone rocks which are everywhere in the Alps marked by sharp peaks and ridges and precipitous crags; the middle part is enclosed by great masses of Tertiary conglomerate, called in Switzerland Nagelfluhe, which constitutes such mountains as the Righi and the Bürgenstein, showing steep faces with gently sloping summits; while the western extremity is surrounded by swelling hills richly planted and dotted with bright looking hamlets or solitary farm-houses. The forests which once covered the greater part of this region, and give the local designation to the four original cantons of Switzerland, have been extensively thinned, but enough yet remain to add another element to the charms of the scenery. Vineyards with their formal rows of stakes are scarcely seen on the shores of the lake, but orchards surround most of the houses, and the walnut grows to great perfection. Lucerne is the only town on the lake. Altdorf, the chief town of Uri, stands nearly 2 miles from the head of the Bay of Uri, and Schwyz, capital of the canton of that name, is more than 3 miles from the shore; but since the introduction of steam navigation several of the villages on its coast have largely increased in population.

Modern scepticism has thrown doubt upon many of the details in the popular history of the origin of Swiss independence; but it is certain that the shores of this lake nurtured the men who commenced the heroic efforts that secured freedom for their country. Here, at the beginning of the 14th century, in an age when nearly all Europe was in the hands of feudal oppressors, a handful of mountaineers drove out the local tyrants and levelled their strong holds, and a few years later, on the fields of Morgarten and Sempach, confronted and put to flight the chivalry of Austria. The man who can visit unmoved the Grütli, the spot, overlooking the Bay of Uri, consecrated by popular tradition as the scene of the first meeting of the confederates on the night of the 7th October 1307, must be devoid of all sense of the sublime in natural scenery and of the heroic in human action. (J. B.)

LUCIA, or Lucy, St, was a noble Christian virgin of Syracuse, who lived in the reign of Diocletian. Her mother, having been miraculously cured of an illness at the sepulchre of St Agatha in Catania, was persuaded by Lucia to distribute all her wealth to the poor. The youth to whom the daughter had been betrothed forthwith denounced her to Paschasius the prefect, who ordered that she should be taken away and subjected to shameful outrage. But it was found that no force which could be applied was able to move her from the spot on which she stood; even boiling oil and burning pitch had no power to hurt her, until at last she was slain with the sword. Such in substance is the narrative of the appropriate lessons given in the Roman Breviary for the festival of St Lucia on December 13 (duplex); a later legend represents her as having plucked out her eyes when they threatened to become a snare to her lover, and as having had them afterwards restored to her more beautiful than before. In art she is represented as suffering martyrdom, as bearing her eyes on a salver, or as carrying a flaming lamp in her hand; in the last case she is the type of celestial light or wisdom (comp. Dante, *Inf.*, ii.; *Purg.*, ix.; *Par.*, xxxii.). She is invoked in cases of eye-disease, and is also regarded as the patroness of the labouring poor.

LUCIAN, one of the principal essay-writers (λογογράφοι) and satirists of the post-Christian era, the silver age of Greek literature, was born at Samosata on the Euphrates in northern Syria.[1] We have no indication of the precise date of his birth, but it is probable that he flourished about or after the middle of the 2d century, as he mentions Marcus Aurelius and his war with the German Marcomanni and Quadi (170–74 A.D.) in his *Alexander* (§ 43). He tells us in the *Somnium* or *Vita Luciani*, § 1, that his means being small he was at first apprenticed to his maternal uncle, a statuary, or rather sculptor of the stone pillars called Hermæ.[2] When a schoolboy he had been in the habit of scraping the wax from his tablets and using it for moulding or modelling little figures of dogs, horses, or men.[3] Having made an unlucky beginning by breaking a marble slab, and having been well beaten for it, he absconded and returned home. Here he had a dream or vision of two women, representing Statuary and Literature. Both plead their cause at length, setting forth the advantages and the prospects of their respective professions; but the youth chooses Παιδεία, and decides to pursue learning. For some time he seems to have made money as a ῥήτωρ, following the example of Demosthenes, on whose merits and patriotism he expatiates in the dialogue *Demosthenis Encomium*. It is clear from his numerous writings that he was very familiar with the rival schools of philosophy, and he must have well studied their teachings; but he lashes them all alike, the Cynics, perhaps, being the chief object of his derision.[4] A large number of philosophers, both ancient and contemporary, are mentioned by name, nearly always in ridicule or disparagement. Lucian was not only a sceptic; he was a scoffer and a downright unbeliever. He felt that men's actions and conduct always fall far short of their professions, and therefore he concluded that the professions themselves were worthless, and a mere guise to secure popularity or respect. Of Christianity he shows some knowledge, and it must have been somewhat largely professed in Syria at the close of the 2d century.[5] In the *Philopatris*, though the dialogue so called is generally regarded as spurious, there is a statement of the doctrine of the Trinity,[6] and the "Galilæan who had ascended to the third heaven" (§ 12), and "renewed" (ἀνεκαίνισεν) by the waters of baptism, may possibly allude to St Paul. The doctrines of the Λόγος and the "Light of the world," and that God is in heaven making a record of the good and bad actions of men,[7] seem to have come from the same source, though the notion of a written catalogue of human actions to be used in judgment was familiar to Æschylus and Euripides.

As a satirist and a wit Lucian stands without a rival. In these respects he may be said to occupy in prose literature the unique position which Aristophanes holds in Greek poetry. But whether he is a mere satirist, who laughs while he lashes, or a misanthrope, who hates while he derides, is not very clear. In favour of the former view it may be said that the two main objects of his ridicule are mythology and the sects of philosophy; in favour of the latter, his bitter exposure of imposture and chicanery in the *Alexander*, and the very severe attacks he makes on the "humbug" of philosophy,[8] which he everywhere assails with the most acrimonious and contemptuous epithets.

As a writer Lucian is fluent, easy, and unaffected, and a close follower of the best Attic models, such as Plato and the orators. His style is simpler than Plutarch's, and some of his compositions, especially the *Dialogues of the Gods* (pp. 204–287) and *of the Marine Deities* (288–327), and, above all, the *Dialogues of the Dead* (329–454), are models of witty, polished, and accurate Greek composition. Not less clever, though rather lax in morality, are the ἑταιρικοὶ διάλογοι (pp. 280–325), which remind us somewhat of the letters of Alciphron. The sarcasms on the popular mythology, the conversations of Pluto, Hermes, Charon, and others of the powers in Hades, show a positive disbelief of any future state of existence. The model Lucian followed in these dialogues, as well in the style as in the sparkling and playful repartee, was the Platonic conversations, founded on the drama, of which the dialogue may be called the prose representative. Aristotle never adopted it, perhaps regarding it as beneath the true dignity of philosophy. The dialogue, in fact, was revived and improved by Lucian,[9] the old traditions of the λογοποιοί and λογογράφοι, and above all, the immense influence of rhetoric as an art, having thrown some discredit on a style of composition which, as introduced by Plato, had formed quite a new era in Greek prose composition. For rhetoric loved to talk, expatiate, and declaim, while dialectic strove to refute by the employment of question and answer, often in the briefest form.

In his language, as tested by the best classical models, Lucian is at once elegant and correct. But he occasionally indulges in idioms slightly solecistic, as in the use of κἂν

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[1] He mentions it only once, in the treatise πῶς δεῖ ἱστορίαν συγγράφειν, where he speaks of τὴν ἐμὴν πατρίδα τὰ Σαμόσατα (§ 24). In *Piscator* (§ 18), he speaks of himself as Σύρος τῶν Ἐπευφρατιδίων.

[2] The words ἄριστος ἑρμογλύφος εἶναι δοκῶν (§ 3) are probably satirical, and really mean φαῦλος, "second-rate," for it is clear that he disliked his uncle.

[3] *Ibid.*, § 2.

[4] Hence Diogenes is made to say in *Piscator*, § 23, ὑπὲρ ἅπαντας ὕβρισμαι, sc. πρὸς Λουκιάνου. In βίων πρᾶσις (p. 551) the same philosopher asserts that "any one will be looked up to and get a reputation if only he has impudence and abuse." At the auction Diogenes is valued at *twopence* (§ 11). That Lucian had practised in law courts, and turned his eloquence afterwards against the philosophers, is asserted in *Piscat.*, § 25.

[5] In the *Alexandrus* (§ 25) we are told that the province of Pontus, due north of Syria, was "full of Christians."

[6] § 12, ὑψιμέδοντα Θεὸν μέγαν ἄμβροτον οὐρανίωνα, υἱὸν Πατρὸς, Πνεῦμα ἐκ πατρὸς ἐκπορευόμενον, ἓν ἐκ τριῶν καὶ ἐξ ἑνὸς τρία, a passage which bears on the controverted procession "a Patre Filioque."

[7] *Ibid.*, § 13. Æsch., *Eum.*, 265, δελτογράφῳ δὲ πάντ᾽ ἐπωπᾷ φρενί.

[8] At p. 792 Hermotimus says to Lycinus (who must be assumed to represent Lucian himself), ὑβριστὴς ἀεὶ σὺ, καὶ οὐκ οἶδ᾽ ὅ τι παθὼν μισεῖς φιλοσοφίαν καὶ ἐς τοὺς φιλοσοφοῦντας ἀποσκώπτεις. In *Icaromenippus* (§ 5) he says he always guessed who were the best physical philosophers "by their sour-faced looks, their paleness of complexion, and the length of their beards." See also *ibid.*, § 29.

[9] He says (speaking as Σύρος in *Bis accusatus*, § 34) that he found dialogue somewhat out of repute from the too numerous questions (*i.e.*, employed by Plato), and brought it up to a more human and natural standard, substituting banter and repartee for dialectic quibbles and close logical reasoning.

(*καὶ ἂν*) with a future or even an imperative, *μὴ* in place of *οὐ*, the particle *ἂν* misplaced or wrongly added, and a subjunctive mood instead of an optative.[1] Nevertheless, he evinces a perfect mastery over a language as wonderful in its inflexions as in its immense and varied vocabulary; and it is a well-merited praise of the author to say that to a good Greek scholar the pages of Lucian are almost as easy and as entertaining as an English or French novel. In this respect they form a contrast with the somewhat "crabbed" style of Plutarch, many of whose moral treatises are by no means easy reading.

Of course Greek, like every other language, is progressive, and the notion of fixing it to any given period as absolutely the best is quite arbitrary. We shall not be surprised at finding in Lucian some forms and compounds which were not in use in the time of Plato or Demosthenes. Thus, he has *ὑπερείδεις* for *ὑπερορᾷς* (p. 99), *πεπεμμένος* as the participle of the perfect passive of *πέμπω* (p. 240), *ἐνσέσεικε* the perfect of *ἐνσείω* (p. 705), to which a purist would object; and there are occasional tendencies to Latinism which can hardly surprise us. From a writer living under Roman rule we may expect some Latin words in his vocabulary, as Σακέρδως for *Sacerdos*, and Roman names like Μάγνος, Κελσός, Κέληρ (*Celer*), Ῥουτιλλίανος, &c. In the *Lexiphanes* a long passage is read from a treatise composed in words of the strangest and most out-of-the-way form and sound, on hearing which Lucian pretends to be almost driven crazy (p. 342). His own sentiments on the propriety of diction are shown by his reproof to Lexiphanes (§ 24), "if anywhere you have picked up an out-of-the-way word, or coined one which you think good, you labour to adapt the sense of it, and think it a loss if you do not succeed in dragging it in somewhere, even when it is not really wanted." The free use of such a vocabulary[2] even in satire shows Lucian's intimate knowledge of the spurious bombast which had begun to corrupt the classic dialect.

Lucian founded his style, or obtained his fluency, from the successful study of rhetoric, by which he appears to have made a good income from composing speeches which attracted much attention.[3] At a later period in life he seems to have held a lucrative office in Egypt. When he "all but had one foot in Charon's boat" (he says in *Apologia*, § 1), "he lent his neck to be bound by a golden collar." This office was to register the actions and verdicts of the law courts,—he was a kind of "Master of the Rolls," who had the custody of the state documents, and received his salary directly from the king (*ibid.*, § 12). He speaks of the emoluments as *οὐ σμικρὸς μισθὸς ἀλλὰ πολυτάλαντος*. We do not know the date of Lucian's death, but he may have lived till about 200 A.D.

The extant works of this writer are so numerous that of some of the principal only a short sketch can be given. To understand them aright we must remember that the whole moral code, the entire "duty of man," was included, in the estimation of the pagan Greek, in the various schools of philosophy. As these were generally rivals, and the systems they taught were more or less directly antagonistic, truth presented itself to the inquirer, not as one, but as manifold. The absurdity and the impossibility of this forms the burden of all Lucian's writings. He could only form one conclusion, viz., that there is no such a thing as truth.

One of the best written and most amusing treatises of antiquity is Lucian's *True History*, which forms a rather long narrative in two books. It is composed, he says in a brief introduction, not only as a pastime and a diversion from severer studies, but avowedly as a satire (*οὐκ ἀκωμῳδήτως*, p. 71) on the poets and logographers who have written so many marvellous tales, *πολλὰ τεράστια καὶ μυθώδη*. He names Ctesias and Homer; but Hellanicus and Herodotus, perhaps other *λογοποιοί* still earlier, appear to have been in his mind.[4] The only true statement in his *History*, he wittily says (p. 72), is that it contains nothing but lies from beginning to end.

The main purport of the story is to describe a voyage to the moon. He set out, he tells us, with fifty companions, in a well-provisioned ship, from the "Pillars of Hercules," intending to explore the western ocean. After eighty days rough sailing they came to an island on which they found a Greek inscription, "This was the limit of the expedition of Heracles and Dionysus"; and the visit of the wine-god seemed attested by some miraculous vines which they found there. After leaving the island they were suddenly carried up, ship and all, by a whirlwind into the air, and on the eighth day came in sight of a great round island shining with a bright light (p. 77), and lying a little above the moon. In a short time they are arrested by a troop of gigantic "horse-vultures" (*ἱππόγυποι*), and brought as captives to the "man in the moon," who proves to be Endymion. He is engaged in a war with the inhabitants of the sun, which is ruled by King Phaethon, the quarrel having arisen from an attempt to colonize the planet Venus (Lucifer). The voyagers are enlisted as "Moonites," and a long description follows of the monsters and flying dragons engaged in the contest. A fight ensues, in which the slaughter is so great that the very clouds are tinged with red (p. 84). The long description of the inhabitants of the moon is extremely droll and original, and has often been more or less closely imitated. After descending safely into the sea, the ship is swallowed by a huge "sea serpent" more than 100 miles long. The adventures during the long confinement in the creature's belly are most amusing; but at last they sail out through the chinks between the monster's teeth, and soon find themselves at the "Fortunate Islands." Here they meet with the spirits of heroes and philosophers of antiquity, on whom the author expatiates at some length. The tale comes to an abrupt end with an allusion to Herodotus in the promise that he "will tell the rest in his next books." The story throughout is written in easy and elegant Greek, and shows the most fertile invention.

Another curious and rather long treatise is entitled Λούκιος ἢ ὄνος. The authorship is regarded as doubtful; the style, as it seems to us, does not betray another hand. Parts of the story are coarse enough; the point turns on one Lucius visiting in a Thessalian family, in which the lady of the house was a sorceress. Having seen her changed into a bird by anointing herself with some potent drug, he resolves to try a similar experiment on himself, but finds that he has become an ass, retaining, however, his human senses and memory. The mistake arose from his having filched the wrong ointment; however, he is assured by the attendant, Palæstra, that if he can but procure roses to eat, his natural form will be restored. In the night a party of bandits break into the house and

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[1] Thus in p. 591, *προελόμενοι τινα ἐξ ἁπάντων ὅστις ἄριστα κατηγορῆσαι ἂν δοκῇ*, either *ὅστις ἂν ἄριστα δοκῇ* or *ὅστις ἄριστα ἂν δοκοίη* is required by the laws of Attic Greek.

[2] In describing a banquet Lexiphanes says (§ 7), *ποτήρια δὲ ἔκειτο παντοῖα ἐπὶ τῆς δελφινίδος τραπέζης, ὁ κρυψιμέτωπος καὶ τρυηλὶς μεντορουργὴς εὐλαβῆ ἔχουσα τὴν κέρκον καὶ βομβύλιος καὶ δειροκύπελλον καὶ γηγενῆ πολλὰ οἷα Θηρικλῆς ὤπτα, εὐρυχαδῆ τε καὶ ἄλλα εὔστομα, τὰ μὲν Φωκαῆθεν, τὰ δὲ Κνιδόθεν, πάντα μέντοι ἀνεμοφόρητα καὶ ὑμενόστρακα.*

[3] *Bis accusat.* (§ 27), where Rhetoric declares she had enriched him, *προῖκα οὐ μικρὰν ἐπεσενεγκαμένη πολλοὺς καὶ θαυμασίους λόγους.*

[4] In p. 127 he says that he saw punished in Hades, more severely than any other sinners, writers of false narratives, among whom were Ctesias of Cnidus and Herodotus. Yet in the short essay inscribed *Herodotus*, p. 831, he wishes it were possible for him to imitate the many excellencies of that writer.

carry off the stolen goods into the mountains on the back of the unfortunate donkey, who gets well beaten for stumbling on the rough road. Seeing, as he fancies, some roses in a garden, he goes in quest of them, and again gets beaten as a thief by the gardener (p. 585). After many adventures with the bandits, he attempts to run away, but is caught. A council is held, and he is condemned to die along with a captive girl who had essayed to escape on his back. Suddenly, however, soldiers appear, and the bandits are arrested (p. 595). Again the ass escapes "to the great and populous city of Berœa in Macedonia" (p. 603). Here he is sold to a strolling conjurer, afterwards to a market-gardener; and both experiences are alike painful. Again he passes into the possession of a cook, where he gets fat and sleek on food more suited to his concealed humanity than the hard fare he has of late lived upon (p. 614). At last, during an exhibition in the theatre, he sees some roses being carried past, and, making a successful rush to devour them, he recovers his former shape. "I am Lucius," he exclaims to the wondering president of the exhibition, "and my brother's name is Caius. It was a Thessalian witch that changed me into a donkey." Thus all ends well, and he returns safe to his country. Droll and graphic as many of the adventures are, they but too clearly show the profligate morals of the age.

The treatise *On the Syrian Goddess* (Mylitta, the moon-goddess, the Semitic Venus) is written in the Ionic dialect in imitation perhaps of the style of Herodotus, though the resemblance is by no means close. The writer professes to be an Assyrian (p. 452), and to describe the wonders in the various temples of Palestine and Syria; he descants on the eunuchs of Syria and the origin of the self-imposed privation of manhood professed and practised by the Galli. The account of the temples, altars, and sacrifices is curious, if really authentic; after the manner of Pausanias it is little more than a list, with the reasons in most cases added, or the origin of the custom explained.

De Morte Peregrini is a narrative of one Proteus, a Cynic, who after professing various doctrines, and among them those of Christianity, ended his own life by ascending a burning pyre (p. 357).[1] The founder of the Christian religion is described (p. 334) as "the man who had been crucified (or fixed to a stake, ἀνασκολοπισθέντα) in Palestine," and as one "still worshipped for having introduced a new code of morals into life." The zeal of the early converts is shown by their flocking to the prison when Proteus had been arrested, by the sympathy conveyed from distant cities of Asia (p. 336), by contributions of money for his support, and by their total indifference to life; for "the poor wretches have persuaded themselves that they will live for ever." The founder of the religion, "that first lawgiver of theirs," says Lucian, "made them believe that they are all brothers when once they have abjured the gods of Greece and worshipped the crucified man who is their teacher, and have begun to live according to his laws" (p. 337).

Bis accusatus is a dialogue commencing with a satire on the folly of the popular notion that the gods alone are happy. Zeus is represented as disproving this by enumerating the many and heavy duties that fall to their lot in the government of the world, and Hermes remarks on the vast crowds of philosophers of rival sects, by whose influence the respect and worship formerly paid to the gods have seriously declined. A trial is supposed to be held under the presidency of the goddess Δίκη, between the Academy, the Porch, the schools of the Cynics and Epicureans, and Pleasure, Revelry, Virtue, Luxury, &c., as variously impugned or defended by them. Then Conversation and Rhetoric come before the court, each having an action for defamation to bring against Syrus the essayist, who of course is Lucian himself (p. 823). His defence is heard against the charges of both, and in both cases he is triumphantly acquitted. This essay is brilliant from its clever parodies of Plato and Demosthenes, and the satire on the Socratic method of arguing by short questions and answers.

The *Lover of Lying* (Φιλοψευδής) discusses the reason why some persons seem to take pleasure in falsehood for its own sake, and when there is nothing to be gained by it. Under the category of lying all mythology (*e.g.*, that of Homer and Hesiod) is included, and the question is asked, why the hearers of such stories are amused by them? Quack remedies, charms, and miraculous cures are included among the most popular kinds of falsehood; witchcraft, spiritualism, exorcism, expulsion of devils, spectres, are discussed in turn, and a good ghost story is told in p. 57. An anecdote is given of Democritus, who, to show his disbelief in ghosts, had shut himself up in a tomb, and when some young men, dressed up with death's heads, came to frighten him at night, and suddenly appeared to him while he was engaged in writing, he did not even look up, but called out to them, "Stop your joking" (p. 59). This treatise, a very interesting one, concludes with the reflexion that truth and sound reason are the only remedies for vain and superstitious terrors.

The dialogue *Navigium seu Vota* (Πλοῖον ἢ εὐχαί) gives an apparently authentic account of the measurements and fittings of an Egyptian ship which has arrived with a cargo of corn at the Piræus, driven out of its course to Italy by adverse winds. The full length is 180 feet, the breadth nearly 50, the depth from deck to the bottom of the hold 43 feet. The "wishes" turn on a party of friends, who have been to see the ship, declaring what they would most desire to possess. One would have the ship filled with gold, another a fine house with gold plate; a third would be a "tyrant" with a large force devoted to his interests; a fourth would like to make himself invisible, enter any house that he pleased, and be transported through the air to the objects of his affection. After hearing them all, the first speaker, Lycinus (Lucian), says that he is content with the privilege of laughing heartily at the vanity of human wishes, especially when they are those of professed philosophers.

The dialogue between Philo and Lycinus, *Convivium seu Lapithæ*, is a very amusing description of a banquet, at which a party of dignified philosophers quarrelled over their viands at a marriage feast, and came to blows. The style is a good imitation of Plato, and the scene reminds one of the "clients' dinner" in the fifth satire of Juvenal. One of the party is so irritated by taunts that he flings a goblet half full of wine at the head of another, who retorts by spitting in the face of the aggressor (p. 441). Matters come to a climax by the attempt of one of the guests, Zenothemis, to secure for himself a fatter fowl which had been served to his next neighbour Hermon. Each seizes his bird and hits the other with it in the face, at the same time pulling his beard. Then a general fight ensues, and serious wounds are inflicted. The story is, of course, a satire on philosophy, the favourite topic of a writer who believed neither in gods nor in men.

The *Piscator*, a dialogue between Lucian, Socrates, Pythagoras, Empedocles, Plato, and others, commences with a general attack on the author as the enemy of philosophy. Socrates proposes that the culprit should be tried, and that Philosophia should assist in the prosecution. Lucian declares that he does not know where such a person lives, long as he has been looking for her (§ 11). She is found at last, but declares Lucian has never disparaged

[1] It is open to controversy whether he was not a martyr at the stake.

her, but only impostors and pretenders under her name (§ 15). He makes a long defence (pp. 598–606), abusing the philosophers in the sort of language in which some schools of theologians abuse the monks of the Middle Ages (§ 34). The trial is held in the Acropolis of Athens, and the sham philosophers, dreading a verdict against them, throw themselves from the rock. A Cynic flings away his scrip in the hurry, and on examination it is found to contain, not books or loaves of bread, but gold coins, dice, and fragrant essences (§ 44). The title of *Fisherman* is given to this witty treatise, because at the end Lucian baits his hook with a fig and a gold coin, and catches gluttonous strollers in the city while seated on the wall of the Acropolis.

The *Voyage Home* (Κατάπλους) opens with the complaint that Charon's boat is kept waiting for Hermes, who soon appears with his troop of ghosts to be ferried over the infernal river. Among them is a τύραννος, one Megapenthes, who, as his name is intended to express, mourns greatly over the life he has just left. Amusing appeals are made by other souls for leave to return to life, and even bribes are offered to the presiding goddess of destiny, but Clotho is, of course, inexorable. The moral of the piece is closely like that of the parable of Dives and Lazarus: the rich and prosperous bewail their fate, while the poor and afflicted find rest from their troubles, and have no desire to return to them. The τύραννος here is the man clothed in purple and fine linen, and Lucian shows the same bitter dislike of tyrants which Plato and the tragic writers display. The heavy penalty is adjudged to Megapenthes that he may ever remember in the other world the misdeeds done in life.

The *Sale of Lives* is an auction held by Zeus to see what price the lives of philosophers of the rival sects will bring. A Pythagorean, who speaks in the Ionic, first undergoes an examination as to what he can teach, and this contains an enumeration of the doctrines usually ascribed to that sect, including metempsychosis. He is valued at 7s. 6d., and is succeeded by Diogenes, who avows himself the champion of truth, a cosmopolitan (§ 8), and the enemy of pleasure. Socrates brings two talents, and is purchased by Dion, tyrant of Syracuse (§ 19). Chrysippus, who gives some specimens of his clever quibbles,[1] is bought for fifty pounds, Aristotle for nearly a hundred, while Pyrrho the sceptic (or one of his school), who professes to "know nothing," brings four pounds, "*because* he is dull and stupid and has no more sense than a grub" (§ 27). But the man raises a doubt, "whether or not he has really been bought," and refuses to go with the purchaser till he has fully considered the matter.

Timon is a very amusing and witty dialogue. The misanthrope, once wealthy, has become a poor farm-labourer, and reproaches Zeus for his indifference to the injustice of man. Zeus declares that the noisy disputes in Attica have so disgusted him that he has not been there for a long time (§ 9). He tells Hermes to conduct Plutus to visit Timon, and see what can be done to help him. Plutus, who at first refuses to go, is persuaded after a long conversation with Hermes, and Timon is found by them digging in his field (§ 31). Poverty is unwilling to resign her votary to wealth; and Timon himself, who has become a thorough misanthrope, objects to be made rich again, and is with difficulty persuaded to turn up with his mattock a crock of gold coins. Now that he has once more become rich, his former flatterers, who had long left him, come cringing with their congratulations and respects, but they are all driven off with broken heads or pelted with stones. Between this dialogue and the *Plutus* of Aristophanes there are many close resemblances.

Hermotimus (pp. 739–831) is one of the longer dialogues, Hermotimus, a student of the Stoic philosophy for twenty years (§ 2), and Lucian (Lycinus) being the interlocutors. The long time—forty years at the least—required for climbing up to the temple of virtue and happiness, and the short span of life, if any, left for the enjoyment of it, are discussed. That the greatest philosophers do not always attain perfect indifference, the Stoic *ultimatum*, is shown by the anecdote of one who dragged his pupil into court to make him pay his fee (§ 9), and again by a violent quarrel with another at a banquet (§ 11). Virtue is compared to a city with just, and good, and contented inhabitants; but so many offer themselves as guides to the right road to virtue that the inquirer is bewildered (§ 26). What is truth, and who are the right teachers of it, still remains undetermined. The question is argued at length, and illustrated by a peculiar custom of watching the pairs of athletes and setting aside the reserved combatant (πάρεδρος) at the Olympian games by the marks on the ballots (§§ 40–43). This, it is argued, cannot be done till all the ballots have been examined; so a man cannot select the right way till he has tried all the ways to virtue. But to know the doctrines of all the sects is impossible in the term of a life (§ 49). To take a taste of each, like trying a sample of wine, will not do, because the doctrines taught are not, like the crock of wine, the same throughout, but vary or advance day by day (§ 59). A suggestion is made (§ 68) that the searcher after truth should begin by taking lessons in the science of discrimination, so as to be a good judge of truth before testing the rival claims. But who is a good teacher of such a science? (§ 70). The general conclusion of this well-argued inquiry is that philosophy is not worth the pursuit. "If I ever again," says Hermotimus, "meet a philosopher on the road, I will shun him as I would a mad dog."

The *Alexander* or *False Prophet* is a severe exposure of a clever rogue who seems to have incurred the personal enmity of Lucian (pp. 208–265). Born at Abonoteichus in Bithynia, a town on the southern shore of the Euxine, he is denounced as having filled all the Roman province of Asia with his villainy and plundering. Handsome, clever, and unprincipled, he had been instructed in the arts of imposture by one of the disciples of Apollonius of Tyana. Trusting to the natural credulity of Asiatics (§ 9), he sets up an oracle in his native town, having buried some brazen tablets which pretended that Æsculapius would be worshipped in a temple there. A long account is given of the frauds and deceptions of this pretended hierophant, and the narrative ends with his treacherous attempt to drown Lucian off the coast of Amastris by a secret order given to the pilot,—a design which was frustrated by the honesty of the man (§ 56).

The *Anacharsis* is a dialogue between Solon and the Scythian philosopher, who has come to Athens on purpose to learn the nature of the Greek institutions. Seeing the young men performing athletic exercises in the Lyceum, he expresses his surprise at such a waste of energy and the endurance of so much useless pain. This gives Socrates an opportunity of descanting at length on training as a discipline, and emulation as a motive for excelling. Love of glory, Solon says, is one of the chief goods in life. The argument is rather ingenious and well put; the style reminds us of the minor essays of Xenophon.

In all, one hundred and twenty-four extant treatises of Lucian (excluding about fifty epigrams and two iambic poems of no great merit) are considered genuine. We have given a brief account of

[1] *E.g.*, § 25, "A stone is a body; a living creature is a body; you are a living creature; therefore you are a stone." Again: "Is *every* body possessed of life?" "No." "Is a stone possessed of life?" "No." "Are *you* a body?" "Yes." "A *living* body?" "Yes." "Then, if a living body, you are not a stone."

some of the longest and best, but many others, *e.g.*, *Prometheus*, *Menippus*, *Life of Demonax*, *Toxaris*, *Zeus Tragœdus*, *The Dream or the Cock*, *Icaromenippus* (an amusing satire on the physical philosophers), are of considerable literary value. The excellent edition of C. Jacobitz, in the Teubner series, which is furnished with a very complete index, places the text in the student's hand in a much more satisfactory state than has yet fallen to the lot of Plutarch in his *Opera Moralia*. (F. A. P.)

LUCIAN, the martyr, was born, like the famous heathen writer of the same name, at Samosata. His parents, who were Christians, died when he was in his twelfth year. In his youth he studied under Macarius of Edessa, and after receiving baptism he adopted a strictly ascetic life, and devoted himself with zeal to the continual study of Scripture. Settling at Antioch, he became a presbyter, and, while supporting himself by his skill as a swift writer, became celebrated as a teacher, pupils crowding to him from all quarters, so that he is regarded as the founder of the famous theological school of Antioch. He did not escape suspicion of heresy, and is represented as the connecting link between Paul of Samosata and Arius. Indeed, on the deposition of the former, he was excluded from ecclesiastical fellowship by three successive bishops of Antioch, while the latter seems to have been among his pupils (Theodoret, *H. E.*, i. 3, 4). He was, however, restored before the outbreak of persecution, and the reputation won by his high character and learning was confirmed by his courageous martyrdom. He was carried to Nicomedia before the cruel Maximin, and persisting in his faith perished 312 A.D., under torture and hunger, which he refused to satisfy with food offered to idols. His remains were conveyed to Drepanum in Bithynia, and under Constantine the town was founded anew in his honour with the name of Helenopolis, and exempted from taxes by the emperor (327 A.D., see *Chron. Pasch.*, Bonn ed., p. 527). Here, on the day after Epiphany 387 A.D. (the day on which his martyrdom was commemorated), Chrysostom delivered the panegyrical homily from which, with notices in Eusebius (*H. E.*, ix. 6), Theodoret (*loc. cit.*), and the other ecclesiastical historians, the life by Jerome (*Vir. Ill.*, cap. 77), but especially from the account by S. Metaphrastes (cited at length in Bernhardy's notes to Suidas, *s.v.* νοθεύει), the facts above given are derived. See also, for the celebration of his day in the Syriac churches, Wright, *Cat. of Syr. MSS.*, p. 283.

Jerome says, "Feruntur eius de Fide libelli et breves ad nonnullos epistolæ"; but only a short fragment of one epistle remains (*Chron. Pasch.*, p. 516). The authorship of a confession of faith ascribed to Lucian and put forth at the semi-Arian synod of Antioch (341 A.D.) is questioned. Lucian's most important literary labour was his edition of the Septuagint corrected by the Hebrew text, which, according to Jerome (*Adv. Ruf.*, ii. 77), was in current use from Constantinople to Antioch. That the edition of Lucian is represented by the text used by Chrysostom and Theodoret, as well as by certain extant MSS., such as the Arundelian of the British Museum, was proved by F. Field (*Prol. ad Origenis Hexapla*, cap. ix.), who points out that Lucian filled up lacunæ of the Septuagint text as compared with the Hebrew from the other Greek translations, that his method was harmonistic, and that he sometimes indulged in paraphrastic additions and other changes. Before the publication of Field's *Hexapla*, Lagarde had already directed his attention to the Antiochian text (as that of Lucian may be called). See his *Symmicta* (ii. 142), and *Ankündigung einer neuen Ausg. d. gr. Uebersetzung des A. T.* (1882), in which an edition of this recension is promised, and the means for effecting it described. The accomplishment of this task may be looked to as the first step in the process of tracing backwards the history of the Septuagint.

From a statement of Jerome in his preface to the gospels it seems probable that Lucian had also a share in fixing the Syrian recension of the New Testament text, but of this it is impossible to speak with certainty. Compare the introductory volume of Westcott and Hort's *New Testament*, p. 138.

LUCIFER, bishop of Cagliari (hence called *Calaritanus* or rather *Caralitanus*), an ardent supporter of the cause of Athanasius, after the unfavourable result of the synod of Arles in 353 volunteered to go to the court and endeavour to obtain a new and impartial council; he was accordingly sent by Pope Liberius, along with Pancratius the presbyter and Hilarius the deacon, but did not succeed in preventing the condemnation of Athanasius, which was renewed at Milan in 355. For his own persistent adherence to the orthodox creed he was banished to Germanicia in Commagene; he afterwards lived at Eleutheropolis in Palestine, and finally in the upper Thebaid. His exile came to an end with the publication of Julian's edict in 362. From 363 until his death in 371 he lived at Cagliari in a state of voluntary separation from ecclesiastical fellowship with his former friends Eusebius of Vercelli, Athanasius, and the rest, on account of their mild decision at the synod of Alexandria in 362 with reference to the treatment of those who had unwillingly Arianized under the persecutions of Constantius. The Luciferian sect thus founded did not continue to subsist long after the death of its leader. It is doubtful whether it ever formulated any distinctive doctrine; certainly it developed none of any importance. The memory of Lucifer is still cherished in Sardinia; but, although popularly regarded there as a saint, he has never been canonized.

The controversial writings of Lucifer, dating from his exile, are chiefly remarkable for their passionate zeal and for the boldness and violence of the language addressed to the reigning emperor, whom he did not scruple to call the enemy of God and a second Saul, Ahab, and Jeroboam. Their titles, in the most probable chronological order, are *De non parcendis in Deum delinquentibus*, *De regibus apostaticis*, *Ad Constantium Augustum pro Athanasio libri ii.*, *De non conveniendo cum hæreticis*, and *Moriendum esse pro Filio Dei*. Their quotations of Scripture are of considerable value to the critical student of the Latin text before Jerome. They were first collected and edited by Tilius (Paris, 1586), and afterwards reprinted in the *Bibliotheca Patrum* (1618); the best edition is that of the brothers Colet (Venice, 1778).

LUCILIUS. Among the early Roman poets, of whose writings only fragments have been preserved, Lucilius was second in importance to Ennius. If he did not, like the epic poet of the republic, touch the imagination of his countrymen, and give expression to their highest ideal of national life, he exactly hit their ordinary mood, and expressed the energetic, critical, and combative temper which they carried into political and social life. He was thus regarded as the most genuine literary representative of the pure Roman spirit. The reputation which he enjoyed in the best ages of Roman literature is proved by the terms in which Cicero and Horace speak of him. Persius, Juvenal, and Quintilian vouch for the admiration with which he was regarded in the first century of the empire. The popularity which he enjoyed in his own time is attested by the fact that at his death in 102 B.C., although he had filled none of the offices of state, he received the honour of a public funeral.

His chief claim to distinction is his literary originality. He alone among Roman writers established a new form of composition. He may be called the inventor of poetical satire, as he was the first to impress upon the rude inartistic medley, known to the Romans by the name of *satura*, that character of aggressive and censorious criticism of persons, morals, manners, politics, literature, &c., which the word satire has ever since denoted. In point of form the satire of Lucilius owed nothing to the Greeks. It was a legitimate development of an indigenous dramatic entertainment, popular among the Romans before the first introduction of the forms of Greek art among them; and it seems largely also to have employed the form of the familiar epistle which circumstances had developed among them about the time when Lucilius flourished. But the style, substance, and spirit of his writings were apparently as original as the form. He seems to have commenced his poetical career by ridiculing and parodying the conventional language of epic and tragic poetry, and to have used in his own writings the language commonly employed in the social intercourse of educated men. Even his frequent use of Greek words, phrases, and quotations, reprehended by Horace, was probably taken from the actual practice of men, powerfully stimulated by the new learning, who found their own speech as yet inadequate to give free expression to the new ideas and impressions which they derived from their first contact with Greek philosophy, rhetoric, and poetry. Further, he not only created a style of his own, but, instead of taking the substance of his writings from Greek poetry, or from a remote past, he treated of the familiar matters of daily life, of the personal interests and peculiarities of himself or his contemporaries, of the politics, the wars, the government of the provinces, the administration of justice, the fashions and tastes, the eating and drinking, the money-making and money-spending, the scandals and vices, the airs and affectations, which made up the public and private life of Rome in the last quarter of the second century before our era. This he did in a singularly frank, independent, and courageous spirit, with no private ambition to serve, or party cause to advance, but with an honest desire to expose the iniquity or incompetence of the governing body, the sordid aims of the middle class, and the corruption and venality of the city mob. There was nothing of stoical austerity or of rhetorical indignation in the tone in which he treated the vices and follies of his time. His character and tastes were much more akin to those of Horace than of either Persius or Juvenal. But he was what Horace was not, a thoroughly good hater; and he lived at a time when the utmost freedom of speech and the most unrestrained indulgence of public and private animosity were the characteristics of men who took a prominent part in affairs. Although Lucilius took no active part in the public life of his time, he regarded it in the spirit, not of a recluse or a mere student of books, but of a man of the world and of society, as well as a man of letters. His ideal of public virtue and private worth had been formed by intimate association with the greatest and best of the soldiers and statesmen of an older generation.

The dates assigned by Jerome for his birth and death are 148 and 103 or 102 B.C. But it is impossible to reconcile the first of these dates with other facts recorded of him. We learn from Velleius that he served under Scipio at the siege of Numantia in the year 134 B.C. We learn from Horace that he lived on the most intimate terms of friendship with Scipio and Lælius, and that he celebrated the exploits and virtues of the former in his satires. Fragments of those books of his satires which seem to have been first given to the world (books xxvi.–xxix.) clearly indicate that they were written in the lifetime of Scipio. Some of these bring the poet before us as either corresponding with, or engaged in controversial conversation with, his great friend. One line—

> "Percrepa pugnam Popilli, facta Corneli cane—"

in which the defeat of M. Popillius Lænas, in 138 B.C., is contrasted with the subsequent success of Scipio, bears the stamp of having been written while the news of the capture of Numantia was still fresh. It is in the highest degree improbable that Lucilius served in the army at the age of fourteen; it is still more unlikely that he could have been admitted into the familiar intimacy of Scipio and Lælius at that age. It seems a moral impossibility that between the age of fifteen and nineteen—*i.e.*, between 133 B.C. and 129 B.C., the year of Scipio's death—he could have come before the world as the author of an entirely new kind of composition, and one which, to be at all successful, demands especially maturity of judgment and experience. It may further be said that the well-known words of Horace, in which he characterizes the vivid portraiture of his life, character, and thoughts, which Lucilius bequeathed to the world,

> "quo fit ut omnis
> Votiva pateat veluti descripta tabella
> Vita senis,"[1]

lose much of their force unless *senis* is to be taken in its ordinary sense,—which it cannot be if Lucilius died at the age of forty-six. Two explanations have been given of the error. One is that, from a similarity in the names of the consuls for the years 180 and 148 B.C., Jerome had confused the one year with the other, and thus that the date of the birth of Lucilius must be thrown back thirty-two years. He would thus have been nearly fifty when he served at Numantia, and when he first began to write satire. But the terms which Horace applies to the intimacy of Lucilius and Scipio, such as "discincti ludere," indicate the relations of an older to a much younger man; and the verve and tone of his satires are those of a man not so far advanced in years as he would have been if born in the year 180 B.C. A simpler explanation of the error is supported by Mr Munro, in the *Journal of Philology*, No. xvi. He supposes that Jerome must have written the words "anno xlvi" for "anno lxiv" or "lxvi"; which would make the birth of Lucilius eighteen or twenty years earlier than that usually assigned. Lucilius would thus have been about thirty-three or thirty-five years of age when he served at Numantia, and two or three years older when he gave his first satires to the world. As he lived for about thirty years longer, and as he seems to have continued the composition of his satires during most of what remained of his life, and as it was his practice to commit to them all his private thoughts, the words of Horace would naturally and truthfully describe the record of his observation and experience between the age of thirty-five and his death. His birthplace was Suessa Aurunca in Campania, from which circumstance Juvenal describes him as "magnus Auruncæ alumnus." He belonged to the equestrian order, a fact indicated by Horace's notice of himself as "infra Lucili censum." He was granduncle to Pompey, on the mother's side. Though not himself belonging to any of the great senatorian families, he was in a position to associate with them on equal terms, and to criticize them with independence. And this circumstance contributed to the boldness, originality, and thoroughly national character of his literary work. Had he been a "semi-Græcus," like Ennius and Pacuvius, or of humble origin, like Plautus, Terence, or Accius, he would scarcely have ventured, at a time when the senatorian power was strongly in the ascendant, to revive the rôle which had proved disastrous to Nævius; nor would he have had the intimate knowledge of the political and social life of his day which fitted him to be its painter. Another circumstance determining the bent of his mind to satire was the character of the time in which he began the work of his life. The origin of Roman political and social satire is to be traced to the same disturbing and disorganizing forces which led to the revolutionary projects and legislation of the Gracchi.

The remains of Lucilius extend to about eleven hundred lines. But much the largest number of his fragments are unconnected lines, preserved by late grammarians, as illustrative of peculiar verbal usages. He was, for his time, a voluminous as well as a very discursive writer. He left behind him thirty books of satires, and there is reason to believe that each book, like the books of Horace and Juvenal, was composed of different pieces. The order in which they were known to the grammarians was not that in which they were written. The earliest in order of composition were probably

[1] "And so it happens that the whole life of the old man stands clearly before us, as if it were represented on a votive picture."

those numbered from xxvi. to xxix., which were written in the trochaic and iambic metres that had been employed by Ennius and Pacuvius in their *Saturæ*. In these he made those criticisms on the older tragic and epic poets of which Horace and other ancient writers speak. In them too he speaks of the Numantine War as recently finished, and of Scipio as still living. Book i., on the other hand, in which the philosopher Carneades, who died in 128 B.C., is spoken of as dead, must have been written after the death of Scipio. With the exception of books xxvi.–xxix., and one satire in which he seems to have made an experiment in the unfamiliar elegiac metre, all the satires of Lucilius were written in hexameters. So far as an opinion can be formed from a number of unconnected fragments, he seems to have written the trochaic tetrameter with a smoothness, clearness, and simplicity which he never attained in handling the hexameter. The longer fragments produce the impression of great discursiveness and carelessness, but at the same time of considerable force. The words of Horace, "fluere lutulentum," seem exactly to express the character of his style. He appears, in the composition of his various pieces, to have followed no settled plan, but to have treated everything that occurred to him in the most desultory fashion, sometimes adopting the form of dialogue, sometimes that of an epistle or an imaginary discourse, and often to have spoken in his own name, giving an account of his travels and adventures, or of amusing scenes that he had witnessed, or expressing the results of his private meditations and experiences. Like Horace he largely illustrated his own observations by personal anecdotes and fables. The fragments clearly show how often Horace has imitated him, not only in expression, but in the form of his satires (see for instance i. 5 and ii. 2), in the topics which he treats of, and the class of social vices and the types of character which he satirizes. For students of Latin literature, the chief interest of studying the fragments of Lucilius consists in the light which they throw on the aims and methods of Horace in the composition of his satires, and, though not to the same extent, of his epistles. But they are important also as materials for linguistic study; and they have a considerable historical value as throwing light on the feeling, temper, circumstances, and character of a most interesting time, of which there is scarcely any other contemporary record.

The best edition of the *Fragments* is that of L. Müller (1872). A collection of them by Lachmann has appeared since his death. The emendation of these fragments still employs the ingenuity of both German and English scholars. Important contributions to the subject have been made by Mr Munro in the *Journal of Philology*. (W. Y. S.)

LUCIUS, the name of three popes.

LUCIUS I., whose pontificate of about eight months (253-54) fell between those of Cornelius and Stephen I., had been one of the presbyters who accompanied Cornelius when he withdrew from Rome. After his own election also he appears to have lived for some time in exile, but ultimately to have been permitted to return. No facts of his official life have been recorded, but he is referred to in several letters of Cyprian as having been in agreement with his predecessor Cornelius in preferring the milder view on the question as to how the penitent lapsed should be treated. The manner of his death is uncertain; according to some accounts he was decapitated. In the *Catalogus Liberianus* and in the *Catalogus Corbeiensis* he is said to have been pope for more than three years; but there can be no doubt of the correctness of the statement of Eusebius, that his pontificate was of less than eight months' duration. Like all the early popes he has been canonized in the Church of Rome; and he is commemorated as a martyr on March 4.

LUCIUS II. (Gherardo de Caccianimici), a Bolognese, succeeded Celestine II. on March 4, 1144. Soon after his accession the people of Rome chose a patrician, for whom they claimed the temporal sovereignty; Lucius at the head of the oligarchical party appealed to arms, and perished in an attempt to storm the Capitol on February 25, 1145. He was succeeded by Eugenius III.

LUCIUS III. (Ubaldo Allucingoli), a native of Lucca, was bishop of Ostia and Velletri when he was chosen to succeed Alexander III. on September 1, 1181. For six months he lived at Rome, but in March 1182 he was driven forth by rebellion, and resumed his abode at Velletri; he afterwards lived at Anagni, and finally at Verona. While at the last-named place he pronounced sentence of excommunication against the Cathari, Paterines, Humiliati, Waldensians, and Arnoldists in 1184; but "left the papal thunders to their own unaided effects." He died at Verona on November 25, 1185, and was succeeded by Urban III.

LÜCKE, GOTTFRIED CHRISTIAN FRIEDRICH (1791-1855), theologian, was born on August 24, 1791, at Egeln near Magdeburg, where his father was a merchant, received his early education at the Magdeburg gymnasium, and studied theology at Halle and Göttingen (1810-13). In 1813 he became repetent at Göttingen, and in 1814 he received the degree of doctor in philosophy from Halle; in 1816 he removed to Berlin, where he became licentiate in theology, and qualified as "privatdocent." He soon became intimate with Schleiermacher and De Wette, and was associated with them in 1818 in the redaction of the *Theologische Zeitschrift*. Meanwhile his lectures and publications (among the latter a *Grundriss der Neutestamentlichen Hermeneutik*, 1816) had brought him into considerable repute, and he was appointed professor extraordinarius in the new university of Bonn in the spring of 1818; in the following autumn he became professor ordinarius. From Bonn, where he had Augusti, Gieseler, and Nitzsch for colleagues, he was called to Göttingen to succeed Stäudlin in 1827. Here he remained, declining all further calls elsewhere, as to Erlangen, Kiel, Halle, Tübingen, Jena, and Leipsic, until his death, which occurred on February 14, 1855.

Lücke, who was one of the most learned, many-sided, and influential of the so-called "mediation" school of evangelical theologians, is now known chiefly by his principal work, an *Exposition of the Writings of St John*, of which the first edition, in four volumes, appeared in 1820-32; it has since passed through two new and improved editions (the last volume of the third edition by Bertheau, 1856). He is one of the most intelligent maintainers of the Johannine authorship of the Fourth Gospel; in connexion with this thesis he was one of the first to argue for the early date and non-apostolic authorship of the Apocalypse.

LUCKENWALDE, a busy little town of Prussia, in the province of Brandenburg, district of Potsdam, lies on the river Nuthe and on the Berlin and Anhalt Railway, 30 miles to the south-west of Berlin. Its cloth and wool manufactories are among the most extensive in Prussia, and it also contains cotton-printing works, dye-works, machine shops, and numerous other industrial establishments. The population in 1880 was 14,706. The site of Luckenwalde was occupied in the 12th century by a Cistercian monastery, but the village did not spring up till the reign of Frederick the Great. It was made a town in 1808.

LUCKNOW, a district of Oudh, in the division or commissionership of Lucknow,[1] under the jurisdiction of the lieutenant-governor of the North-Western Provinces, India, lying between 26° 30′ and 27° 9′ 30″ N. lat., and between 80° 36′ and 81° 15′ 30″ E. long., is bounded on the N. by Hardoi and Sítápur districts, on the E. by Bára Bánki, on the S. by Rái Bareli, and on the W. by Unao. The general aspect of the country is that of an open champaign, well studded with villages, finely wooded, and in parts most fertile and highly cultivated. In the vicinity of rivers, however, stretch extensive barren sandy tracts (*bhúr*), and there are many large sterile wastes of saline efflorescence (*usár*). The country is an almost dead level throughout, the average slope, which is from north-west to south-east, being less than a foot per mile. The principal rivers are the Gumti and the Sái, with their

[1] Lucknow division lies between 26° 9′ and 27° 21′ 5″ N. lat. and between 80° 5′ and 81° 54′ E. long., comprises the three districts of Lucknow, Unao, and Bára Bánki, and has an area of 4480 square miles, of which 2520 are returned as under cultivation. The population in 1869 was 2,838,106, viz., 2,449,763 Hindus, 383,260 Mohammedans, 4309 Europeans, and 784 Eurasians.

tributaries. The former enters the district from the north, and, after passing Lucknow city, turns to the east and enters Bára Bánki. The Sái forms the south-west boundary of the district, running almost parallel with the Gumti.

The census of 1869 returned the population of the district at 970,625. Recent changes and transfers to and from other districts have, however, taken place. Allowing for these, Lucknow contains (according to the census of 1869) a population of 789,465 persons (416,960 males and 372,505 females), spread over an area of 965 square miles. Hindus number 614,276; Mohammedans, 167,184; Christians, 4982; the remainder being made up of unclassified prisoners and jail officials. Four towns contain a population exceeding 5000 inhabitants, viz., Lucknow city, Amethi (7182), Kakori (8220), Malihábád (8026). The estimated area under cultivation is returned at 547 square miles. Three harvests are reaped in the year, viz., the *rabí* in spring, comprising wheat, barley, gram, peas, *gujai* (a mixture of wheat and barley), and *birra* (a mixture of barley and gram); the *kharíf* in the rainy season, comprising rice, millets, *sánwán*, *mandwá*, *kákun*, and Indian corn; and the *henwat* in the autumn, consisting of *joar*, *bájra*, *másh*, *múng*, *moth*, *masúr*, and *lobia*. In addition, there are valuable crops of tobacco, opium, cotton, spices, and vegetables. Irrigation is carried on by means of rivers, tanks, and wells. The cultivators are almost all deeply in debt, and under advances of seed grain from their landlords. Wages have remained stationary in the country, but have decreased in the city owing to its diminished wealth and population since the departure of the Oudh court. The price of food, on the other hand, has materially risen of late years. When not paid in grain, an ordinary agricultural labourer receives about 1½d. a day. Artisans, such as smiths and carpenters, receive 4½d. a day for work in their own villages, or 6d. a day if called away from their homes. Famines have occurred in Lucknow in 1769, 1784–86, and 1837, and severe scarcities in 1861, 1865–66, 1869, and 1873—all caused by drought. The district is well provided with communications by road, river, and railway. Three imperial lines of road branch out south, east, and north to Cawnpur, Faizábád, and Sítápur, metalled and bridged throughout, and comprising, exclusive of the roads in Lucknow city and cantonments, a length of about 500 miles. There are also seven principal local lines of road. River communication is not much used. The line of railway is comprised in the Oudh and Rohilkhand railway system. The entire length of railway communication is 52 miles. Manufactures are mainly confined to Lucknow city. In the country towns are a few weavers, dyers, bangle-makers, brass-workers, and potters. Cotton weaving has greatly declined since the introduction of European piece-goods. The principal imports are food-stuffs, piece-goods, arms, hardware, glass, crockery, and salt; while muslins, embroidery, cotton prints, brass vessels, lace, tobacco, &c., are exported. The district is administered by a deputy commissioner, aided by a magistrate in charge of the city, and a second in the cantonments, one or two assistant commissioners, three extra-assistant commissioners, three *tahsildárs*, and four honorary magistrates. Besides, there are a civil judge and a small-cause court judge, who have no criminal or revenue powers. The total imperial and local revenue of Lucknow district in 1871–72 amounted to £162,926, and the expenditure to £70,534; the Government land revenue was £70,580. Excluding Lucknow city, the schools consist of one Anglo-vernacular middle class, five vernacular middle class, and seventy-one primary schools. The prevailing endemic diseases are fevers, skin diseases, and bowel complaints. Cholera is seldom absent. Small-pox is also an annual visitant. The average annual rainfall is 37·6 inches, and the mean annual temperature 78°·8 Fahr.

Lucknow, capital of the above district, and of the province of Oudh, in 26° 52′ N. lat., 80° 58′ E. long., is distant from Cawnpur 42 miles, from Benares 199 miles, and from Calcutta 610 miles, and has an area of 13 square miles. It ranks fourth in size among Indian cities, being only surpassed by the presidency capitals of Calcutta, Madras, and Bombay. It stands on both banks of the Gumti, mostly on the western side, the river being spanned by four bridges, two of them built by native rulers and two since the British annexation in 1856. Viewed from a distance, the city presents a picture of unusual magnificence and architectural splendour, which fades on nearer view into something more like the ordinary aspect of a crowded Oriental town. From the new bridge across the Gumti, the city seems to be embedded in trees. High up the river the ancient stone bridge of Asaf-ud-daulá crosses the stream. To its left rise the walls of the Machí Bháwan fort, enclosing the Lachman *tílá* (Lachman's hill), the earliest inhabited spot in the city, from which it derives its modern name. Close by, the immense Imámbára, or mausoleum of Asaf-ud-daulá, towers above the surrounding buildings. Farther in the distance, the lofty minarets of the Jamá Masjíd or "cathedral mosque" overlook the city; while nearer again, on the same side of the river, the ruined walls of the residency, with its memorial cross, recall the heroic defence made by the British garrison in 1857. In front, close to the water's edge, the Chattar Manzil palace, a huge and irregular pile of buildings, crowned by gilt umbrellas, glitters gaudily in the sunlight; while to the left, at some little distance, two mausoleums flank the entrance to the Kaisar Bágh, the last of the overgrown palaces built by the exiled dynasty of Oudh. Still more picturesque panoramas may be obtained from any of the numerous towers and cupolas which abound in every quarter. But a nearer examination shows that Lucknow does not correspond in its interior arrangements to its brilliant appearance from a little distance. Nevertheless, many of its streets are broader and finer than those of most Indian towns; and the clearance effected for military purposes after the mutiny has been instrumental in greatly improving both the aspect and the sanitary condition of the city. A glacis half a mile broad surrounds the fort; and three military roads, radiating from this point as a centre, cut right through the heart of the native quarter, often at an elevation of some 30 feet above the neighbouring streets. Three other main roads also branch out from the same point, one leading across the bridge, and the others along the banks of the Gumti. The residency crowns a picturesque eminence, the chief ornament of the city, containing, besides many ruined walls, an old mosque and a magnificent banyan tree. An artificial mound rises near at hand, its sides gay with parterres of flowers, while in the rear, half hidden by the feathery foliage of gigantic bamboos, the graveyard covers the remains of some 2000 Europeans, who perished in 1857. The cantonments lie 3 miles to the south-east of the city.

The population of Lucknow, including the cantonments, was returned by the census of 1869 at 284,779. The native civil population consisted of 273,126, viz., 161,739 Hindus and 111,387 Mohammedans. There were also 3648 native soldiers, 4222 Europeans, 760 Eurasians, and 3023 prisoners and jail officials. The traffic of Oudh flows southwards through Lucknow to Cawnpur. Large quantities of grain and timber come in from the trans-Gogra districts to the north, while raw cotton, iron, and imported goods from the south and east are sent in exchange. In 1869–70 goods to the value of nearly three quarters of a million sterling paid taxes at the octroi office. The chief municipal taxable articles are food stuffs, *ghí*, *gúr* or molasses, sugar, spices, oilseeds, and tobacco; besides a large quantity of European manufactured articles brought into the town. Of the total municipal revenue in 1870–71 (£20,018), £16,230 was derived from octroi. Lucknow muslins and other textile fabrics have a high reputation. Gold and silver brocade, however, forms the leading manufacture. It is used for the numerous purposes of Indian pomp, and has a considerable market even in Europe. The gorgeous needlework embroidery upon velvet and cotton, with gold thread, thread and coloured silks, furnishes employment to many hands. Lucknow jewellery, once very famous, has declined since the departure of the native court. Glass work and moulding in clay still maintain their original excellence. A Kashmiri colony has introduced a small manufacture of shawls. The Oudh and Rohilkhand Railway, with its branches, has a central station in Lucknow, and gives direct communication with Benares, Bareilly, and Cawnpur, as well as connecting with the great trunk lines to Calcutta, Bombay, and the Punjab. Before the amalgamation of Oudh with the North-Western Provinces in 1877, Lucknow formed the residence of the chief commissioner and his staff, and it still ranks as the headquarters of officials whose authority extends over the whole province. The principal medical institutions are the King's hospital, Balrampur hospital, Government dispensary and lunatic asylum. The leading educational establishments are the Canning college, Martinière college, Ward's institution, Loretto convent, and a number of schools under the charge of the Church of England and American missions.

History.—The most interesting event in the modern history of Lucknow is the siege during the mutiny of 1857–58. Symptoms of disaffection occurred as early as April 1857, and Sir Henry Lawrence immediately took steps to meet the danger by fortifying the residency and accumulating stores. On the night of the 30th May the expected insurrection broke out; the men of the 71st regiment of native infantry, with a few from the other regiments, began to burn the bungalows of their officers, and to murder the inmates, but were dispersed by the European force and fled towards Sítápur. Though the city thus remained in the hands of the British, the symptoms of disaffection amongst the remaining native troops were unmistakable, and on June 11 the military police and native cavalry broke into open revolt, followed on the succeeding morning by the native infantry. On the 20th news of the fall of Cawnpur arrived; and on the 29th occurred the failure of Lawrence's attack upon the advancing enemy, in consequence of which the British troops fell back on Lucknow, abandoned the Machi Bháwan, and concentrated all their strength upon the residency. The siege of the enclosure began upon July 1. Three unsuccessful assaults were made by the mutineers on July 20, August 10, and August 18; but meanwhile the British within were dwindling away. On September 5 news of the relieving force under Outram and Havelock reached the garrison, and on the 22d the relief arrived at the Alambágh, a walled garden on the Cawnpur road held by the enemy in force. Havelock stormed the Alambágh, and on the 25th fought his way with continuous opposition through the narrow lanes of the city. On the 26th he arrived at the gate of the residency enclosure, and was welcomed by the gallant defenders within. The sufferings of the besieged had been very great; but even after the first relief it became clear that Lucknow could only be temporarily defended till the arrival of further reinforcements should allow the garrison to cut its way out. Night and day the enemy kept up a continual firing against the British position, while Outram, who had reassumed the command which he yielded to Havelock during the relief, retaliated by frequent sorties. Throughout October the garrison continued its gallant defence, and a small party, shut up in the Alambágh, and cut off unexpectedly from the main body, also contrived to hold good its dangerous post. Meanwhile Sir Colin Campbell's force had advanced from Cawnpur, and arrived at the Alambágh on the 10th of November. The Alambágh, the Dílkusha palace, south-east of the town, the Martinière, and the Sikandra Bágh, the chief rebel stronghold, were successively carried in the course of the six following days, and the second relief was successfully accomplished. Even now, however, it remained impossible to hold Lucknow, and Sir Colin Campbell determined, before undertaking any further offensive operations, to return to Cawnpur with his army, escorting the civilians, ladies, and children rescued from their long imprisonment in the residency, with the view of forwarding them to Calcutta. On the morning of the 20th November the troops received orders to march for the Alambágh; and the residency, the scene of so long and stirring a defence, was abandoned for a while to the rebel army. Outram with 3500 men held the Alambágh until the commander-in-chief could return to recapture the capital. The rebels in great strength again surrounded the greater part of the city, for a circuit of 20 miles, with an external line of defence. On the 2d of March 1858 Sir Colin Campbell found himself free enough in the rear to march once more upon Lucknow. He first occupied the Dílkusha, and posted guns to command the Martinière. On the 5th Brigadier Franks arrived with 6000 men; Outram's force then crossed the Gumti, and advanced from the direction of Faizábád, while the main body attacked from the south-east. After a week's hard fighting, March 9–15, the rebels were completely defeated, and their posts captured one by one.

LUCRETIUS (T. Lucretius Carus), more than any of the great Roman writers, has acquired a new interest in the present day. This result is due, not so much to a truer perception of the force and purity of his style, of the majesty and pathos of his poetry, or of the great sincerity of his nature, as to the recognition of the relation of his subject to many of the questions on which speculative curiosity is now engaged. It would be misleading to speak of him, or of the Greek philosophers whose tenets he expounds, as anticipating the more advanced scientific hypotheses of modern times. But it is in his poem that we find the most complete account of the chief effort of the ancient mind to explain the beginning of things, and to understand the course of nature and man's relation to it. Physical philosophy in the present day is occupied with the same problems as those which are discussed in the first two books of the *De Rerum Natura*. The renewed curiosity as to the origin of life, the primitive condition of man, and his progressive advance to civilization finds an attraction in the treatment of the same subjects in the fifth book. The old war between science and theology, which has been revived in the present generation, is fought, though with different weapons, yet in the same ardent and uncompromising spirit throughout the whole poem, as it is in the writings of living thinkers. In comparing the controversies of the present day with those of which we find the record in Lucretius, we are reminded of the poet's own description of the war of elements in the world,—

> "Denique, tantopere inter se cum maxima mundi
> Pugnent membra, pio nequaquam concita bello,
> Nonne vides aliquam longi certaminis ollis
> Posse dari finem?" [1]

But this concurrence with the stream of speculation in the present day is really the least of his permanent claims on the attention of the world. His position both among ancient and modern writers is unique. No one else combines in the same degree the contemplative enthusiasm of a philosopher, the earnest purpose of a reformer and moral teacher, and the profound pathos and sense of beauty of a great poet. He stands alone among his countrymen as much in the ardour with which he observes and reasons on the processes of nature as in the elevation of feeling with which he recognizes the majesty of her laws, and the vivid sympathy with which he interprets the manifold variety of her life. It would have been an instructive study to have traced some connexion between his personal circumstances and the intellectual and moral position which he holds. We naturally ask what influence of teachers in Rome or Athens first attracted him to this study and observation of natural phenomena, what early impressions or experience gave so sombre a colouring to his view of life, how far the delight, so strange in an ancient Roman, which he seems to find in a kind of recluse communion with nature, and the spirit of pathetic or indignant satire in which he treats the more violent phases of passion and the more extravagant modes of luxury, was a recoil from the fascination of pleasures in which his contemporaries and equals freely indulged. We should like also to know how far the serene heights which he professed to have attained procured him exemption from or alleviation of the actual sorrows of life. But such questions, suggested by the strong interest which the impress of personal feeling and character stamped on the poem awakens in the reader, can only be raised; there are no ascertained facts by which they can be settled. There is no ancient poet, with the exception of Homer, of whose history so little is positively known. Unlike Catullus, Horace, Virgil, Cicero, Tacitus, and nearly all the great Roman writers, he is absolutely silent on the subject of his own position and fortunes. Nor is this silence compensated by any personal reference to him in the works of his two eminent contemporaries by whom the social life of their age is so amply illustrated, Cicero and Catullus, although it is certain that each of them read his poem almost immediately after it was given to the world. The great poets of the following ages were influenced by his genius, but they tell us nothing as to his career. So consistently does he seem to have followed the maxim of his master, "Pass through life unnoticed," and to have realized, in the midst of the excited political, intellectual, and social life of the last years of the republic, the ideal of those "who do not wish to be known even while living." [2]

Our sole information concerning his life is found in the brief summary of Jerome, written more than four centuries after the poet's death. Scholars are now agreed that in these summaries, added to his translation of the Eusebian

[1] "In fine, as the mightiest members of the world are battling fiercely together in an unhallowed feud, seest thou not that some end of the long warfare may be reached by them?"

[2] Quoted from Pliny by M. Martha in *Le Poëme de Lucrèce*.

Chronicle, Jerome followed, often carelessly and inaccurately, the accounts contained in the lost work of Suetonius *De Viris Illustribus.* But that work was written about two centuries after the death of Lucretius; and, although it is likely that Suetonius used the information transmitted by earlier grammarians, there is nothing to guide us to the original sources from which the tradition concerning the life of Lucretius was derived. The strange character of the story which has been transmitted to us, and the want of any support to it from external evidence, oblige us to receive it with a certain reserve.

According to this account the poet was born in the year 94 B.C.; he became mad ("in furorem versus") in consequence of the administration of a love-philtre; and after composing several books in his lucid intervals, which were subsequently corrected by Cicero, he died by his own hand in the forty-fourth year of his age. The statement of Donatus in his life of Virgil, a work also based on the lost work of Suetonius, that Lucretius died on the 15th of October 55 B.C., the same day on which Virgil assumed the *toga virilis*, is inconsistent either with the date assigned for the poet's birth or with the age at which he is said to have died. A single mention of the poem (which from the condition in which it has reached us may be assumed to have been published posthumously) in a letter of Cicero's, written early in 54 B.C., is confirmatory of the date given by Donatus as that of the poet's death. Similar errors in chronology are common in the summaries of Jerome; and, where there is an inconsistency between the date assigned for the birth of any author and the age at which he is said to have died (as, for instance, in the case of Catullus), there are grounds for believing that the error lies in the first date. Taking the statements of Donatus and of Jerome together, we may consider it probable that Lucretius died in the October of 55 B.C., in the forty-fourth year of his age, and that he was born either late in the year 99 B.C. or early in the year 98 B.C. He would thus be about seven years younger than Cicero, a year or two younger than Julius Cæsar, about the same age as Memmius, to whom the poem is dedicated, and about fifteen years older than Catullus and Calvus, the younger poets of his generation, from whom he is widely separated both by his more archaic style and rhythm and by the greater seriousness of his art and the more earnest dignity of his character. The other statements of Jerome have been questioned or disbelieved on the ground of their intrinsic improbability. They have been regarded as a fiction invented in a later time by the enemies of Epicureanism, with the view of discrediting the most powerful work ever produced by any disciple of that sect. It is more in conformity with ancient credulity than with modern science to attribute a permanent tendency to derangement to the accidental administration of any drug, however potent. A work characterized by such strength, consistency, and continuity of thought is not likely to have been composed "per intervalla insaniæ." Donatus, in mentioning the poet's death, gives no hint of the act of suicide. The poets of the Augustan age, who were deeply interested both in his philosophy and his poetry, are entirely silent about the tragical story of his life. Cicero, by his professed antagonism to the doctrines of Epicurus, by his inadequate appreciation of Lucretius himself, and by the indifference which he shows to other contemporary poets, seems to have been neither fitted for the task of correcting the unfinished work of a writer whose genius was so distinct from his own, nor likely to have cordially undertaken such a task.

Yet these considerations do not lead to the absolute rejection of the story as a pure invention of a hostile and uncritical age. The evidence afforded by the poem rather leads to the conclusion that the tradition contains some germ of fact. We need not attach any importance to the supposed efficacy of the love-philtre in producing mental alienation, nor are we called upon to think of Lucretius as one liable to recurring fits of insanity, in the ordinary sense of the word. But it is remarkable, as was first observed by Mr Munro, his English editor, that in more than one passage of his poem he writes with extraordinary vividness of the impression produced both by dreams and by waking visions. It is true that the philosophy of Epicurus put great stress on these, as affording the explanation of the origin of supernatural beliefs. But the insistence with which Lucretius returns to the subject, and the horror with which he recalls the effects of such abnormal phenomena, suggest the inference that he himself may have been liable to such hallucinations, which are said to be consistent with perfect sanity, though they may be the precursors either of madness or of a state of despair and melancholy which often ends in suicide.[1] Other passages in his poem, as, for instance, the lines

> "Nos agere hoc autem, et naturam quærere rerum,
> Semper et inventam patriis exponere chartis,"[2]

where he describes himself as ever engaged, even in his dreams, on his task of inquiry and composition, produce the impression of an unrelieved strain of mind and feeling, which may have ended in some extreme reaction of spirit, or in some failure of intellectual power, from the consciousness of which he may, in accordance with examples which he himself quotes, have taken refuge in suicide. But the strongest confirmation of the existence of some germ of fact in the tradition is found in the unfinished condition in which the poem has reached us. The subject appears indeed to have been fully treated in accordance with the plan sketched out in the introduction to the first book. But that book is the only one which is finished in style and in the arrangement of its matter. In all the others, and especially in the last three, the continuity of the argument is frequently broken by passages which must have been inserted after the first draft of the arguments was written out. Thus, for instance, in his account of the transition from savage to civilized life, he assumes at v. 1011 the discovery of the use of skins, fire, &c., and the first beginning of civil society, and proceeds at 1028 to explain the origin of language, and then again returns, from 1090 to 1160, to speculate upon the first use of fire and the earliest stages of political life. These breaks in the continuity of the argument show what might also be inferred from frequent repetitions of lines which have appeared earlier in the poem, and from the rough workmanship of passages in the later books, that the poem could not have received the final revision of the author, and must have been given to the world by some editor after his death. Nor is there any great difficulty in believing that that editor was Cicero. It is not necessary to press the meaning of the word "emendavit" as applied to the task fulfilled by him. Cicero certainly was incapable of "improving" any of the poetry of Lucretius, and the slight mention which he makes of the poem in a letter to his brother ("the poem of Lucretius is, as you describe it, a work not of much genius but of much art"[3]) seems to imply that he was not very capable of appreciating it. But other motives, besides appreciation of the poet's genius or sympathy with his doctrines, may have induced

[1] *Cf. Fortnightly Review*, September 1878.

[2] "While I seem to be ever busily plying this task, to be inquiring into the nature of things, and to be expounding my discoveries by writings in my native tongue."

[3] The reading is so uncertain that it is doubtful whether it is the claim of genius or of art that Cicero refuses to concede. Some interpretations of the passage imply that he conceded both.

him to undertake a task which has not been very successfully performed. It may be remarked further that scepticism as to statements about their lives is less warranted in the case of the great Roman than of the great Greek writers, from the fact that the work of criticism went on at Rome contemporaneously with the progress of original creation, and that the line of grammarians and commentators by whom these statements were transmitted continued unbroken almost from the first beginning of Latin literature.

We find in the instance of nearly all the other Latin poets, even of the most obscure among them, that their birthplace has been recorded, and it has often been remarked that Latin poetry was an Italian and provincial rather than a purely Roman product. From the absence of any claim on the part of any other district of Italy to the honour of having given birth to Lucretius it is inferred that he was an exception to the rule, and was of purely Roman origin. No writer certainly is more purely Roman in personal character and in strength of understanding. He seems to speak of Rome as his native state in such expressions as "patriai tempore iniquo," "patrii sermonis egestas," and "patriis chartis." His silence on the subject of Roman greatness and glory as contrasted with the prominence of these subjects in the poetry of men of provincial birth such as Ennius, Virgil, and Horace, may be explained by the principle that the familiarity of long-inherited traditions had made the subject one of less wonder and novelty to him. The Lucretian *gens* to which he belonged was one of the oldest of the great Roman houses, nor do we hear of the name, as we do of other great family names, as being diffused over other parts of Italy, or as designating men of obscure or servile origin. It seems from the evidence of the name, confirmed by the tone in which he writes, as probable as any such inference can be that Lucretius was a member of the Roman aristocracy, belonging either to a senatorian or to one of the great equestrian families, living in easy circumstances, and familiar with the spectacle of luxury and artistic enjoyment which the great houses of Rome and the great country houses in the most beautiful parts of Italy presented. If the Roman aristocracy of his time had lost much of the virtue and of the governing qualities of their ancestors, they showed in the last years before the establishment of monarchy a taste for intellectual culture which might have made Rome as great in literature as in arms and law, if the republic could have continued. The discussions which Cicero puts in the mouth of Velleius, Cotta, &c., indicate the new taste for philosophy developed among members of the governing class during the youth of Lucretius; and we hear of eminent Greek teachers of the Epicurean sect being settled at Rome at the same time, and living on terms of intimacy with them. The inference that Lucretius belonged to this class, and shared in the liberal culture which it received, is confirmed by the tone in which he addresses Memmius, a man of an eminent senatorian family, and of considerable oratorical and poetical accomplishment, to whom the poem is dedicated. His tone to Memmius is quite unlike that in which Virgil or even Horace addresses Mæcenas. He addresses him as an equal; he expresses sympathy with the prominent part his friend played in public life, and admiration for his varied accomplishment, but on his own subject claims to speak to him in the tones of authority.

Although our conception of the poet's life and circumstances is necessarily vague and meagre, yet his personal force is so remarkable and so vividly impressed on his poem, and his language bears so unmistakably the stamp of sincerity, that we seem able to form a consistent idea of his tastes and habits, his sympathies and convictions, his moral and emotional nature. If we know nothing of the particular experience which determined his passionate adherence to the Epicurean creed and his attitude of spiritual and social isolation from the ordinary course of Roman life and belief, we can at least say that the choice of a contemplative life was not the result of indifference to the fate of the world, or of any natural coldness or even calmness of temperament. In some of his most powerful poetry, as in the opening lines of the second and of the third books, we can mark the strong recoil of a humane and sensitive spirit from the horrors of the reign of terror which he witnessed in his youth, and from the anarchy and confusion which prevailed at Rome during the later years of his life; while his vivid realization of the pains and disappointments of passion, of the unsatisfying nature of all violent emotion, and of the restlessness and weariness of life which excessive luxury entails, suggest at least the inference that he had not been through his whole career so much estranged from the social life of his day as he seems to have been in his later years. Passages in his poem attest his familiarity with the pomp and luxury of city life, with the attractions of the public games, and with the pageantry of great military spectacles. But much the greater mass of the illustrations of his philosophy scattered through the poem indicate that, while engaged in its composition, and in the studies preparatory to it, he must have lived in the country or by the sea-shore, and that he must have passed much of his time in the open air, exercising at once the keen observation of a naturalist and the contemplative vision of a poet. He shows a fellow feeling with the habits and moods of the animals associated with human toil and adventure. He seems to have found a pleasure, more congenial to the modern than to the ancient temperament, in ascending mountains or wandering among their solitudes (vi. 469, iv. 575). References to companionship in these wanderings, and the well-known description of the charm of a rustic meal (ii. 29) enjoyed with comrades amid beautiful scenery and in fine weather, speak of kindly sociality rather than of any austere separation from his fellows.

Other expressions in his poem (*e.g.*, iii. 10, &c.) imply that he was an ardent student of books, as well as a sympathetic observer of outward phenomena. Foremost among these were the writings of his master Epicurus; but he had also an intimate knowledge and appreciation of the philosophical poem of Empedocles, and at least an acquaintance with the works of Democritus, Anaxagoras, Heraclitus, Plato, and the Stoical writers. Of other Greek prose writers he knew Thucydides and Hippocrates; while of the poets he expresses in more than one passage the highest admiration of Homer, whom he has imitated in several places. Next to Homer Euripides is most frequently reproduced by him. There is an evident struggle between the impulses of his imaginative temperament, prompting him to recognize the supremacy of the great masters in art and poetry, and the influence of the teaching of Epicurus, in accordance with which the old poets and painters of Greece are condemned as the authors and propagators of false ideas both of nature and the gods. But his poetical sympathy was not limited to the poets of Greece. For his own countryman Ennius he expresses an affectionate admiration; and he imitates his language, his rhythm, and his manner in many places. The fragments of the old tragedian Pacuvius and of the satirist Lucilius show that Lucretius had made use of their expressions and materials. In his studies he was attracted by the older writers, both Greek and Roman, in whose masculine temperament and understanding he recognized an affinity with his own. He had a most enthusiastic admiration for genius, especially when exercised in the investigation and discovery of truth. His devotion to Epicurus seems at first sight more difficult to explain than his enthusiasm for Empedocles or Ennius. Probably he found in his calmness of temperament, in his natural or acquired indifference to all violent emotion, even in his want of imagination, a sense of rest and of exemption from the disturbing influences of life which the passionate heart of the poet denied himself; while in his physical philosophy he found both an answer to the questions which perplexed him and an inexhaustible stimulus to his intellectual curiosity. The combative energy, the sense of superiority, the spirit of satire, characteristic of him as a Roman, unite with his loyalty to Epicurus to render him not only polemical but intolerant and contemptuous in his tone toward the great antagonists of his system, the Stoics, whom, while constantly referring to them, he does not condescend even to name. With his admiration of the genius of others he combines a strong sense of his own power. He is quite conscious of the great importance and of the difficulty of his task; but he feels his own ability to cope with it. He has the keenest capacity for intellectual pleasure, and speaks of the constant charm which he found both in the collection of his materials and in the exercise of his art. If his mind was overstrained by the incessant devotion to his task of which he speaks, he allows no expression of fatigue or discouragement to escape from him. The ardour of study, the delight in contemplative thought, the "sweet love of the muses," the "great hope of fame," all combined to bear him buoyantly through all the difficulties and fatigues of his long and lonely adventure.

It is more difficult to infer the moral than the intellectual characteristics of a great writer from the personal impress left by him on his work. Yet it is not too much to say that there is no work in any literature that produces a profounder impression of sincerity. No writer shows a juster scorn of all mere rhetoric and exaggeration. This is one of the main causes of the spell which the poem exercises over us. By no Stoic even could the doctrine of independence of the world, and of the superiority of simplicity over show and luxury, be more forcibly and consistently inculcated. No one shows truer courage, not marred by irreverence, in confronting the great problems of human destiny, or greater strength in triumphing over human weakness. No one shows a truer humanity and a more tender sympathy with natural sorrow. In reverence for the sanctities of human affection, Virgil alone is his equal, nor is it an unlikely surmise that it was to the power of this sentiment, and the influence which it had on his relation with others, that he owed the *cognomen* of "Carus"[1] or the "beloved."

The peculiarity of the poem of Lucretius, that which makes it unique in literature, is that it is a reasoned system of philosophy, written in verse. The subject was chosen and the method of exposition adopted, not primarily with the idea of moving and satisfying the imagination, but of communicating truth. The prosaic title *De Rerum Natura*, a translation of the Greek περὶ φύσεως, implies the subordination of the artistic to a speculative motive. As in the case of nearly all the great works of Roman literary genius, the form of the poem was borrowed from the Greeks. The rise of speculative philosophy in Greece was coincident with the beginning of prose composition, and many of the earliest philosophers gave their thoughts to the world in the prose of the Ionic dialect; others however, and especially the writers of the Greek colonies in Italy and Sicily, expounded their systems in continuous poems composed in the epic hexameter. These writers flourished in the beginning and first half of the 5th century B.C.,—the great awakening time of the intellectual, imaginative, and artistic faculties of the ancient world. The names most famous in connexion with this kind of poetry are those of Xenophanes and Parmenides, the Eleatics, and that of Empedocles of Agrigentum. The last was less important as a philosopher, but greater than the others both as a poet and a physicist. On both of these grounds he had a greater attraction to Lucretius. The fragments of the poem of Empedocles show that the Roman poet regarded that work as his model. In accordance with this model he has given to his own poem the form of a personal address, he has developed his argument systematically, and has applied the sustained impetus of epic poetry to the treatment of some of the driest and abstrusest topics. Many ideas and expressions of the Sicilian have been reproduced by the Roman poet; and the same tone of impassioned solemnity and melancholy seems to have pervaded both works. But Lucretius, if less original as a thinker, was probably a much greater poet than Empedocles. With the speculative enthusiasm of the Greeks he combines, in a remarkable measure, the Italian susceptibility to the charm of nature, and the greater humanity of feeling which belongs to a more advanced stage of human history. But what chiefly distinguishes him from his Greek prototypes is that his purpose is rather ethical than purely speculative. He shares with them the delight in inquiry and discovery; but the zeal of a teacher and reformer is more strong in him than even the intellectual passion of a thinker. His speculative ideas, his moral teaching, and his poetical power are indeed interdependent on one another, and this interdependence is what mainly constitutes their power and interest. But of the three claims which he makes to immortality,—

> "Primum quod magnis doceo de rebus, et artis
> Religionum animum nodis exsolvere pergo,
> Deinde quod obscura de re tam lucida pango
> Carmina musæo contingens cuncta lepore,—"[2]

that which he himself regarded as supreme was the second,—the claim of a liberator of the human spirit from the cramping bonds of superstition.

This purpose is announced by him over and over again, as for instance at the beginning of the argument in the first, second, third, and sixth books. The main idea of the poem is the irreconcilable opposition between the truth of the laws of nature and the falsehood of the old superstitions. But it is not merely by the intellectual opposition between truth and falsehood that he is moved. The happiness and the dignity of life are regarded by him as absolutely dependent on the acceptance of the true and the rejection of the false doctrine. The ground of his extravagant eulogies of Epicurus is that he recognized in him the first great champion in the war of liberation, and in his system of philosophy he believed that he had found the weapons by which this war could be most effectually waged. Following in his footsteps, he sets before himself the aim of finally crushing that fear of the gods and that fear of death resulting from it which he regards as the source of all the human ills. Incidentally he desires also to purify the heart from other violent passions which corrupt it and mar its peace. But the source even of these—the passions of ambition and avarice—he finds in the fear of death; and that fear he resolves into the fear of eternal punishment after death.

The selection of his subject and the order in which it is treated are determined by this motive. Although the title

[1] *Cf.* Martha, *Le Poëme de Lucrèce*, p. 28

[2] "First, by reason of the greatness of my argument, and my purpose to set free the mind from the close drawn bonds of superstitions; next, because on so dark a theme I write such lucid verse, casting over all the charm of poesy."

of the poem implies that it is a treatise on the "whole nature of things," the aim of Lucretius is not to treat exhaustively the whole of natural science, recognized in the Epicurean system, but only those branches of it which are necessary to clear the mind from the fear of the gods and the terrors of a future state. In the two earliest books, accordingly, he lays down and largely illustrates the first principles of being with the view of showing that the world is not governed by capricious agency, but has come into existence, continues in existence, and will ultimately pass away in accordance with the primary conditions of the elemental atoms which, along with empty space, are the only eternal and immutable substances. These atoms are themselves infinite in number but limited in their varieties, and by their ceaseless movement and combinations during infinite time and through infinite space the whole process of creation is maintained. In the third book he applies the principles of the atomic philosophy to explain the nature of the mind and vital principle, with the view of showing that the soul perishes with the body. In the fourth book he discusses the Epicurean doctrine of the "simulacra," or images, which are cast from all bodies, and which act either on the senses or immediately on the mind, in dreams or waking visions, as affording the explanation of the belief in the continued existence of the spirits of the departed. The fifth book, which has the most general interest, professes to explain the process by which the earth, the sea, the sky, the sun, moon, and stars, were formed, the origin of life, and the gradual advance of man from the most savage to the most civilized condition. All these topics are treated with the view of showing that the world is not itself divine nor directed by divine agency. The sixth book is devoted to the explanation, in accordance with natural causes, of some of the more abnormal phenomena, such as thunderstorms, volcanoes, earthquakes, &c., which are special causes of supernatural terrors.

It would be impossible, within the limits of this article, to give any detailed account or criticism of an argument which is carried on, with the interruption only of occasional episodes, in which the moral teaching of the poet is enforced, through a poem extending to between six and seven thousand lines. Readers who are especially interested in the science of Lucretius will find the subject clearly treated in chapter v. of Lange's *History of Materialism.* The consecutive study of the argument produces on most readers a mixed feeling of dissatisfaction and admiration. They are repelled by the dryness of much of the matter, the unsuitableness of many of the topics discussed for poetic treatment, the arbitrary assumption of premisses, the entire failure to establish the connexion between the concrete phenomena which the author professes to explain and these assumptions, and the erroneousness of many of the doctrines which are stated with dogmatic confidence. On the other hand they are constantly impressed by his power of reasoning both deductively and inductively, by the subtlety and fertility of invention with which he applies analogies, by the clearness and keenness of his observation, by the fulness of matter with which his mind is stored, and by the consecutive force, the precision, and distinctness of his style, when employed in the processes of scientific exposition. The first two books enable us better than anything else in ancient literature to appreciate the boldness and, on the whole, the reasonableness of the ancient mind in forming hypotheses on great matters that still baffle the investigations of science. The third and fourth books give evidence of acuteness in psychological analysis; the fourth and sixth of the most active and varied observation of natural phenomena; the fifth of original insight and strong common sense in conceiving the origin of society and the progressive advance of man to civilization. But the chief value of Lucretius as a thinker lies in his firm grasp of speculative ideas, and in his application of them to the interpretation of human life and nature. It is in this application that the most powerful interest of his poetry lies. All phenomena, moral as well as material, are contemplated by him in their relation to one great organic whole, which he acknowledges under the name of "Natura dædala rerum," and the most beneficent manifestations of which he seems to symbolize and almost to deify in the "Alma Venus," whom, in apparent contradiction to his denial of a divine interference with human affairs, he invokes with prayer in the opening lines of the poem. In this conception of nature are united the conceptions of law and order, of ever-changing life and interdependence, of immensity, individuality, and all-pervading subtlety, under which the universe is apprehended both by his intelligence and his imagination.

Nothing can be more unlike the religious and moral attitude of Lucretius than the old popular conception of him as an atheist and a preacher of the doctrine of pleasure. It is true that he denies the two bases of all religion, the doctrines of a supernatural government of the world and of a future life. But his arguments against the first are really only valid against the limited and unworthy conceptions of divine agency involved in the ancient religions; his denial of the second is prompted by his vivid realization of all that is meant by the arbitrary infliction of eternal torment after death. His war with the popular beliefs of his time is waged, not in the interests of licence, but in vindication of the sanctity of human feeling. The great and cardinal line of the poem,

"Tantum religio potuit suadere malorum,"

is elicited from him as his protest against the wicked and impious sacrifice of Iphigenia by the hand of her father. But in his very denial of a cruel, limited, and capricious agency of the gods, and in his imaginative recognition of an orderly, all-pervading, all-regulating power,—the "Natura dædala rerum,"—we find at least a nearer approach to the higher conceptions of modern theism than in any of the other imaginative conceptions of ancient poetry and art, unless we include the hymn of Cleanthes among the utterances of poets. But his conception even of the ancient gods and of their indirect influence on human life is more worthy than the popular one. They are conceived of by him as living a life of eternal peace and exemption from passion, in a world of their own; and the highest ideal of man is, through the exercise of his reason, to realize an image of this life,

"Ut nil impediat dignam dis degere vitam."

Although they are conceived of as unconcerned with the interests of our world, yet influences are supposed to emanate from them which the human heart is capable of receiving and assimilating. The effect of unworthy conceptions of the divine nature is that they render a man incapable of visiting the temples of the gods in a calm spirit, or of receiving the emanations "divinæ nuntia pacis" in peaceful tranquillity.

"Nec delubra deum placido cum pectore adibis,
Nec de corpore quæ sancto simulacra feruntur
In mentis hominum divinæ nuntia pacis
Suscipere hæc animi tranquilla pace valebis." [1]

It is in no iconoclastic spirit that he regards even the temples and solemn rites of the gods, except when he finds the acts of worship tainted with "the foul stain of super-

[1] "Nor wilt thou approach the temples of the gods with a calm spirit, nor wilt thou be able, in tranquil peace of heart, to receive those images which are borne from their holy bodies into the minds of men, carrying tidings of the divine peace" (vi. 75–78).

stition." Thus he describes with a grave solemnity of feeling the procession of the image of Cybele through the cities of men, and acknowledges the beneficent influence of the truths symbolized by that procession. The supposed "atheism" of Lucretius proceeds from a more deeply reverential spirit than that of the majority of professed believers in all times.

His moral attitude is also far removed from that either of ordinary ancient Epicureanism or ordinary modern materialism. Though he acknowledges pleasure to be the law of life,—"dux vitæ dia voluptas,"—yet he is far from regarding its attainment as the end of life. What man needs is not enjoyment, but "peace and a pure heart."

"At bene non poterat sine puro pectore vivi."

The victory to be won by man is the triumph over fear, ambition, passion, luxury. With the conquest over these nature herself supplies all that is needed for happiness. Self-control and renunciation are the lessons which he preaches with as much fervour and as real conviction as any of the preachers of Stoicism. "Great riches consist in living plainly with a contented spirit"—

"Divitiæ grandes homini sunt vivere parce
Æquo animo."

As was mentioned above, it is uncertain whether the short criticism of Cicero ("Lucretii poemata," &c.) concedes to Lucretius the gifts of genius or the accomplishment of art. Readers of a later time, who could compare his work with the finished works of the Augustan age, would, if they refused his claim to the full possession of the two necessary constituents of the greatest poets, have certainly disparaged his art rather than his power. But with Cicero it was different. He greatly admired, or professed to admire, the genius of the early Roman poets, while he shows that indifference to the poetical genius of his younger contemporaries which men who have formed their taste for poetry in youth, and whose own intellectual interests have been practical and political, often do to the new ideas and new modes of feeling which an original poet brings into the world. On the other hand, as one who had himself written many verses in his youth, and as one of the greatest masters of style who have ever lived, he could not have been insensible to the immense superiority in rhythmical smoothness which the hexameter of Lucretius has over that of Ennius and Lucilius. And no reader of Lucretius can doubt that he attached the greatest importance to artistic execution, and that he took a great pleasure, not only in propelling "the long roll of his hexameter" to its culminating break at the conclusion of some weighty paragraph, but also in producing the effects of alliteration, assonance, &c., which are so marked a peculiarity in the style of Plautus and the earlier Roman poets. He allows his taste for these tricks of style, which, when used with moderation by writers of a more finished sense of art such as Virgil and even Terence, have the happiest effect, to degenerate into mannerism. And this is the only drawback to the impression of absolute spontaneity which his style produces. But those who recognize in him one of the most powerful and original poetical forces which have appeared in the world feel, when they compare him with the greatest poets of all times, that he was unfortunate in living before the natural rudeness of Latin art—the "traces of the country," which continued to linger "in rude Latium" down to the time of Horace—had been successfully grappled with. His only important precursors in serious poetry were Ennius and Lucilius, and, though he derived from the first of these an impulse to shape the Latin tongue into a fitting vehicle for the expression of elevated emotion and imaginative conception, he could find in neither a guide to follow in the task he set before himself. He had thus, in a great measure, to discover the way for himself, and to act as the pioneer to those who came after him. The difficulty and novelty of his task enhances our sense of his power. His finest passages are thus characterized by a freshness of feeling and enthusiasm of discovery, as of one ascending, alone and for the first time, the "pathless heights of the Muses."[1] But the result of these conditions and of his own inadequate conception of the proper limits of his art is that more than in the case of any other work of genius his best poetry is clogged with a great mass of alien matter, which no treatment in the world could have made poetically endurable. If the distinction suggested by a brilliant living poet and critic between the Titans and the Olympians of literature be a valid one, it is among the former certainly that Lucretius is to be classed.

The genius of Lucretius, as of all the greatest poets, does not reveal itself as any mere isolated or exceptional faculty, but as the impassioned and imaginative movement of his whole moral and intellectual being. It is the force through which the sincerity and simplicity, the reverence, the courage, the whole heart of the man have found an outlet for themselves. It is also the force from which both his speculative and his observant faculty derive their most potent impulse. His poetical style is as simple, sensuous, and passionate as that of the poets who reproduce only the immediate appearances and impressions of the world of nature and of human feeling. But it assumes a more majestic and elevated tone from the recognition of the truth that the beauty of the world, the unceasing life and movement in nature, the destructive as well as the beneficent forces of the elements, the whole wonder and pathos of human existence, are themselves manifestations of secret invisible agencies and of eternal and immutable laws.

The fullest account of the MSS. and of the various editions of Lucretius, and of the influence which he exercised on the later poets of Rome, is to be found in the introductions to the critical and explanatory notes of Mr Munro's edition of the poet, a work recognized as the most important contribution to Latin scholarship made in England during the present century. For scholars that edition contains all that is needed for the full understanding of the author. For those who are not classical scholars, the work of C. Martha, *Le Poëme de Lucrèce*, may be recommended, as containing an interesting and eloquent estimate of the genius of the poet, and of his moral, religious, and scientific position. Among recent English works on the author, an essay, by Professor Veitch, and one by Mr J. A. Symonds, are especially good. The subject is also discussed at length in chaps. xi.-xiv. of the *Roman Poets of the Republic*, by Professor Sellar. (W. Y. S.)

LUCULLUS. The Luculli appear in Roman history shortly after the close of the second Punic war. They belonged to the Licinian "gens," a plebeian house which became noted for its special ability in amassing wealth. By far the most famous of its members was Lucius Licinius Lucullus, surnamed Ponticus from his victorious campaigns in Asia Minor against one of the most formidable enemies Rome ever encountered, the great Mithridates, king of Pontus. His father had held an important military command in Sicily, but on his return to Rome he was considered to have acquitted himself so discreditably that he was prosecuted on a charge of bribery and corrupt practices, and was condemned to exile. His mother was Cæcilia, of the family of the Metelli, and was the sister of the distinguished Metellus Numidicus. The career of Lucullus coincides with the first half of the 1st century B.C. It appears that he was rather senior to Pompey, who was born in 106 B.C. We hear of him when quite a young man as making a determined though unsuccessful attempt to avenge his father's downfall on the author of the prosecution, and this won him credit and popularity. Early in life he attached himself to the party of Sulla, and to that party

[1] "Avia Pieridum peragro loca, nullius ante
Trita solo."

he remained constant to his life's end. Sulla's favourable notice was secured by good military service in the so-called Social War, which finally completed the subjugation of Rome's Italian allies and in fact of the whole peninsula. In 88 B.C. came the great Mithridatic war in the East, with the direction of which Sulla was charged. In that year the young Lucullus went with him as his quæstor to Greece and Asia Minor, and, while Sulla was besieging Athens, he raised a fleet and drove Mithridates out of the Mediterranean. He won a brilliant victory off Tenedos, and it seems probable that, had he been as faithful to Rome as he was to Sulla and his party, he might have ended a perilous war. But, like many of his contemporaries, Lucullus was too much of a party man to be a genuine patriot.

In 84 B.C. peace was concluded with Mithridates, and the great king had to cede the Greek islands and a large part of his Asiatic possessions, and was practically reduced to the position of a mere Roman dependant. Sulla returned to Rome, while Lucullus remained in Asia, and by a series of wise and generous financial reforms laid the foundation of the future wealth and prosperity of the province. The result of his policy was that he stood particularly well with the provincials, but unfortunately for himself made a host of enemies among the powerful class which farmed the public revenue. He was in Asia till 80 B.C., and then returned to Rome as curule ædile, in which capacity he exhibited together with his colleague, his brother Marcus, games which were long remembered by the citizens of Rome for their exceptional magnificence. We may infer that thus early in life he had found the means of acquiring an immense fortune, which throughout his whole career it was his delight lavishly to display. Soon afterwards he was elected prætor, and was next appointed to the province of Africa, where again he won a good name as a just and considerate governor. In the year 74 B.C. he became consul, with Aurelius Cotta as his colleague. An attempt was made at this time by a leader of the democratic party to repeal the legislation of Sulla, and its failure appears to have been mainly due to the strenuous efforts of Lucullus.

The East was now again unsettled, and Bithynia, which had been bequeathed to Rome by its king Nicomedes, was threatened by Mithridates. The new province with the command of the fleet fell to Cotta, but Lucullus was called to lead the armies of Rome against this dangerous enemy. In 74 B.C. he was in Asia at the head of a force of about 30,000 foot and 2000 horse. The king of Pontus was already on Roman ground in Bithynia, and Cotta was shut up in Chalcedon on the Propontis by a vast host of 150,000 men. The enemy's fleet had forced its way into the harbour, and had burnt all the Roman vessels lying at anchor. The advance of Lucullus, however, forced the king to raise the siege and retire along the sea-coast, till he halted before the strong city of Cyzicus, the key of Asia, as it was called, built on an island at a little distance from the mainland, with which it was connected by a bridge. All the attempts of Mithridates on the place were foiled by a gallant defence, and it was not long before Lucullus took up a threatening position in the rear of his army, which cut off all his land communications and left him only master of the sea. Bad weather and violent storms and scant supplies soon drove the king from the walls of Cyzicus, and his vast army was dispersed without having had the chance of fighting a single pitched battle. His fleet too, which as yet had had the command of the Ægean, was soon afterwards destroyed by Lucullus, and thus his whole power for offensive warfare had completely collapsed. He himself withdrew into his own proper territory, and all that the Roman general had to fear was that he might baffle pursuit by a flight eastward into the remote wilds of Armenia. However, in the autumn of 73 B.C., Lucullus pushed into the heart of Pontus far beyond the Halys, the limit of the famous Scipio's advance eastward, and continued his onward march, regardless of the murmurs of his weary soldiery, to Cabeira or Neocæsarea (now Niksar), where the king had gone into winter quarters with a vague hope that his son-in-law, Tigranes, the powerful king of Armenia, and possibly even the Parthians, might, for their own sakes, come to his aid against a common foe. It was by a very toilsome march through difficult roads that the Roman army at last reached Cabeira, to find themselves confronted by a greatly superior force. But the troops of Mithridates were no more a match for the Roman legionaries than were the Persians for Alexander, and a large detachment of his army was decisively cut up by one of Lucullus's lieutenant-generals. The king decided on instant retreat, but the retreat soon became a disorderly flight, and Lucullus, seizing the moment for attack, annihilated his enemy, Mithridates himself escaping with difficulty over the mountain range between Pontus and Cappadocia into Lesser Armenia. He found a sort of refuge in the dominions of Tigranes, but he was in fact detained as a prisoner rather than received as an honoured friend and ally.

Pontus thus, with the exception of some of the maritime cities, such as Sinope, Heraclea, and Amisus, which still clung to the king under whom they had enjoyed a free Greek constitution, became Roman territory. Two years were occupied in the siege and capture of these strongholds, while Lucullus busied himself with a general reform of the administration of the province of Asia. His next step was to demand the surrender of Mithridates and to threaten Tigranes with war in the event of refusal. He had indeed no direct authority from the home government to attempt the conquest of Armenia, but he may well have supposed that in invading the country he would be following out Sulla's policy, and securing Rome in the East from a serious danger. Nor was it unnatural that there should be a fascination in the idea of winning renown in the distant and almost unknown regions beyond the Euphrates. In the spring of the year 69 B.C., at the head of only two legions, which, it appears, by no means liked the hardships of the expedition, he marched through Sophene, the south-western portion of Armenia, crossed the Tigris, and pushed on to the newly-built royal city, Tigranocerta, situated on one of the affluents of that river. A motley host, made up out of the tribes bordering on the Black Sea and the Caspian, hovered round his small army, but failed to hinder him from laying siege to the town. On this occasion Lucullus showed consummate military capacity, contriving to maintain the siege and at the same time to give battle to the enemy with a force which must have been inferior in the ratio of something like one to twenty. According to his own account he put the Armenians to rout with a loss of five Roman soldiers, leaving 100,000 dead on the field of battle. The victory before the walls of Tigranocerta was undoubtedly a very glorious one for the arms of Rome, and it resulted in the dissolution of the Armenian king's extensive empire. There might now have been peace but for the interference of Mithridates, who for his own sake pressed Tigranes to renew the war and to seek the aid and alliance of Parthia. The Parthian king, however, was disposed to prefer a treaty with Rome to a treaty with Armenia, and desired simply to have the Euphrates recognized as his western boundary. Mithridates next appealed to the national spirit of the peoples of the East generally, and endeavoured to rouse them to a united effort against Roman aggression. He hoped to crush his enemy amid the mountains of Armenia, and indeed the position of Lucullus was highly critical. The home government was for recalling him, and seemed to think little of his splendid successes; and his little army, which one might have been supposed would have been proud of their general, was on the verge of mutiny. One can hardly understand how under such circumstances Lucullus should have persisted in marching his men northwards from Tigranocerta over the high table-land of central Armenia, with the enemy's cavalry and innumerable mounted archers hanging on his columns, in the hope of reaching the distant Artaxata on the Araxes. The vexation of his troops broke out into an open mutiny, which compelled him to recross the Tigris into the Mesopotamian valley. Here, on a dark tempestuous night, he surprised and stormed Nisibis, the capital of the Armenian district of Mesopotamia, and in this city, which yielded him a rich booty, he found satisfactory winter quarters.

Meantime Mithridates was again in Pontus, and the Roman forces which had been left there were soon overwhelmed. In one disastrous engagement at Ziela the Roman camp was taken and the army slaughtered to a man. Lucullus was still thwarted by the mutinous spirit of his troops, and after all his brilliant achievements he was obliged to pursue his retreat into Asia Minor with the full knowledge that Tigranes and Mithridates were the unresisted masters of Pontus and Cappadocia. The work of eight years of war was undone. Commissioners sent from Rome to settle the affairs of the East had to report to the senate that a large part of Asia Minor was in the enemy's hands. In the year 66 B.C. Lucullus was recalled, and superseded in his command by Pompey.

He had indeed fairly earned by his brilliant victories the honour of a triumph, but he had powerful enemies at Rome, and charges of maladministration, to which no doubt his immense wealth gave no unreasonable colour, caused it to be deferred for three years. In 63 B.C., however, it was celebrated with extraordinary magnificence. By this time Lucullus seems to have felt that he had done his work. He had little taste for the increasingly turbulent political contests of the time, and, with the exception of occasional appearances in public life, he gave himself up to elegant luxury, with which, however, he combined a sort of dilettante pursuit of philosophy, literature, and art. Cicero, who was on terms of close intimacy with him, always speaks of him with enthusiasm and in terms of the highest praise. Lucullus is with him a *vir fortissimus et clarissimus*, and a man too of the highest and most refined intellectual culture. As a provincial governor, in his humane consideration for the conquered and his statesmanlike discernment of what was best suited to their circumstances, he was a man after Cicero's own heart. In this respect he reminds us of the younger Pliny. Very possibly Cicero may have spoken too flatteringly of him, but we cannot think his praise was altogether undeserved.

As a soldier, considering what he achieved and the victories he won with but small forces under peculiarly unfavourable conditions, he must have been a man of no ordinary capacity. It is true that he does not seem to have had the confidence of his troops to the extent to which a great general ought to possess it, and it is just possible that he may have erred on the side of an excessive aristocratic hauteur, which to his men may have looked like a selfish indifference to their hardships. But it is also possible that out of a strict regard to the lives and property of the provincials he may have been too strict a disciplinarian for the taste of the soldiers. Some of his unpopularity, it is pretty certain, was due to the restraints which he had put on the rapacity of the capitalists, who thought themselves aggrieved if they could not make rapid and enormous fortunes by farming the revenue of the rich provinces of the East. We can hardly doubt that with very decided aristocratic feeling and thorough devotion to his political party Lucullus combined much generous uprightness and kindliness of heart.

His name calls up before the mind visions of boundless luxury and magnificence, and among the Roman nobles who revelled in the newly acquired riches of the East Lucullus, it is certain, stood pre-eminent. His park and pleasure grounds in the immediate vicinity of the capital were the wonder and admiration of his own and of the succeeding age. Pompey is said to have styled him the Roman Xerxes, in allusion, not only to his splendour, but also to the costly and laborious works to be seen in his parks and villas at Tusculum, near Naples, where rocks and hills had been pierced at an almost infinite expense. On one of his luxurious entertainments he is said to have spent upwards of £2000. Far the most pleasing trait in his character is the liberal patronage which he gave more especially to Greek philosophers and men of letters, and the fact that he collected a vast and valuable library, to which such men had free access. On the whole we may take Lucullus to have been a man who in many respects rose above his age, and was a decidedly favourable specimen of a great Roman noble.

Of his latter years but little is recorded. He had, as we have seen, almost wholly retired from public life. It appears that he sank into a condition of mental feebleness and imbecility some years before his death, and was obliged to surrender the management of his affairs to his brother Marcus. The usual funeral panegyric was pronounced on him in the Forum, and the people would have had him buried by the side of the great Sulla in the Campus Martius, but he was laid at his brother's special request in his splendid villa at Tusculum.

The best account of Lucullus's campaign in the East is to be found in Mommsen's *History of Rome*, bk. v. chap. 2. Our knowledge of him is drawn mainly from Plutarch, Appian's *Mithridatic War*, the epitomes of the lost books of Livy, and very frequent allusions to him in Cicero's works. (W. J. B.)

LUDDITES, The, were organized bands of rioters for the destruction of machinery, who made their first appearance in Nottingham and the neighbouring midland districts of England about the end of 1811. The origin of the name is curious, and is given as follows in the *Life of Lord Sidmouth* (vol. iii. p. 80). In 1779 there lived in a village in Leicestershire a person of weak intellect, called Ned Lud, who was the butt of the boys of the village. On one occasion Lud pursued one of his tormentors into a house where were two of the frames used in the stocking manufacture, and, not being able to catch the boy, vented his anger on the frames. Afterwards, whenever any frames were broken, it became a common saying that Lud had done it. It is curious also that the leader of the riotous bands took the name of General Lud. The Luddite riots arose out of the severe distress caused by commercial depression and the consequent want of employment. They were specially directed against machinery because of the widespread prejudice that its use directly operated in producing a scarcity of labour. Apart from the prejudice, it was inevitable that the economic and social revolution implied in the change from manual work to work by machinery should give rise to great misery by upsetting all the old industrial habits and arrangements. The riots began at Nottingham, in November 1811, with the destruction of stocking and lace frames, and, continuing through the winter and following spring, spread into Yorkshire and Lancashire. They were met by severe repressive legislation,—a notable feature in the opposition to it being Lord Byron's speech in the House of Lords, the first which he delivered there. In 1816 the rioting was resumed, through the fearful depression that followed on the European peace, aggravated by one of the worst of recorded harvests, when wheat rose from 52s. 6d. to 103s. a quarter (in Yorkshire it was more than a guinea a bushel), when the corn was still green in October, and the potato crop was a failure. In that year, though the centre of the rioting was again in Nottingham, it extended over almost the whole kingdom, and took more decidedly the form of a general discontent and seditious restlessness. The rioters were also thoroughly organized. While part of the band with extraordinary quickness and thoroughness destroyed the machinery in the houses, sentinels were posted to give warning of the approach of the military and police; and all had generally disappeared before the least risk of discovery. Under the influence of vigorous repressive measures, and especially of reviving prosperity, the spirit of rioting ere long died out.

See the *Annual Register* for the years concerned; *Life of Lord Sidmouth*, by the Hon. George Pellew, dean of Norwich, vol. iii.; and Spencer Walpole, *History of England*, vol. i.

LUDHIÁNA, a district in the lieutenant-governorship of the Punjab, India, lying between 30° 33′ and 31° 1′ N. lat. and between 75° 24′ 30″ and 76° 27′ E. long., is bounded on the N. by the Sutlej river, on the E. by Umballa (Ambála) district, on the S. by Patiála, Nábha, and Maler Kotla states, and on the W. by Firozpur district. The surface of Ludhiána consists for the most part of a broad plain, without hills or rivers, and stretching northward from the native borders to the ancient bed of the Sutlej. The soil is composed of a rich clay, broken by large patches of shifting sand. On the eastern edge, towards Umballa, the soil improves greatly, the clay being here surmounted by a bed of rich mould, suitable for the cultivation of cotton and sugar-cane. Towards the west the sand occurs in union with the superficial clay, and forms a light friable soil, on which cereals form the most profitable crop. Even here, however, the earth is so retentive of moisture that good harvests are reaped from fields which appear to the eye mere stretches of dry and sandy waste, but are covered, after the autumn rains, by waving sheets of wheat and millet. These southern uplands descend to the valley of the Sutlej by an abrupt terrace, which marks the former bed of the river. The principal stream has now shifted to the opposite side of the valley, leaving a broad alluvial strip, 10 miles in width, between its ancient and its modern bed. The Sutlej itself is here only navigable for boats of small burden. A branch of the Sirhind Canal, now in course of construction, will irrigate a large part of the western *parganás*. At present irrigation is almost entirely confined to wells. The district is singularly bare of trees.

The census of 1868 returned a total population of 583,245 persons (319,342 males and 263,903 females), spread over an area of 1359 square miles, inhabiting 879 villages and towns, and 151,934 houses. Hindus numbered 219,371; Mohammedans, 206,603; Síkhs, 95,463; and "others," 61,858. In ethnical classification the Játs rank first, both in number (205,304) and in agricultural importance; they form one-third of the total population, and nearly two-thirds of the cultivating class. The Gújars come next with 30,009 persons. Rájputs number 23,961, and cluster thickly in the fertile strip along the bank of the Sutlej. Though they hold the richest portion of the district, they are but careless and improvident cultivators. Bráhmans number 21,165, but their social importance is small, and they own but a single village. The mercantile classes are represented by 15,251 Kshattriyas and 8174 Banias. There are also 5549 Kashmirís, employed in weaving shawls and woollen goods. Four towns were returned in 1868 as containing upwards of 5000 inhabitants, viz., Ludhiána, 39,983; Ráikot, 9165; Jagráon, 7096; and Machiwára, 6062. Ludhiána is a flourishing agricultural district in spite of the general unpromising appearance of its soil, a result mainly attributable to the untiring diligence of its Ját cultivators. Almost all the available land has been brought under the plough, and in many villages no waste land is left for pasturage, the cattle being fed from cultivated produce. Under *rabí* or spring crops there were in 1872–73 198,279 acres of wheat, 30,620 of barley, 162,649 of gram, and 576 of poppy. The *kharíf* or rain crops comprised 129,589 acres of *joár*, 49,047 of Indian corn, 55,293 of *moth*, and 15,894 of cotton. In spite of their industrious habits, many of the peasantry are deeply in debt, and the rate of interest is high. Most of the land is held by tenants-at-will. Agricultural labourers are paid in grain; in the towns, unskilled labour is paid at the rate of from 3d. to 4½d. per diem. Ludhiána is comparatively free from danger of actual famine, though it suffers much from drought. The exports, of which the annual value is estimated at £377,120, are chiefly confined to grain, cotton, wool, saltpetre, and indigo; the principal imports (£365,552) are English goods, spices, and red madder dye. Manufactures include shawls, *pashmína* cloth, stockings, gloves, cotton goods, furniture, carriages, and firearms. Eight large silk factories and upwards of four hundred private silk-looms give employment to over three thousand persons. Communication is afforded by the Sind, Punjab, and Delhi Railway, which runs through the centre of the district, and by several lines of good metalled roads.

The administrative staff of the district comprises a deputy commissioner, with an assistant and two extra assistants, a small-cause court judge, and three *tahsíldárs*, besides the usual medical and constabulary officers. The total revenue in 1872–73 was £103,795, of which £85,215 was contributed by the land tax. Education in 1873 was afforded by 184 schools, of which 68 were in receipt of Government grants in aid; the total number of enrolled pupils was 6733. In the upland portion of the district the atmosphere is dry and healthy; in the Sutlej valley, however, the air is extremely noxious after the rainy season floods, and fever prevails often in an epidemic form; ophthalmia is also common. The mean temperature in 1872 was 87°·59 Fahr. in May, 85°·67 in July, and 54°·85 in December, the maximum being 117°, and the minimum 31°. The average annual rainfall is 28 inches.

History.—Though the present town of Ludhiána dates no farther back than the 15th century, other cities in the district can claim a much greater antiquity. At Sunet, close to the modern station, are ruins of an extensive brick-built town, whose greatness had already passed away before the period of Mohammedan invasion; and the old Hindu city of Máchiwára is of still earlier date, being mentioned in the *Mahábhárata*. During the Mussulman epoch, the history of the district is bound up with that of the Ráis of Ráikot, a family of converted Rájputs, who received the country as a fief under the Sayyid dynasty, about the year 1445. The town of Ludhiána was founded in 1480 by two of the Lodí race (then ruling at Delhi), from whom it derives its name, and was built in great part from the prehistoric bricks of Sunet. The Lodís continued in possession until 1620, when it again fell into the hands of the Ráis of Ráikot. Throughout the palmy days of the Mughal empire the Ráikot family held sway, but the Sikhs took advantage of the troubled period which accompanied the Mughal decadence to establish their supremacy south of the Sutlej. Several of their chieftains made encroachments on the domains of the Ráis, who were only able to hold their own by the aid of George Thomas, the famous adventurer of Hariána. In 1806 Ranjít Sinh crossed the Sutlej and reduced the obstinate Mohammedan family, and distributed their territory amongst his own co-religionists. Since the British occupation of the Punjab Ludhiána has grown in wealth and population, but its history has been uneventful.

LUDHIÁNA, the chief town and headquarters station of Ludhiána district, is situated on the south bank of the old bed of the Sutlej, 8 miles from the present bed of the river, in 30° 55′ 25″ N. lat. and 75° 53′ 30″ E. long. The population in 1868 was 39,983, viz., Mohammedans, 27,860; Hindus, 10,208; Síkhs, 45; Christians, 79; "others," 1791. The Kashmirís retain their hereditary skill as weavers of shawls and *pashmína* cloth, the value of the quantity exported in 1871–72 being returned at £13,350. Shawls of the soft Rámpur wool, cotton cloths, scarfs, turbans, furniture, and carriages also form large items in the thriving trade of the town. Since the opening of the railway Ludhiána has become a great central grain mart, having extensive export transactions both with the north and south. The American Presbyterian Mission has a church and school, with a small colony of native Christians. The town bears a bad reputation for unhealthiness.

LUDLOW, a municipal and parliamentary borough and market-town of Shropshire, England, is situated at the junction of the Teme and Corve on the borders of Herefordshire, 27 miles south-east from Shrewsbury and 10 north from Leominster. The old castle, on an eminence above the Teme, presents an imposing and massive appearance, the Norman towers and the greater part of the walls being still complete. The parish church of St Lawrence, a fine cruciform structure in the Gothic style, with a lofty central tower, dates from the reign of Edward III.; it was restored in 1859-60. The grammar school, founded in the reign of John, was incorporated by Edward I. The other principal public buildings are the guild-hall, the town-hall and market-house, and the public rooms, which include the assembly-rooms and a museum of natural history. Tanning and malting are carried on to a small extent, and there are also flour-mills. The population of the municipal borough (280 acres) in 1871 was 5087, and in 1881 5035. The population of the parliamentary borough (1371 acres) in the same years was 6203 and 6663.

Ludlow is said to have existed as a British town under the name of *Dinan*. After the Conquest it was granted to Roger de Montgomery, who is said to have been the founder of the castle. For some time the castle was a royal residence, and from the reign of Henry VIII. to that of William III. it was the seat of the council of the marches. In the reign of Charles I. it was garrisoned for the king, but it surrendered to the parliamentary forces in June 1646. The town had a charter of incorporation at a very early period, which was confirmed by Edward IV.

LUDLOW, Edmund (1620-1693), was born at Maiden Bradley, Wiltshire, in 1620, of an ancient and honourable family. He studied at Trinity College, Oxford (where he took his B.A. degree in 1636), and at the Temple. When the war broke out he engaged as a volunteer in the life guard of Lord Essex, consisting of one hundred gentlemen. His first essay in arms was at Worcester, his next at Edgehill. He was made governor of Wardour Castle in 1643, which place he surrendered on honourable terms after ten months' siege. On being exchanged soon afterwards, he engaged as major of Sir A. Haslerig's regiment of horse, in which capacity he did good service in the western counties. He was present at the second battle of Newbury, October 1644. In 1645 he was elected M.P. for Wilts in the room of his father Sir Henry Ludlow, and attached himself inflexibly to the republican party. In 1648 he was one of a committee of six who arranged the violent action known as Pride's Purge. He was one of the king's judges, and put his hand to the warrant for his execution. In January 1651 Ludlow was sent into Ireland as lieutenant-general of horse, holding also a civil commission. Here he spared neither health nor money in the public service. Ireton, the deputy of Ireland, died 27th November 1651, and for six months Ludlow held the chief place, which he then resigned to Fleetwood. Though disapproving of Cromwell's action in dissolving the Long Parliament, he maintained his employment, but when Cromwell was declared Protector he declined to acknowledge his authority, and was soon after recalled to England. He refused the Protector face to face when ordered to submit to his government, and in December 1655 retired to his own house in Essex. After Oliver Cromwell's death Ludlow was returned for the borough of Hindon, and took his seat in Richard's parliament in 1659. He sat also in the restored Rump, and was a member of its council of state and of the committee of safety after its second expulsion. He also held office for a short time in Ireland. After the Restoration, finding that his life was in danger, he left England, in September 1660, and travelled through France and Geneva, and thence to Vevey, then under the protection of the canton of Bern. There he spent the rest of his long life unmolested, to the great credit of the Government of that canton, which had also extended its protection to other regicides. He was, however, in constant danger from Cavalier assassins. He steadily refused during thirty years of exile to have anything to do with the desperate enterprises of republican plotters. But in 1689 he returned to England, hoping to be employed in Irish affairs. He was, however, known only as a regicide; and an address from the House of Commons was presented to William III. by Sir Edward Seymour, requesting the king to issue a proclamation for his arrest. Ludlow escaped again, and returned to Vevey, where he died in 1693, aged seventy-three, and where a monument raised to his memory by his widow is still to be seen in the church of St Martin. Over the door of the house in which he lived was placed the inscription "Omne solum forti patria, quia Patris." His memoirs, extending to the year 1688, were published in 1698-99 at Vevey.

LUDOLF, or Leutholf, Hiob (1624-1704), a learned Orientalist, was born at Erfurt on June 15, 1624. At an early age he manifested a passion for the acquisition of foreign tongues; and after exhausting the imperfect educational resources of his native place he went in 1645 to Leyden, where for upwards of a year he was the pupil of Erpenius, Golius, and other linguists. Having received an appointment as tutor, he afterwards travelled in France (where he became acquainted with Bochart at Caen) and in England, and in 1649 he was commissioned by the Swedish ambassador at the French court to go to Rome in quest of certain papers which had been lost, and which Queen Christina wished to recover. In this mission he was unsuccessful, but while in Italy he became acquainted with four Abyssinians, from whom he acquired his knowledge (at that time unique) of Ethiopic. In 1652 he entered the diplomatic service of the duke of Saxe-Gotha; in this he continued (acting also for some time as tutor to the young princes) until 1678, when he retired to Frankfort-on-the-Main. At the conferences held there in 1681 and 1682 he held a commission to act for the dukes of Saxony. In 1683 he visited England to promote a cherished scheme for establishing trade with Abyssinia, but his efforts were unsuccessful, chiefly through the bigotry of the authorities of the Coptic Church. Returning to Frankfort in 1684, he gave himself wholly to literary work, which he continued almost to his death on April 8, 1704. In 1690 he had the honour to be appointed president of the "Collegium Imperiale Historicum."

His works, of which a complete list will be found in Chauffepié's *Dictionnaire*, include *Historia Ethiopica* (fol. 1681), with *Commentarius ad Hist. Eth.* (1691), and *Appendix* (1693); *Grammatica Amharicæ Linguæ, quæ vernacula est Habessinorum*, 1698; *Lexicon Amharico-Latinum*, 1698; *Lexicon Ethiopico-Latinum*, of which the first edition was published in London in 1661, but with many inaccuracies for which Ludolf refused responsibility (a second edition appeared at Frankfort in 1699); *Grammatica Linguæ Ethiopicæ* (London, 1661; Frankfort, 1702). Ludolf holds a very high place among the older Orientalists, and his works on Ethiopic in particular continued to be the standard text-books till they were superseded by those of Dillmann.

LUDWIGSBURG, the second royal residence of Würtemberg, is situated 9 miles to the north of Stuttgart and 1½ miles from the Neckar. It was laid out at the beginning of last century by Duke Eberhard Ludwig as a rival to Stuttgart, and was greatly enlarged by Duke Charles, who resided there from 1764 to 1785. Constructed as the adjunct of a palace, the town bears the impress of its artificial origin, and its straight streets and spacious squares have a dull and lifeless appearance. Its main importance now consists in its being the chief military depôt of Würtemberg, as which it contains extensive barracks, a cannon foundry, an arsenal, and a military academy. The royal palace, one of the largest and finest in Germany, stands in a beautiful park, and contains a portrait-gallery and the burial vault of the sovereigns of Würtemberg. Among the other prominent buildings are four churches and several educational and charitable institutions. Ludwigsburg also carries on manufactures of organs, woollen and linen cloth, japanned tin-wares, picture frames, and chicory. In 1880 it contained 16,100 inhabitants, about one-fourth of whom belonged to the garrison. David Strauss, author of the *Life of Jesus*, was a native of Ludwigsburg. In the vicinity is the beautiful royal chateau of Monrepos, connected with the park of Ludwigsburg by a fine avenue of limes.

LUDWIGSHAFEN. See MANNHEIM.

LUGANO, a town of Switzerland, which divides with Locarno and Bellinzona the first rank in the canton of Tessin (Ticino). It stands on the shore of the lake of the same name, on a narrow strip of Swiss territory which projects into Lombardy and is everywhere close to the Italian frontier. The prosperity of the town is due to its position on the main line of land communication between Milan and the pass of the St Gotthard, and the facility of intercourse by land and water, whether for legitimate or contraband trade, between this outlying fragment of Switzerland and the rich region that surrounds it. The buildings are not remarkable, but the church of Santa Maria degli Angioli contains several important pictures by Luini, a native of the adjoining district. The monastery to which the church formerly belonged is now converted into a large hotel. During the struggle of the people of northern Italy to expel the Austrians from Lombardy, between the years 1848 and 1866, Lugano served as head-quarters for Mazzini and his followers. Books and tracts intended for circulation throughout Italy were produced there, and at the neighbouring village of Capolago, on a large scale, and the efforts of the Austrian police to check their circulation were completely powerless. The population is Italian in character and features, and the Italian tongue is exclusively spoken. On the quay is a statue of Tell by Vela, and there are other works by the same eminent sculptor, a native of the canton, in private grounds near the town. About 2 miles distant, and nearly due south, a steep hill—called Monte Salvatore—rises more than 2000 feet above the surface of the lake, and commands a fine panoramic view, limited in some directions by the higher mountains on the opposite side of the lake, but extending in one direction to Monte Rosa, and in another to the cathedral of Milan.

LUGANO, LAKE OF (sometimes called *Lago Ceresio* by the Italians, from the Roman name *Lacus Ceresius*), situated partly in Lombardy and partly in the Swiss canton Tessin or Ticino, takes its ordinary name from the town of Lugano, the only considerable place on its banks. Its form is very irregular, and has been compared to a sickle, a fish-hook, and various other objects. It lies altogether amidst the outer ranges of the Alps that divide the basin of the Ticino from that of the Adda, where the calcareous strata have been disturbed by the intrusion of porphyry and other igneous rocks. It is not connected with any considerable valley, but is fed by numerous torrents in various directions issuing from short glens in the surrounding mountains, and is drained by the Tresa, an unimportant stream that flows westward into the Lago Maggiore. The surface of the lake is 889 feet above the sea, and the form of its bed seems to be very irregular. In some parts soundings of more than 1000 feet have been taken, while in one place the lake is so shallow that a causeway half a mile in length, supporting the road and the railway, has been carried from shore to shore. The scenery is of a varied character: in great part, and especially in the north-east arm extending from Lugano to the Lombard village of Porlezza, the lake is enclosed between mountains that rise steeply to a height of some 2000 feet from the water's edge, while on its southern and western branches it is encompassed by gently swelling hills rich with the luxuriance of Italian vegetation.

LUGANSK, a town of Russia, in the government of Ekaterinoslaff, district of Slavianoserbsk, 300 miles to the eastward of the capital of the province, is connected by a branch with the railway between Kharkoff and Azoff, as well as with other towns and iron-works of the Donetz coal-mines district. It stands on the small river Lugan, 10 miles from its junction with the northern Donetz, in the Lugan mine district, of which it is the chief town. This district, which comprises the important coal-mines of Lisitchansk and the anthracite mines of Gorodische, occupies an area of about 110,000 acres on the banks of the Donetz river, and has a population of more than 15,000. Although it is mentioned in Russian history as early as the 16th century, and coal was discovered in it at the time of Peter I., it was not until 1795 that an Englishman, Gascoyne or Gaskoin, established its first iron-work for supplying the Black Sea fleet and the southern fortresses with guns and shot. This proved a failure, owing to the great distance from the sea, and the manufacture of supplies for the navy was suspended; but during the Crimean war the iron-works of Lugan again largely produced shot, shell, and gun-carriages. Since 1864 agricultural implements, steam-engines, and the various machinery required for beetroot sugar-works, distilleries, &c., have been the chief manufactures. The Lugan works, which employ about 1200 men, are the chief centre for smelting the ores of the neighbouring iron-mines. The town is the seat of the mining authorities for the district, and has a first-class meteorological and magnetic observatory. The 11,000 inhabitants of Lugansk also carry on a very active trade in cattle, tallow, wools, skins, linseed, wine, corn, and manufactured wares. The weekly fairs are much frequented. There are also in the town many tallow-melting works, and the smith trade is largely carried on.

LUGO, a maritime province of Spain, one of the four into which Galicia has since 1833 been divided, is bounded on the E. by Oviedo and Leon, on the S. by Orense, on the W. by Pontevedra and Coruña, and on the N. by the Atlantic. Its extreme length from north to south is about 98 miles, its breadth 58, and the area 3787 square miles. The coast, which extends for about 40 miles from the estuary of Rivadeo to Cape Vares, is extremely rugged and inaccessible, and few of the inlets that exist, except those of Rivadeo and Vivero, admit vessels of any size. The province, especially in the north and east, is mountainous in its character, being traversed by the great Cantabrian chain and its offshoots; the sierra by which it is separated from Leon attains in some places a height of 6000 feet. A large part of the area is drained by the Miño, which rises on the western slope of the Sierra de Meira, and follows a southerly direction until it is joined by the Sil; the latter for a considerable distance forms the southern boundary of the province. Of the rivers of the northern versant the most important are the Navia (which has its lower course through Oviedo), the Eo (for some distance the boundary between the two provinces), the Masma, the Oro, and the Landrobe. The Eume, one of the rivers of Coruña, and the Ulla, which separates that province from Pontevedra, both have their rise on the western slopes of Lugo. Some of the northern valleys even, in their lower portions, are fertile, and yield not only corn but fruit and wine, but the principal agricultural wealth is on the Miño and Sil, where rye, maize, wheat, legumes of various kinds, flax, hemp, and a little silk are produced. The hills are comparatively well wooded. Iron is found at Caurel and Incio, antimony at Castroverde and Cervantes, argentiferous lead at Riotorto; and there are quarries of granite, marble, and various kinds of slate and building stone. Linen and woollen cloths are manufactured, but to an insignificant extent, and the trade of the province is unimportant. The internal communications are still very imperfect. There is only one railway, that connecting Lugo with Coruña; but connexions with Leon (Brañuelas) and with Orense are in contemplation. The total population in 1877 was 410,387, being a decrease of 22,129 since 1860. There are ten towns with a population over 10,000—Chantada, Fonsagrada, Lugo, Mondoñedo, Monforte, Panton, Sarria, Saviñao, Villalba, and Vivero.

LUGO, the capital of the above province, stands on a small hill near the northern bank of the river Miño, at a height of 1930 feet above the level of the sea, 60 miles south-west from Coruña, and 353 north-west from Madrid, on the highway between these two cities. With the former it is continuously connected by rail. The form of the town, which is nearly quadrangular, is defined by a massive Roman wall, from 30 to 40 feet in height and 20 feet thick, with projecting semicircular towers which, prior to the civil war in 1809, were eighty-five in number; it now serves as a promenade, commanding an extensive and delightful prospect. The principal public places are the Plaza de la Constitucion, a spacious arcaded square, the Plaza de San Domingo, the Plaza del Hospital, and the busy Plaza del Campo, where fairs and markets are held. The most important of the public buildings is the Gothic cathedral on the south side of the town; it dates from the 12th century, but was modernized in the 18th, and possesses no special architectural merit. Other churches are those of the Capuchins and that of San Domingo; the only other buildings of note are the episcopal palace, the secondary school, the hospital, and the prison. The principal industries are tanning, and the manufacture of linen cloth and of cream of tartar; there is some trade in silk wares. About a mile to the south of the town, on the left bank of the Miño, are the famous hot sulphur baths of Lugo; the bathing house dates from 1847. The population of the ayuntamiento in 1877 was 18,909.

Lugo (*Lucus Augusti*) was made by Augustus the seat of a *conventus juridicus*. Its sulphur baths were even then well known. It suffered greatly in the 5th century, during the Moorish wars, and, more recently, during the war of independence. The bishopric dates from a very early period, and it is said to have acquired metropolitan rank in the middle of the 6th century; it is now suffragan to Santiago.

LUGOS, a market-town of Hungary, capital of the trans-Tisian county of Krassó, is situated on the Temes, and on the railway from Temesvár to Karánsebes, 32 miles east-south-east of the former, in 45° 41′ N. lat., 21° 53′ E. long. The two main portions of the town, separated by the river, and named respectively Német- (German) Lugos and Román- (Roumanian) Lugos, are connected by a wooden bridge 312 feet in length. Lugos is the seat of a Greek Catholic (Roumanian) bishopric, of royal and circuit courts of law, and of the usual bureaus of a county administration. The public and other buildings include Greek Orthodox, Greek Catholic, Roman Catholic, and Lutheran churches, a synagogue, a royal upper gymnasium (founded in 1823), a Minorite convent, an episcopal palace, the barracks, and the ruins of a castle. The surrounding country is mountainous and well-wooded, and produces large quantities of grapes and plums. In 1880 the population was 11,287, of whom 3476, chiefly Germans, were in Német-Lugos, and 7811, Roumanians, with a few Slavonians and Magyars, in Román-Lugos.

Lugos was once a strong fortress and of greater relative importance than at present. During the 16th and 17th centuries it suffered much at the hands of the Turks. At the close of the Hungarian revolutionary war (August 1849) it was the last resort of Kossuth and several other leaders of the national cause previous to their escape to Turkey.

LUINI, BERNARDINO, the most celebrated master of the Lombard school of painting founded upon the style of Leonardo da Vinci, was born at Luino, a village on the Lago Maggiore, towards 1465. He himself wrote his name as "Bernardin Lovino," but the spelling "Luini" is now very generally adopted. Few facts are known regarding the life of this illustrious and delightful painter, and it is only since a comparatively recent date that he has even been credited with the production of his own works, and with the fame thereto appertaining, as many of them had, in the lapse of years and laxity of attribution, got assigned to Leonardo. It appears that Luini studied painting at Vercelli under Giovenone, or perhaps under Lo Scotto. He reached Milan either after the departure of Da Vinci in 1500, or shortly before that event; it is thus left uncertain whether or not the two artists had any personal acquaintance, but Luini was at any rate in the painting-school established in Milan by the great Florentine. In the latter works of Luini a certain influence from the style of Raphael is superadded to that, far more prominent and fundamental, from the style of Leonardo; but there is nothing to show that he ever visited Rome. His two sons are the only pupils who have with confidence been assigned to him; and even this can scarcely be true of the younger, who was born in 1530, when Bernardino was well advanced in years, and was not far from the close of his career. Gaudenzio Ferrari has also been termed his disciple. One of the sons, Evangelista, has left little which can now be identified; the other, Aurelio, was accomplished in perspective and landscape work. There was likewise a brother of Bernardino, named Ambrogio, a competent painter. Bernardino, who hardly ever left Lombardy, had some merit as a poet, and is said to have composed a treatise on painting. The precise date of his death is unknown; he may perhaps have survived till about 1540. A serene, contented, and happy mind, naturally expressing itself in forms of grace and beauty, seems stamped upon all the works of Luini. The same character is traceable in his portrait, painted in an upper group in his fresco of Christ Crowned with Thorns in the Ambrosian library in Milan,—a venerable bearded personage. The only anecdote which has been preserved of him tells a similar tale. It is said that for the single figures of saints in the church at Saronno he received a sum of money equal to 22 francs per day, along with wine, bread, and lodging; and he was so well satisfied with this remuneration that, in completing the commission, he painted a Nativity for nothing.

Along with this natural sweetness of character, a dignified suavity is the most marked characteristic of Luini's works. They are constantly beautiful, with a beauty which depends at least as much upon the loving self-withdrawn expression as upon the mere refinement and attractiveness of form. This quality of expression appears in all Luini's productions, whether secular or sacred, and imbues the latter with a peculiarly religious grace—not ecclesiastical unction, but the devoutness of the heart. His heads, while extremely like those painted by Leonardo, have less subtlety and involution and less variety of expression, but fully as much amenity. He began indeed with a somewhat dry style, as in the Pietà in the church of the Passione; but this soon developed into the quality which distinguishes all his most renowned works; although his execution, especially as regards modelling, was never absolutely on a par with that of Leonardo. Luini's paintings do not exhibit an impetuous style of execution, and certainly not a negligent one; yet it appears that he was in fact a very rapid worker, as his picture of the Crowning with Thorns, painted for the College del S. Sepolcro, and containing a large number of figures, is recorded to have occupied him only thirty-eight days, to which an assistant added eleven. His method was simple and expeditious, the shadows being painted with the pure colour laid on thick, while the lights are of the same colour thinly used, and mixed with a little white. The frescos exhibit more freedom of hand than the oil pictures; and they are on the whole less like the work of Da Vinci, having at an early date a certain resemblance to the style of Mantegna, as later on to that of Raphael. Luini's colouring is mostly rich, and his light and shade forcible.

Among his principal works the following are to be mentioned. At Saronno are frescos painted towards 1525, representing the life of the Madonna—her Marriage, the Presentation of the Infant Saviour in the Temple, the Adoration of the Magi, and other incidents. His own portrait appears in the subject of the youthful Jesus with the Doctors in the Temple. This series—in which some comparatively archaic details occur, such as gilded nimbuses—was partly repeated from one which Luini had executed towards 1520 in S. Croce. In the Brera Gallery, Milan, are frescos from the suppressed church of La Pace and the Convent della Pelucca,—the former treating subjects from the life of the Virgin, the latter, of a classic kind, more decorative in manner. The subject of girls playing at the game of "hot-cockles," and that of three angels depositing St Catherine in her sepulchre, are particularly memorable, each of them a work of perfect charm and grace in its way. In the Casa Silva, Milan, are frescos from Ovid's *Metamorphoses*. The Monastero Maggiore of Milan (or church of S. Maurizio) is a noble treasure-house of Luini's art,—including a large Crucifixion, with about one hundred and forty figures; Christ Bound to the Column, between figures of Saints Catherine and Stephen, and the founder of the chapel kneeling before Catherine; the Martyrdom of this Saint; the Entombment of Christ; and a large number of other subjects. In the Ambrosian library is the fresco (already mentioned), covering one entire wall of the Sala della S. Corona, of Christ Crowned with Thorns, with two executioners, and on each side six members of a confraternity; in the same building the Infant Baptist Playing with a Lamb; in the Brera, the Virgin Enthroned, with Saints, dated 1521; in the Louvre, the Daughter of Herodias receiving the Head of the Baptist; in the Esterhazy Gallery, Vienna, the Virgin between Saints Catherine and Barbara; in the National Gallery, London, Christ Disputing with the Doctors. Many or most of these gallery pictures used to pass for the handiwork of Da Vinci. The same is the case with the highly celebrated Vanity and Modesty in the Sciarra Palace, Rome, which also may nevertheless in all probability be assigned to Luini. Another singularly beautiful picture by him, which seems to pass almost entirely unobserved by tourists and by writers, is in the Royal Palace in Milan—a large composition of Women Bathing. That Luini was also pre-eminent as a decorative artist is shown by his works in the Certosa of Pavia.

LUKE, whose name is traditionally attached to the Third Gospel, appears to have been one of the companions of Paul, being mentioned as such in Col. iv. 14, Philem. 24, and 2 Tim. iv. 11; even if, as some critics suppose, these epistles were not written by Paul himself, they are at any rate likely to have preserved the local colouring. Assuming, as is probable, that the same person is intended in all three passages, we gather (1) that Luke was not a born Jew, since in Col. iv. 11, "those who are of the circumcision" appear to be separated from those, among whom is Luke, who are mentioned afterwards (but there is nothing to determine the question, which has since been raised, whether he had been a Jewish proselyte or a Gentile), and (2) that he was a physician. There was an early belief, first mentioned by Irenæus, that he is spoken of, though not mentioned by name, in 2 Cor. viii. 18, as "the brother whose praise is in the gospel throughout all the churches"; and the subscription of that epistle in some MSS., and in the Peschito and other versions, embodies this belief. Of his birth and country nothing is positively known; but it is a possible inference from his name *Lucas*, which is a contraction of *Lucanus* (the full form occurs in some early MSS. of the Itala), that he was of Italian (Lucanian) descent.

From the time of Irenæus, whose testimony is soon followed by that of Clement of Alexandria, Tertullian, and Origen, this companion of Paul has generally been considered to be the author of the third canonical Gospel and of the Acts of the Apostles; but no other facts are mentioned by early writers as to his personal history, except such as may be gathered from the writings which are attributed to him. Tertullian, for example, speaks of him as "non apostolus sed apostolicus," and as "posterioris apostoli sectator" (*Adv. Marcion.*, 4, 2); and the Muratorian fragment says that he had not seen the Lord in the flesh. The most important of these biographical inferences are those which were made by Eusebius, who, translating, or mistranslating, παρηκολουθηκότι πᾶσι, in the preface to the Gospel, by "having accompanied all," *i.e.*, the "eyewitnesses and ministers of the word," infers that Luke was a companion not of Paul only but also of the other apostles, and, probably referring to Acts xiii. 1, says that he was "one of those from Antioch."[1] These inferences of Eusebius are further elaborated by Jerome, who adds, without quoting any authority, that he wrote the Gospel in Achaia or Bœotia (many MSS. have Bithynia), and the Acts at Rome.[2]

Those who accept this tradition of his having been the author of the Acts of the Apostles usually infer from the sections of that work in which the pronoun "we" is employed that he accompanied Paul on part of his second and third missionary journeys, and also on his voyage to Rome. The first of these sections begins with the apostle's determination to go into Macedonia, and ends when he has left Philippi (Acts xvi. 10–40); the second begins when the apostle returns to Philippi, and ends with his arrival at Jerusalem (Acts xx. 6–xxi. 18); the third begins with his sailing from Cæsarea, and ends with his arrival at Rome (Acts xxvii. 1-xxviii. 16). Even some of those who assign the greater part of the book to a much later date think that these sections may be extracts from an original diary of a companion of Paul, and that this companion may have been Luke. Others, however, think it improbable that Luke, without being specially mentioned either in them or elsewhere, should have accompanied Paul on his voyage to Rome, and assign these sections to Timothy, or Titus, or Silas (some have added the very improbable conjecture that Luke and Silas are the same person).

The other biographical details which are found in patristic literature, and which are not inferences from the New Testament, rest upon no certain evidence, and are frequently at variance not only with one another but also with earlier documents. It is sometimes stated that he was one of the seventy disciples; this statement is found in Epiphanius (*Hæres.*, li. 11), in pseudo-Origen (*De recta in Deum fide*, ed. De la Rue, vol. i. p. 806), in Gregory the Great (*Moral.* i. 1), and elsewhere; but it is inconsistent, not only with Tertullian and the Muratorian fragment, but also with the clear inference from the preface to the Gospel that its author was not himself an eyewitness of what he narrates. It is also stated that he was one of the two disciples who went to Emmaus (S. Greg. Magn., *Moral.* i. 1; Paul. Diacon., *Homil.* 59 *in Natali S. Lucæ*; and others); but this statement is discredited by the same facts as the preceding. Like all the other disciples whose names are mentioned in the New Testament, he is said to have gone forth as a preacher of the gospel; but statements vary widely as to the place in which he preached: Gregory of Nazianzus says Achaia; Epiphanius says Dalmatia, Gaul, Italy, and Macedonia; Œcumenius says Africa; later legends mention his having been at Enns in Austria (Hansiz, *Germ. Sacra*, vol. i. p. 15). And also, like most of the other early disciples, he is said not only to have preached the gospel but also to have suffered death for its sake. Gaudentius of Brescia says that this occurred at Patra in Achaia, and Nicephorus specifies as the manner of his martyrdom that he was hung on an olive tree. But elsewhere it is stated or implied that he died an ordinary death, either at Thebes in Bœotia (*Martyrol. Basil.*), or in Bithynia (Paulus Diaconus, Isidore of Seville, and the *Martyrologies* of Ado and Usuardi). Most traditions agree in stating that his body was transferred by Constantius to Constantinople ("Chron. Hieron.," ap. Mai, *Nov. Script. Coll*; Prosper Aquitanus, Paulus Diaconus, Nicephorus, and others), but its place of burial seems to have been forgotten, and Procopius (*De ædif. Justin.*, i. 4) mentions that it was discovered in Justinian's time in digging the foundations of a new

[1] Some have thought that, like the persons who are mentioned by Origen, *Comm. in Rom.*, chap. x. (vol. iv. p. 686, ed. De la Rue), Eusebius here confuses the two names Lucas and Lucius.

[2] *De Viris Illustr.*, chap. vii.; *Comm. in Matth.*, pref., vol. vii. p. 3

church; a subsequent tradition stated that it was afterwards removed to Italy, and in the 15th century Pius II. commissioned Cardinal Bessarion to decide upon a violent controversy between the Minorite monastery of S. Job at Venice and the Benedictine monastery of S. Giustina at Padua, each of which claimed to possess the perfect relics of the evangelist.

A late tradition represents Luke to have been a painter as well as a physician; the tradition first appears in a doubtful fragment of an author of doubtful date, Theodorus Lector (printed in H. Valois's edition of Theodoret, p. 618), who mentions that the empress Eudocia sent to Pulcheria, from Jerusalem to Constantinople, a picture of the Virgin painted by Luke. The same story is mentioned in an almost certainly spurious oration of John of Damascus (*Orat. in Constant. Copron.*, c. 6., vol. i. p. 618, ed. Le Quien); and the first certain authorities for the tradition are Symeon Metaphrastes and the *Menologium* of Basil the younger, both of which belong to the 10th century. That the tradition is not of much earlier growth is proved by the fact that, if it had existed, it could not fail to have been largely used in the iconoclastic controversy.

The martyrologies and calendars for the most part agree in fixing Luke's festival on October 18; but a doubt is expressed whether that day should be regarded as the anniversary of his birth or of the translation of his remains to Constantinople.

In Christian art he is usually symbolized by an ox (with reference to Ezekiel i. 10, Revelation iv. 7), on the significance of which symbol various statements were made by both Eastern and Western writers (some of them will be found quoted by Ciampini, *Vet. Monum.*, vol. i. 192). (E. HA.)

LUKE, Gospel of. See Gospels.

LUKOW, a town of Russian Poland, in the province of Siedlce, 60 miles by rail to the west of Brest-Litovsky. Owing to its situation on the railway and in the centre of a rich district, it is rapidly developing. The population is 11,050.

LUKOYANOFF, a district town in Russia, in the government of Nijni-Novgorod, 108 miles south-south-east of the chief town of the government, on the highway to Saratoff, at the sources of the Tesha river, tributary of the Oka. It is situated in a district where agriculture is carried on to a large extent, corn being sold to distilleries, and hemp exported, while the extensive forests furnish materials for the production of wooden wares. Wooden spoons, buckets, sledges, carts, implements for linen weaving, are made in large quantities by the peasants of the neighbouring villages, and exported to the steppe provinces of southern Russia; and there is also considerable trade in timber, felts, fishing nets, nails, &c. Population 9600.

LULLY, Giovanni Battista (1633-1687), was born in Florence, and joined in 1650, as a violinist, the orchestra of the French court. Though friendless and in a foreign country, his genius soon opened for him a road to honours and wealth. He was appointed director of music to King Louis XIV., and director of the Paris opera. The influence of his music was so great as to produce a radical revolution in the style of the dances of the court itself. Instead of the slow and stately movements, which had prevailed until then, he introduced lively and rhythmically quick ballets. Having found a congenial poet in Quinault, Lully composed twenty operas, which met with a most enthusiastic reception from a delighted public. He effected important improvements in the composition of the orchestra, into which he introduced several new instruments. Lully enjoyed the friendship of Molière, for some of whose best plays he composed illustrative music. His *Miserere*, written for the funeral of the minister Sequier, is a splendid work of genius; and very remarkable are also his minor sacred compositions. On his death-bed he wrote *Bisogna morire, peccatore.* Lully's right to be numbered among the most original and the best musicians is undoubted. His music is full of the most charming and enthralling forms of Italian melody; and the fact of its being even now performed, after the lapse of so many years, is proof sufficient of its inherent beauty and intrinsic worth.

LULLY, Raymond (1235-1315), the inventor of a fantastic system of logic by which Mohammedans should be converted to Christianity, was born at Palma, in the island of Majorca, in 1235. His father had been born at Barcelona, and belonged to a distinguished Catalonian family; but for his services in helping to recover the Balearic islands from the Saracens he was rewarded with a gift of land in the conquered territory, and the paternal estates descended to his enthusiastically-minded son. The younger Lully, however, showed at first but little of the speculative tendencies which he afterwards developed, and his early years were spent in the gaiety and even profligacy of a courtier in the service of James II., of Aragon, who appointed him grand seneschal of the isle. He married, but notwithstanding sought the reputation of a gallant, and was mixed up in more than one intrigue. Something, however, of the nature of a cancer, which attacked one of the objects of his passion, Signora Ambrosia,—such is the way in which we are asked to account for his "conversion,"—affected him so deeply that he abandoned in his thirty-second year his licentious life, and, having distributed the greater portion of his goods to his family and the poor, he withdrew to the retirement of a cell on Mount Randa, the only part of his property which he had reserved for himself. Visions of a crucified Saviour and like phenomena confirmed him in his devotion to the cause of Christ, and in the course of a nine years' retreat on Randa he came to regard himself as commissioned by God to refute the errors of Mohammed.

This missionary call became henceforth the actuating principle in Lully's life. To realize it, he went to Paris in his fortieth year, to prosecute the study of Latin and logic; and, with a view to becoming familiar with the language of the infidels, he engaged the services of an unlettered Arabian, who, finding that Lully was seeking to demolish the faith of Islam, attempted to assassinate his master. This need of acquiring a knowledge of the language of the church's adversary became itself now one of Lully's favourite ideas. In 1286 he began a series of visits, which he made to Rome to induce the supreme pontiff to found colleges for the study of Arabic; but the small success which would attend his efforts in this direction was foreshadowed by the death of Honorius (then pope) before he could attain an audience of him. Meanwhile Lully had become discontented with the methods of science commonly in use, and had set himself to construct his "great art," a method which, by mechanically presenting all the predicates which could attach to any subject, was adapted to answer any question on any topic, and would (its author imagined) by the cogency of its inferences necessarily convert the heathen. His natural enthusiasm respecting the consequences of this art were strengthened by revelations (as he judged them) of the co-operation of God in his designs, and he gave himself up, with the fervour of a divinely appointed missionary, to the work of spreading a knowledge of his "great art" in every country. He expounded it at Paris and Montpellier in 1286, and after a visit to Pope Nicholas, to solicit his help in founding linguistic colleges, and a serious illness at Genoa, brought on apparently by an isolated fit of nervous cowardice in face of the dangers he was going to encounter, he sailed to Tunis, to apply his new method to the errors of Mohammedanism. At Tunis his attacks upon the religion of the country led to his being cast into prison, and it was only by the mediation of a sheikh, who had been impressed by the earnestness of the Christian preacher, that he managed to escape to sea, not without the roughest treatment at the hands of the mob, and find his way to Naples.

A new influence was brought to bear on Lully's life at

Naples. He made the acquaintance of the alchemist Arnaud de Villeneuve, and acquired, we may believe, not only that skill in transmuting metals for which Lully himself became in popular tradition famous, but imbibed also something of that spirit which brought down the censure of the church on Villeneuve for maintaining that medicine and charity were more pleasing to God than religious services. For the next few years the scene of Lully's labours was continually changing. He made an unsuccessful attempt to interest Pope Boniface in the missionary colleges which he wished to see established, and similar appeals to the kings of France and Cyprus met with no more favourable a response. From Cyprus Lully proceeded (1306) to Bougiah in Africa, and repeated the experiences he had already had at Tunis. But, though Mohammedanism showed little disposition to welcome the "great art" and its author, the European world had meanwhile begun to show itself more favourably disposed towards Lully's projects. In 1297 he had received at Montpellier, from the general of the Franciscans, letters recommending him to the superiors of all Franciscan houses; and in 1309 his "art" was publicly approved by a decree of the university of Paris. Emboldened perhaps by such recognition, he appeared before the council of Vienne in southern France in 1311, and petitioned the assembled fathers to reduce the different and often-contending religious orders to one great order serving simply under Christ, and to meet Mohammedanism abroad and Averroism at home by founding colleges for the study of Arabic. Nothing would seem to have come directly of these petitions, but we may perhaps trace their result in some chairs of Syriac and Arabic which Clement V. instituted at Rome, and in a college for training Franciscans in Oriental languages which James of Aragon established in Majorca. Lully was now nearly eighty years of age, but his zeal in combating the foes of Christianity did not abate. He sailed again for Africa, and received the martyr's crown, which would seem to have become the ambition of his life. At Bougiah he again proclaimed the doctrines of the church, and his preaching raised such a tumultuous attack that although he managed to get on board a Genoese vessel, he succumbed during the voyage to the injuries he had received, and died in sight of his native town of Palma (1315).

During his lifetime Lully composed a vast number of treatises, some of which have never yet been printed. They were written partly in Latin, partly in Catalonian, Lully deserving mention as one of the first in mediæval times who tried to find a national expression for philosophy in the language of the country. Some of these works may be described as dealing with apologetic theology, *e.g.*, the *Liber de Gentili et Tribus Sapientibus*, in which a Jew, Christian, and Saracen explain the nature of their faith, or the *Disputatio Fidelis et Infidelis*; others again relate to dogmatic divinity, *e.g.*, *Liber de XIV. Articulis, De Deo et Jesu Christo*; a third class refer to particular questions of logic, *e.g.*, *De Prima et Secunda Intentione, Ars Inveniendi Particularia in Universalibus, De Venatione Medii*; and a large number are reputed to deal with questions of alchemy. But the "Great Art" of discovery itself is the subject of most of Lully's treatises. So it is with the *Ars Demonstrativa, Compendium Artis Demonstrativæ, Ars Universalis, Ars Inventiva Veritatis, De Auditu Cabbalistico, Ars Magna et Ultima.* And even when Lully is engaged with such treatises as the *Principia Medicinæ* or *Principia Juris* it is to the universal key of knowledge which the great art supplies that he invariably falls back.

The reasonableness and demonstrability of Christianity is the assumption underlying the exercise of this great method. Nothing, Lully holds, interferes more with the spread of Christianity than the attempt of its advocates to present its doctrines as undemonstrated and undemonstrable truths; the very difference between Christianity and Antichrist lies in the fact that the former can *prove* the truth of its beliefs; and the glory of the faith, repeats the *Liber Magnus Contemplationis*, is not that it maintains the indemonstrable but simply the supersensuous. The demonstration, however, which is wanted in the service of Christianity is not, Lully thinks, that of the ordinary logic; we require a method which will reason not only from effect to cause, or from cause to effect, but *per æquiparantiam*, and show that contrary attributes can coexist together in one subject. This method, however, must be real, not merely formal and subjective; it must deal not only with the second intentions, but rather with the first intentions, that is, the things themselves. The great art in fact goes beyond logic and metaphysic; as a universal topic it provides a universal art of discovery, and contains the formulæ to which every demonstration in every science can be reduced. This *ars investigandi*, however, turns out to be not so much a key to all possible knowledge as a tabulation of the different points of view from which propositions may be framed about various objects—a mechanical contrivance for finding out the different ways in which categories apply to things. Just, Lully thought, as by knowing the typical terminations of cases and tenses we could inflect and conjugate any word whatever, so by a knowledge of the different types of existence and their possible combinations as portrayed by his method we should possess implicitly a knowledge of the whole of nature.

The great art accordingly begins by laying down an alphabet according to which the nine letters from B to K stand for the different kinds of substances and attributes. Thus, in the series of substances, B stands for God, C angel, D heaven, E man, and so on; in the series of absolute attributes, B represents goodness, C greatness, D duration; or again, in the nine questions, B stands for *Utrum*, C for *Quid*, D for *De quo*. The manipulating of these letters in such a way as will show the relationship between different subjects and predicates constitutes accordingly the peculiarity of the "new art," this manipulation being effected by the help of certain so-called "figures." The construction of these figures varies somewhat in different parts of Lully's writings, but their general character is always the same. Circles and other mathematical figures divided into sections and marked by Lully's symbolical letters are so arranged, sometimes with the help of different colours, as to show the possible combinations of which the letters are capable. Thus for example one figure exhibits the possible combination of the attributes of God, another the possible conditions of the soul, and so on. These figures are fenced about by various definitions and rules, and their use is further specified by various "evacuations" and "multiplications" which show us how to exhaust and draw out *all* the possible combinations and sets of questions which the terms under consideration can admit. When so "multiplied," the fourth figure is, Lully himself says, that by which other sciences can be most easily and rapidly acquired; and it may accordingly be taken as no unfair specimen of Lully's method. This fourth figure then is simply an arrangement of three concentric circles (made of tin or pasteboard) each divided into nine sections B, C, D, &c., and so constructed that while the upper and smaller circle remains fixed, the two lower and outer revolve round it. Taking then the letters in the sense of the series which seems most fitted for the subject under discussion, we are enabled by making the outer circles revolve to find out the possible relationships between different conceptions and elucidate the agreement or disagreement which subsists between them, while, at the same time, we discover the intermediate terms (in the middle circle) by which they are to be connected or disconnected.

The weakness of Lully's art is the weakness of every system which pretends, as Bacon's also did, to equalize all intellects, and provide a method which will produce discovery as surely as compasses will construct a circle. But it would be unfair to say that Lully supposed that thinking and reasoning could be reduced to a mere rotation of pasteboard circles. The real value of his art lies not in being an *a priori* compendium of knowledge but a method of investigation—a tabulation of the different sides from which a question must be regarded, and in embodying the ideal which science puts before herself of finally bringing all conceptions into unity and correlation. It is easy, with the Port-Royal logic, to speak of Lully's art as merely enabling us "to talk without judgment of that which we do not know"; but in his conception of scientific method as tending to the glory of God and the good of man, in his departure from the school logic and his wish for a real interpretation of nature, in his conception of a universal method and his application of the vernacular languages to philosophy, he appears as a precursor of Bacon himself. And in his assertion of the place of reason in religion, in his demand that a *rational* Christianity should be presented to heathendom, in his missionary zeal and his project of linguistic colleges, Lully, with all his quixotic character, goes far beyond the ideas and the aspirations of the century in which he lived.

A few of Lully's works were published by Zetzner in 1598 and frequently reprinted; but the first systematic edition was begun by Salzinger in 1721, and after Salzinger's death completed in 1742. This edition is nominally in 10 vols., but vols. vii. and viii. were never published. In addition to older works, such as Perroquet (1667) and Nic. de Hauteville (1666) and the *Acta Sanctorum* (vol. xxiv.), the best account of Lully's life is to be found in an article by Delecluze in the *Revue d. d. Mondes* for 1840, and the fullest account of his method in Prantl, *Geschichte d. Logik*, iii. 145–177, and Erdmann, *Grundriss d. Gesch. d. Philosophie*, i. § 206. The philological importance of Lully's writings is brought out by A. Helfferich, *Raymond Lull und die Anfänge d. Catalonischen Literatur*, Berlin, 1858. (E. W.)

LUMBAGO, a term in medicine applied to a painful ailment affecting the muscles of the lower part of the back, generally regarded as of rheumatic origin. An attack of lumbago may occur alone, or be associated with rheumatism in other parts of the body at the time. It usually comes on by a seizure, often sudden, of pain in one or both sides of the small of the back, of a severe cutting or stabbing character, greatly aggravated on movement of the body, especially in attempting to rise from the recumbent posture, and also in the acts of drawing a deep breath, coughing, or sneezing. So intense is the suffering that it is apt to suggest the existence of inflammation in some of the neighbouring internal organs, such as the kidneys, bowels, &c., but the absence of the symptoms specially characteristic of these latter complaints, or of any great constitutional disturbance beyond the pain, renders the diagnosis a matter of no great difficulty. Lumbago seems to be brought on by exposure to cold and damp, and by the other exciting causes of rheumatism. Sometimes it follows a strain of the muscles of the loins. The attack is in general of short duration, but occasionally it continues for a long time, not in such an acute form as at first, but rather as a feeling of soreness and stiffness on movement. The treatment includes that for rheumatic affections in general (see RHEUMATISM) and the application of local remedies to allay the severe pain. Of these the best are hot fomentations with turpentine or laudanum applied by means of flannel or spongio-piline to the part; or the rubbing in, if this can be borne, of stimulating liniments, such as those of opium, belladonna, chloroform, aconite, &c. The old and homely plan of counter-irritation by applying a heated iron to the part with a sheet of brown paper interposed is often beneficial in chronic cases, as is also, on similar principles, Corrigan's button cautery. The subcutaneous injection of morphia or atropia is called for when the attack is very severe and prevents sleep.

LUMP-SUCKER, or LUMP-FISH (*Cyclopterus lumpus*), a marine fish, which with another genus (*Liparis*) forms a small family (*Discoboli*) closely allied to the Gobies (see GOBY). Like many fishes of the latter family, the lump-suckers have the ventral fins united into a circular concave disk, which, acting as a sucker, enables them to attach themselves firmly to rocks or stones. The body of the lump-sucker (properly so called) is short and thick, with a thick and scaleless skin, covered with rough tubercles, the larger of which are arranged in four series along each side of the body. The first dorsal fin is almost entirely concealed by the skin, appearing merely as a lump on the back. The lump-sucker inhabits the coasts of both sides of the North Atlantic; it is not rare on the British coasts, but becomes more common farther north. It is so sluggish in its habits that individuals have been caught with sea-weed growing on their backs. In the spring the fish approaches the shores to spawn, clearing out a hollow on a stony bottom in which it deposits an immense quantity of pink-coloured ova. Fishermen assert that the male watches the spawn until the young are hatched, a statement which receives confirmation from the fact that the allied gobies, or at least some of them, take similar care of their progeny. The vernacular name, "cock and hen paddle," given to the lump-fish on some parts of the coast, is probably expressive of the difference between the two sexes in their outward appearance, the male being only half or one-third the size of the female, and assuming during the spawning season a bright blue coloration, with red on the lower parts. This fish is generally not esteemed as food, but Faber (*Fisch. Islands*, p. 53) states that the Icelanders consider the flesh of the male as a delicacy.[1] Very peculiar is the structure of the bones, which are so soft, and contain so little inorganic matter, that the old ichthyologists placed the lump-sucker among the cartilaginous fishes.

[1] The "cock-padle" was formerly esteemed also in Scotland, and figures in the *Antiquary*, chap. xi.

LUND, a town of Sweden, in the län of Malmöhus, lies at a distance of 10 miles by rail north-east from Malmö. It is chiefly remarkable for its university, the second in Sweden, founded by Charles XI. in 1666, with faculties of philosophy, law, medicine, and theology; the number of students ranges from 500 to 600. The library contains about 100,000 volumes and 2000 MSS., and there are valuable collections in archæology and natural history. Among the more distinguished of its professors may be mentioned the names of Puffendorf and the poet Tegner. Linnæus was one of its alumni. The cathedral, a Byzantine structure, dedicated to St Lawrence, and said to be on the whole the finest church in Scandinavia, was founded about the middle of the 11th century, and consecrated in 1145. The crypt under the transept and choir is one of the largest in the world. The town has little else of interest to show. The statue of Tegner stands in the Tegner's Plats, and the house in which he lived from 1813 to 1826 is indicated by a stone slab with an inscription. The manufactures of Lund (woollen cloth, leather, tobacco, sugar, &c.) are unimportant. The population in December 1878 was 13,611.

Lund (*Londinum Gothorum*), the "Lunda at Eyrarsundi" of the *Egil's Saga*, was in Egil's time (about 920 A.D.) a place of considerable importance; one gathers that, if not actually a seaport, it was at least nearer the Sound then than at present. In the middle of the 11th century it was made a bishopric, and in 1103 it was advanced to the dignity of an archiepiscopal see, the archbishop receiving primatial rank over all Scandinavia in 1163. The archbishop of Upsala is now primate of Sweden, Lund since 1536 having been reduced to the rank of an ordinary bishopric, and lost its quondam title of "Metropolis Daniæ."

LÜNEBURG, the chief town of a district in the Prussian province of Hanover, is situated near the foot of a small hill named the Kalkberg, and on the river Ilmenau, 14 miles above its confluence with the Elbe, and 30 miles to the south-east of Hamburg. Numerous handsome mediæval buildings testify to its former prosperity, and part of the old town-wall also still survives. Of its four churches three—those of St John, St Nicholas, and St Michael—are large and fine Gothic edifices of the 14th and 15th centuries. The principal secular buildings are the town-house, a huge pile dating from the 13th to the 18th century, the old palace, and the convent of St Michael, now converted into a school. Lüneburg owes its importance chiefly to the gypsum and lime quarries of the Kalkberg, which afford the materials for its cement works, and to the productive salt-spring at its base. Hence the ancient saying, which, grouping with these the commercial facilities afforded by the bridge over the Ilmenau, ascribes the prosperity of Lüneburg to its *mons*, *fons*, *pons*. The industries of the town also include the making of iron-ware, soda, and haircloth. Population in 1880, 19,045.

Lüneburg existed as early as the days of Charlemagne, but did not become of any importance till after the erection of a convent and a castle on the Kalkberg in the 10th century. The decisive event, however, in fixing its future development was the destruction, in 1189, of Bardewieck, situated on the Ilmenau below Lüneburg, and then the chief commercial town in North Germany. Lüneburg inherited its trade, and subsequently appears as one of the leading towns in the Hanseatic League. From 1267 to 1369 it was the capital of an independent principality of its own name, and it was afterwards frequently involved in the quarrels of the Guelphic princes. It reached the height of its prosperity in the 15th century, and even in the 17th was the depôt for all the merchandise exported from Saxony and Bohemia to the mouth of the Elbe. The German war of liberation in 1813 was begun by an engagement with the French under General Morand near Lüneburg. Lüneburg gives its name to the Lüneburger Haide or Lüneburg Heath, an immense tract of moorland occupying the greater part of eastern Hanover.

Compare Volger, *Führer durch die Stadt Lüneburg* and *Urkundenbuch der Stadt Lüneburg*; also the *Alterthümer der Stadt Lüneburg*, 1852-72

LUNÉVILLE, the chief place of an arrondissement in the department of Meurthe and Moselle, France, 240 miles east of Paris by rail on the line to Strasburg, stands in the midst of meadows between the Meurthe and the Vezouze a little above their confluence. It is a handsome town regularly built. The chateau, designed early in the 18th century by the royal architect Boffrand, was the favourite residence of Duke Leopold of Lorraine, where he gathered round him the academy composed of eminent men of the district. It is now a cavalry barrack. Lunéville has always been an important cavalry station, and has a riding school where two hundred horsemen can exercise at the same time. The church of St Jacques, with its two towers, dates from the same period as the chateau. The church of St Maur, in the Byzantine style, is but thirty years old. The district round Lunéville is mainly agricultural, and the town has a fine corn exchange. The manufactures include pottery, embroideries, gloves, cotton cloth, and cooking stoves. There are starch works and gypsum kilns, and a considerable trade in grain, flour, hops, and other agricultural produce. The population in 1876 was 16,041.

The name of Lunéville is derived from an ancient cult of Diana. A sacred fountain and medals with the effigy of this goddess have been found at Leormont, some 2 miles east of the town. Lunéville formed part of Austrasia, and after various changes fell to the crown of Lorraine. A walled town in the Middle Ages, it suffered in the Thirty Years' War and in the campaigns of Louis XIV. from war and its consequences—plague and famine. The town flourished again under Dukes Leopold and Stanislas, on the death of the latter of whom, which took place at Lunéville, Lorraine was united to France (1766). The treaty of Lunéville between France and Austria (1801) confirmed the former power in the possession of the left bank of the Rhine. The town was the birthplace of the emperor Francis, husband of Maria Theresa, and of the painter Jean Girardet.

LUPERCALIA, one of the most remarkable and interesting Roman festivals. Its origin is attributed to Evander, or to Romulus before he founded the city, and its ceremonial is in many respects unique in Roman ritual. In front of the Porta Romana, on the western side of the Palatine hill, close to the *Ficus Ruminalis* and the *Casa Romuli*, was the cave of Lupercus; in it, according to the legend, the she-wolf had suckled the twins, and the bronze wolf which is still preserved in the Capitol was placed in it in 296 B.C. But the festival itself, which was held on February 15th under the direction of the *flamen dialis*, contains no reference to the Romulus legend, which is probably later in origin (see Mommsen in *Hermes*, 1881). The celebrants, who were called Luperci, offered in sacrifice goats and a dog; the *flamen dialis* himself was forbidden to touch either kind of animal, and it can hardly be doubted that the Lupercal sacrifice is older than the prohibition. After the sacrifice two of the Luperci were led to the altar, their foreheads were touched with a bloody sword, and the blood wiped off with wool dipped in milk; then the ritual required that the two young men should laugh. The sacrificial feast followed, after which the Luperci cut thongs from the skins of the victims and ran in two bands round the walls of the old Palatine city, striking the people who crowded near. A blow from the thong prevented sterility in women. These thongs were called *Februa*, the festival *Februatio*, and the day *Dies Februetus*; hence arose the name of the month February, the last of the old Roman year. The nearest analogy in the Roman religion to the Lupercalia is the occasional Amburbium, in which the victims were led round the walls of Rome and then sacrificed. The Lupercalia was associated with the circuit of the Palatine city, which had been a city long before the seven-hilled Rome, and the line of the old Palatine walls was marked with stones for the Luperci to run round. Unger has proved that the festival was originally a rite peculiar to the tribe of the Ramnes, the old dwellers on the Palatine, and that it was in the 3d century B.C. widened to a festival of the whole city. It is probable that then the whole ceremonial was modified; the Luperci, who were originally chosen from the Ramnes alone, were chosen from the whole body of the Equites, the people assembled round the hill, and the ceremony of scourging to avert sterility was added. Originally therefore the Luperci simply encompassed the walls as the victims did at the Amburbium, and the ceremonial connected with the two young men has generally been taken as a proof that they were at one time actually sacrificed after being led round the walls, and that a vicarious sacrifice was afterwards substituted for the ancient human offering. The Lupercalia was therefore a ceremony of purification performed for the walls and for the whole of the old Palatine city, from which it follows that it was dedicated to the peculiar god of that city. In early time the name of the god was kept strictly secret, as it was unsafe that an enemy should know it and be able to invoke him. Hence arise many conflicting statements as to the name. In later times, when the bonds of early religion were relaxed, the name became known. The god was, as Livy relates, Inuus, an old Italian deity known chiefly in southern Etruria, where there existed two towns named Castrum Inui. He was a form of the supreme heaven-god, very like Mars in character, and the rites with which his anger was averted may be compared with those of Zeus on Mount Pelion or with the Maimacteria in Athens. The Luperci were divided into two *collegia* called Quintiliani or Quinctiales (the form is doubtful, see Mommsen, *Röm. Forsch.*, i. 17) and Fabiani; at the head of each was a *magister*. In 44 B.C. a third *collegium*, *Juliani*, was instituted in honour of Julius Cæsar, the first *magister* of which was M. Antony.

This account follows in almost every particular that of Unger (*Rhein. Mus.*, 1881). He derives Lupercus from *lua* and *parco* in the old sense of restrain, and Inuus from a root seen in *avis inubra* or *inebra*, ἀναίνομαι, &c., meaning to avert or prohibit, and sees in the festival a national ceremony of the Palatine city, not with Marquardt (*Röm. Staatsverw.*, iii. 421) a widened gentile cultus of the Fabri and Quinctii or Quintilii.

LUPINE, *Lupinus*, L., a genus, of over eighty species, of the tribe *Genisteæ* of the order *Leguminosæ*. Species with digitate leaves range along the west side of America from British Columbia to Bolivia, while a few occur in the Mediterranean regions. A few others with entire leaves are found in South Carolina, the Cape, and Cochin-China (DC., *Prod.*, ii. p. 406; Benth. and Hook., *Gen. Pl.*, i. 480). The leaves are remarkable for "sleeping" in three different ways. From being in the form of a horizontal star by day, the leaflets either fall and form a hollow cone with their bases upwards (*L. pilosus*), or rise and the cone is inverted (*L. luteus*), or else the shorter leaflets fall and the longer rise, and so together form a vertical star (many sp.); the object in every case being to protect the surfaces of the leaflets from radiation (Darwin, *Movements of Pl.*, p. 340). The flowers are of the usual "papilionaceous" or pea-like form, blue, white, purple, or yellow, in long terminal spikes. The stamens are monadelphous and bear dimorphic anthers. The species of which earliest mention is made is probably *L. Termis*, Forsk., of Egypt. This is possibly the ἐρέβινθος of Homer (*Il.*, xiii. 589). It is no longer found in Greece, but is extensively cultivated in Egypt. Its seeds are eaten by the poor after being steeped in water to remove their bitterness; the stems furnish fuel and the best charcoal for gunpowder (Pick., *Chron. Hist. of Pl.*, 183). Two other species appear to have been cultivated by the ancients, *L. sativus* (*albus*, L.) allied to *L. Termis*, and *L. hirsutus*, L., this latter only about Sparta (Pick., *l.c.*, p. 202); *L. angustifolius*, L., was a corn-field weed, the θέρμος ἄγριος of Dioscorides. The θέρμος ἥμερος was used to counteract the effects of drink (Athen., 55, C.). The seeds were used as money on the stage (Plaut., *Pœn.*, 3, 2, 20; Hor., *Ep.*, i. 7, 23). *L. albus*, L., was also cultivated as a field lupine, the *L. sativus* of the Romans, referred to by Cato, *R. R.*, 34, 2; Virgil, *Georg.*, i. 75; Pliny, xviii. 36; &c. In 1597 Gerard (*Herball*, p. 1042) writes:—"There be diuers sortes of the flat Beane called Lupine, some of the garden, and others wild"; and he figures three species, *L. sativus* (now *L. albus*, L.), *L. luteus*, L., and *L. varius*, L. Few species are in cultivation now, but the varieties are very numerous (see Paxton's *Bot. Dict.*, p. 345; Hemsley's *Hand. of Hardy Trees*, &c., p. 115). Of species now grown, *L. albus*, L., is still extensively cultivated in Italy, Sicily, and other Mediterranean countries for forage, for ploughing in to enrich the land, and for its round flat seeds, which form an article of food. This, as well as the other two mentioned by Gerard, have been superseded as garden flowers by the American species, *e.g.*, *L. arboreus*, Sims, and *L. polyphyllus*, from California; *L. versicolor* and *L. tomentosus*, from Peru.

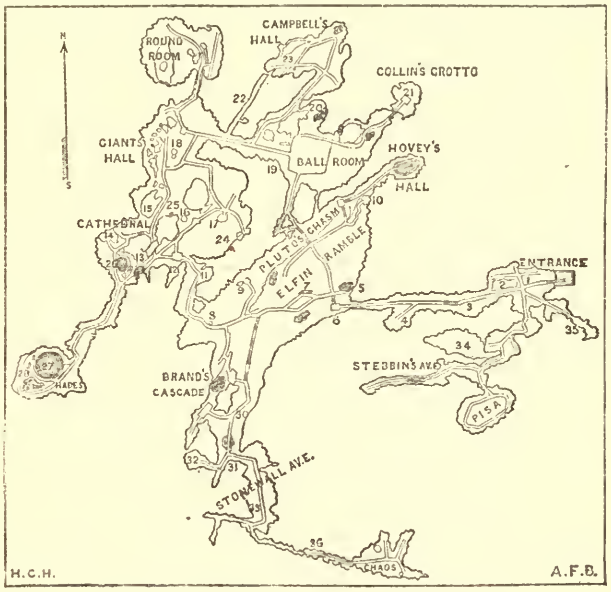
LURAY CAVERN, in Page county, Virginia, United States, 39° 35′ N. lat. and 78° 17′ W. long., is 1 mile west of the village of Luray, on the Shenandoah Valley Railroad. The valley, here 10 miles wide, extends from the Blue Ridge to the Massanutton mountain, and displays remarkably fine scenery. These ridges lie in vast folds and wrinkles; and elevations in the valley are often found to be pierced by erosion. Cave Hill, 300 feet above the water-level, had long been an object of local interest on account of its pits and oval hollows, or sink-holes, through one of which, August 13, 1878, Mr Andrew J. Campbell and others entered, thus discovering the extensive and beautiful cavern now described.

Geologically considered, the Luray cavern does not date beyond the Tertiary period, though carved from the Silurian limestone. At some period long subsequent to its original excavation, and after many large stalactites had grown, it was completely filled with glacial mud charged with acid, whereby the dripstone was eroded into singularly grotesque shapes. After the mud had been mostly removed by flowing water, these eroded forms remained amid the new growths. To this contrast may be ascribed some of the most striking scenes in the cave. The many and extraordinary monuments of aqueous energy include massive columns wrenched from their place in the ceiling and prostrate on the floor; the hollow column 40 feet high and 30 feet in diameter, standing erect, but pierced by a tubular passage from top to bottom; the leaning column, nearly as large, undermined and tilting like the campanile of Pisa; the organ, a cluster of stalactites dropped points downward and standing thus in the room known as the cathedral; besides a vast bed of disintegrated carbonates left by the whirling flood in its retreat through the great space called the Elfin Ramble.

The stalactitic display exceeds that of any other cavern known, and there is hardly a square yard on the walls or ceiling that is not thus ornamented. The old material is yellow, brown, or red; and its wavy surface often shows layers like the gnarled grain of costly woods. The new stalactites growing from the old, and made of hard carbonates that had already once been used, are usually white as snow, though often pink, blue, or amber-coloured. The size attained by single specimens is surprising. The Empress Column is a stalagmite 35 feet high, rose-coloured, and elaborately draped. The double column, named from Professors Henry and Baird, is made of two fluted pillars side by side, the one 25 and the other 60 feet high, a mass of snowy alabaster. Several stalactites in the Giant Hall exceed 50 feet in length. The smaller pendents are innumerable; in the canopy above the Imperial Spring it is estimated that 40,000 are visible at once.

The "cascades" pointed out are wonderful formations like foaming cataracts caught in mid-air and transformed into milk-white or amber alabaster. The Chalcedony Cascade displays a variety of colours. Brand's Cascade, which is the finest of all, being 40 feet high and 30 feet wide, is unsullied and wax-like white, each ripple and braided rill seeming to have been polished.

The Swords of the Titans are monstrous blades, eight in number, 50 feet long, 3 to 8 feet wide, hollow, 1 to 2 feet thick, but drawn down to an extremely thin edge, and filling the cavern with tones like tolling bells when struck heavily by the hand. Their origin and also that of certain so-called scarfs and blankets exhibited is from carbonates deposited by water trickling down a sloping and corrugated



Luray Cavern. Scale 290 feet to the inch.

1. The Vestibule.	13. Saracen's Tent.	25. Helen's Scarf.
2. Washington's Pillar.	14. The Organ.	26. Chapman's Lake.
3. Flower Garden.	15. Tower of Babel.	27. Broaddus Lake.
4. Amphitheatre.	16. Empress Column.	28. Castles on the Rhine.
5. Natural Bridge.	17. Hollow Column.	29. Imperial Spring.
6. Fish Market.	18. Henry-Baird Column.	30. The Skeleton.
7. Crystal Spring.	19. Chalcedony Cascade.	31. The Twin Lakes.
8. Proserpine's Pillar.	20. Coral Spring.	32. The Engine Room.
9. The Spectral Column.	21. The Dragon.	33. Miller's Room.
10. Hovey's Balcony.	22. Bootjack Alley.	34. Hawes Cabinet.
11. Oberon's Grot.	23. Scaly Column.	35. Specimen Avenue.
12. Titania's Veil.	24. Lost Blanket.	36. Proposed Exit.

surface. Sixteen of these alabaster scarfs hang side by side in Hovey's Balcony, three white and fine as crape shawls, thirteen striated like agate with every shade of brown, and all perfectly translucent. Down the edge of each a tiny rill glistens like silver, and this is the ever-plying shuttle that weaves the fairy fabric.

Streams and true springs are absent, but there are hundreds of basins, varying from 1 to 50 feet in diameter, and from 6 inches to 15 feet in depth. The water in them is exquisitely pure, except as it is impregnated by the carbonate of lime, which often forms concretions, called, according to their size, pearls, eggs, and snowballs. A large one is known as the cannon ball. On fracture these spherical growths are found to be radiated in structure.

Calcite crystals, drusy, feathery, or fern-like, line the sides and bottom of every water-filled cavity, and indeed constitute the substance of which they are made. Variations of level at different periods are marked by rings, ridges, and ruffled margins. These are strongly marked about Broaddus Lake, and the curved ramparts of the Castles on the Rhine. Here also are polished stalagmites, a rich buff slashed with white, and others, like huge mushrooms, with a velvety coat of red, purple, or olive-tinted crystals. In some of the smaller basins it sometimes happens that when the excess of carbonic acid escapes rapidly there is formed, besides the crystal bed below, a film above, shot like a sheet of ice across the surface. One pool 12 feet wide is thus covered so as to show but a third of its surface. The quantity of water in the cavern varies greatly at different seasons. Hence some stalactites have their tips under water long enough to allow tassels of crystals to grow on them, which, in a drier season, are again coated over with stalactitic matter; and thus singular distortions are occasioned. Contiguous stalactites are often inwrapped thus till they assume an almost globular form, through which, by making a section, the primary tubes appear. Twig-like projections, lateral outgrowths, to which the term helictite has been applied, are met with in certain portions of the cave, and are interesting by their strange and uncouth contortions. Their presence is partly due to the existence of a diminutive fungus peculiar to the locality, and designated from its habitat *Mucor stalactitis*. The Toy-Shop is an amusing collection of these freaks of nature.

The dimensions of the various chambers included in Luray Cavern cannot easily be stated, on account of the great irregularity of their outlines. Their size may be seen from the diagram on p. 67. But it should be understood that there are several tiers of galleries, and the vertical depth from the highest to the lowest is 260 feet. The tract of 100 acres owned by the Luray Cave Company covers all possible modes of entrance; and the explored area is much less than that.

The waters of this cavern appear to be entirely destitute of life; and the existing fauna is quite meagre, comprising only a few bats, rats, mice, spiders, flies, and small centipedes. When the cave was first entered, the floor was covered with thousands of tracks of raccoons, wolves, and bears,—most of them probably made long ago, as impressions made in the tenacious clay that composes most of the cavern floor would remain unchanged for centuries. Layers of excrementitious matter appear, and also many small bones, along with a few large ones, all of existing species. The traces of human occupation as yet discovered are pieces of charcoal, flints, moccasin tracks, and a single skeleton imbedded in stalagmite in one of the chasms, estimated to have lain where found for not more than five hundred years, judging from the present rate of stalagmitic growth.

The temperature is uniformly 54° Fahr., coinciding with that of the Mammoth Cave, Kentucky. The air is very pure, and the avenues are not uncomfortably damp.

The portions open to the public are now lighted by electric lamps. The registered number of visiters in 1881 was 12,000. (H. C. H.)

LURGAN, a market-town in the county of Armagh and province of Ulster, Ireland, is situated a few miles south of Lough Neagh, and 20 miles south-west of Belfast by rail. It consists principally of one spacious and well-built street. The parish church of Shankill has a finely proportioned tower. The other principal public buildings are the town-hall, the mechanics' institute, the model school, and the linen-hall. Contiguous to the town is Brownlow House, a fine Elizabethan structure, the seat of Lord Lurgan. Of late years the linen trade of the town has much increased, and there are also tobacco factories and coach factories. From 7774 in 1861 the population increased in 1871 to 10,632, but in 1881 it was only 10,184.

Lurgan was built by William Brownlow, to whom a grant of the town was made by James I. In 1619 it consisted of forty-two houses, all inhabited by English settlers. It was burned by the insurgents in 1641, and again by the troops of James II. After its restoration in 1690 a patent for a market and fair was obtained.

LURISTAN, or LÚRISTÁN, a province of western Persia, with ill-defined limits, but lying mainly between 31° and 33° N. lat. and between 47° and 52° E. long., and bounded N. and E. by Irak-Adjemi, S. by Farsistan, W. by Khuzistan and the Turkish vilayet of Baghdad. It thus stretches north-west and south-east some 260 miles, with a mean breadth of 70 miles and an area of rather less than 20,000 square miles. The surface is mostly mountainous, being occupied in the west by the Pusht-i-koh range, which forms the frontier line towards Turkey, in the east by the Bakhtiari (Zagros) range, which runs north-west and south-east, thus connecting the Kurdistan with the Kuh-Dinar or Farsistan highland systems. Between the parallel Pusht-i-koh and Bakhtiari chains there stretch some naturally fertile plains and low hilly districts, which, however, are little cultivated, although well-watered by the Karun, Dizful, and Kerkhah, the three chief rivers of the province. There are two main divisions—Luri Buzurg, or "Great Luristan," comprising the Bakhtiari highlands westwards to river Dizful, and Luri Kuchak, or "Little Luristan," stretching thence to Khuzistan and Turkey. The latter is again divided into the Pesh-koh and Pusht-i-koh districts ("before" and "behind" the mountains), and notwithstanding its name is by far the most populous and productive of the two. From the 12th to the 17th century it formed an independent principality under hereditary rulers with the title of "atabeg," the last of whom was deposed by Shah Abbas, and the government transferred to Husen Khan, chief of the Faili tribe, with the title of "vali." His descendants are still at the head of the administration; but the power of the valis has been much reduced since the transfer of the Pesh-koh district to Kirmanshah.

Lúristán takes its name from the Luri,[1] a semi-nomad people of Iranian stock and speech, who still form the vast majority of the population. Great uncertainty has hitherto prevailed regarding the nomenclature, the main divisions and the true affinity of the Luri to the other branches of the Iranian family. Thus, from the name of the present ruling clan all the tribes of Luri Kuchak are commonly spoken of as "Faili," a term which is now rejected by the Pesh-koh tribes, and which, if used at all as a general ethnical expression, ought to be restricted to those of Pusht-i-koh, still under the rule of the vali. The classifications of Layard, Rawlinson, and A. H. Schindler differ materially, while contradictory statements are made by well-informed writers regarding the physical and linguistic relations of the Luri to the neighbouring Kurds and Persians. From a careful consideration of the available evidence it would appear that the Luri are the true aborigines of their present domain, where they occupy an intermediate position between the Kurds and Persians, but resembling the former much more than the latter in speech, temperament, social habits, and physical appearance. Although they themselves reject the name of Kurd, the two languages are essentially one, so that the natives of Kirmanshah and Dizful have little difficulty in conversing together. Like the Kurds, they are also of a restless and unruly disposition, averse from a settled life, still dwellers in tents, mostly owners of flocks and herds, holding agriculture in contempt, and of predatory habits. "In appearance the Bakhtiari look rather fierce, owing probably to the mode of life they lead; the features of their face are cast in a rough mould, but although coarse they are in general regular. Their black eyes look wild and expressive, and the two black tufts of hair behind their ears give them, if possible, a still darker appearance. They are muscular built, and are chiefly of a middle stature" (E. Balfour). In a word, the Luri must be classed anthropologically in the same group as the Kurds. They are excellent stock breeders, and their horses and mules are regarded as the very best in Persia. Of the mules, about a thousand are annually exported to the surrounding provinces. Most of the hard work is left to the women, who tend the flocks, till the little land under cultivation, tread out the corn, and weave the carpets, black goat-hair tents, and horse cloths for which Luristan is famous. The men put their hands to no useful work, go about armed, and are always ready for a foray. Their constant intertribal feuds render the country unsafe for trade and travel, while their revolts against the central government often cause a total interruption of communi-

[1] Not to be confounded with the *Luri* or *Lori* of Baluchistan and Sind, tinkers, bards, strolling minstrels, &c., betraying a "marked affinity to the Gipsies of Europe" (Pottinger).

cation between the several districts. This evil, however, has somewhat abated since the tribal chiefs have been compelled to give hostages as security for their good behaviour.

Outwardly Mohammedans of the Shiah sect, the Lúri show little veneration either for the Prophet or the Koran. Their religion seems to be a curious mixture of Ali-Ilahism, involving a belief in successive incarnations and the worship of the national saint, Baba Buzurg, combined with many mysterious rites, sacrifices, and secret meetings certainly anterior to Islam, and possibly traceable to the ancient rites of Mithras and Anaitis.

The chiefs enjoy almost unlimited authority over their subjects, and the tribal organization is strongly marked by the feudal spirit.

The total population of Luristan is about 320,000, and the average revenue nearly £40,000 sterling.

LUSATIA (German, *Lausitz*) is a common name applied to two neighbouring districts in Germany, Lusatia Superior and Lusatia Inferior (Oberlausitz and Niederlausitz), belonging in part to Prussia and in part to Saxony. The country now known as Upper Lusatia was occupied in the 7th century by the Milcieni, a Slavonic tribe. In the 10th century it was annexed to the German kingdom by the margraves of Meissen, and from this time for several centuries it was called Budissin (Bautzen), from the name of the principal fortress. In the 11th and 12th centuries Budissin changed hands several times, being connected at different periods with Meissen, Poland, and Bohemia. The emperor Frederick I. granted it in 1158 to King Ladislaus of Bohemia, and under him and his immediate successors it was largely colonized by German immigrants. Between 1253 and 1319 it belonged to Brandenburg, to the margrave of which it was given in pledge by King Ottocar II. of Bohemia; and in 1268 it was divided into an eastern and a western part—Budissin proper and Görlitz. In 1319 Budissin proper was restored to Bohemia, which also recovered Görlitz in 1346. It was during this period that the fortunes of Budissin were associated with those of the country afterwards called Lower Lusatia, but originally Lusatia. It was inhabited by a Slavonic tribe, the Lusici, and reached in the earliest times from the Black Elster to the Spree. The Lusici were conquered by Margrave Gero in 963, and their land was soon formed into a separate march, sometimes attached to, sometimes independent of, the march of Meissen. In 1303 it passed, as Budissin had done, to Brandenburg, and in 1373, after several changes, it fell into the hands of the emperor Charles IV. as king of Bohemia. During the Hussite wars the people of Lusatia and Budissin remained loyal to the Roman Catholic Church, and in 1467 they recognized as their sovereign King Matthias of Hungary. Twenty-three years later they were again united to Bohemia, but in the meantime they had received from the Hungarian Government the names which they have since retained. In the 16th century the Reformation made way rapidly in Upper Lusatia, and the majority of the people became Protestants. The two countries were conquered in 1620, with the sanction of Ferdinand II., by the Saxon elector, John George I., to whom they were ceded in 1635, the emperor as king of Bohemia retaining a certain supremacy for the purpose of guarding the rights and privileges of the Roman Catholic Church. In 1815 the whole of Lower Lusatia and the half of Upper Lusatia were transferred from Saxony to Prussia. Lower Lusatia has 395,800 inhabitants, of whom 50,000 are Wends; the portion of Upper Lusatia belonging to Prussia has 243,500 inhabitants, of whom 32,000 are Wends. There are 300,000 inhabitants, including 50,000 Wends, in Saxon Upper Lusatia. Laws relating to Upper Lusatia, which are passed by the Saxon Parliament, must still be submitted to the Lusatian diet at Bautzen.

LUSHAI OR KUKI HILLS, a wild and imperfectly known tract of country on the north-eastern frontier of India, extending along the southern border of the Assam district of Cáchár and the eastern border of the Bengal district of Chittagong. On the east, the Lushái Hills stretch away into the unexplored mountains of Independent Burmah. This extensive region is occupied by a numerous family of tribes known to us indifferently as Lusháis or Kukis. All these tribes are nomadic in their habits, and subject to successive waves of migration. It is said that at the present time the entire race of the Lusháis is being forced southwards into British territory under pressure from the Soktis, a tribe advancing upon them from Independent Burmah. The principal characteristic common to all the Lusháis, and in which they markedly differ from the other tribes on the Assam frontier, is their feudal organization under hereditary chiefs. Each village is under the military command of a chief, who must come of a certain royal stock. The chief exercises absolute power in the village; and his dignity and wealth are maintained by a large number of slaves and by fixed contributions of labour from his free subjects. Cultivation is carried on according to the nomadic system of tillage on temporary clearings in the jungle; but the main occupation of the people is hunting and warfare

From the earliest times the Lusháis have been notorious for their sanguinary raids into British territory, which are said to be instigated by their desire to obtain human heads for use at their funeral ceremonies. The first of which we have record was in 1777. In 1849 a colony of Lusháis settled within Cáchár, was attacked by their independent kinsmen, and forced to migrate northwards across the Barák river, where they now live as peaceable British subjects, and are known as "Old Kukis." In 1860 a raid was made upon Tipperah district, in which 186 Bengálí villagers were massacred and 100 carried away into captivity. Retributive expeditions, consisting of small forces of sepoys, were repeatedly sent to punish these raids, but, owing to the difficult nature of the country and the fugitive tactics of the enemy, no permanent advantage was gained. At last the disturbed state of the frontier attracted the attention of the supreme government. A military demonstration in 1869 had entirely failed in its object. Relying upon their belief in the impracticable character of their native country, the Lusháis made a series of simultaneous attacks in January 1871 upon British villages in Cáchár, Sylhet, and Tipperah, as well as on the independent state of Manipur. The outpost of Monierkhál repelled a number of attacks, lasting through two days, made by a second body of Lusháis from the eastern tribes, who finally retired with a large amount of plunder, including many coolies and guns. Lord Mayo, the viceroy, resolved to make a vigorous effort to stop those inroads, once and for all. A punitive expedition was organized, composed of two Gúrkha battalions, two Punjab and two Bengal native infantry regiments, two companies of sappers and miners, and a detachment of the Pesháwar mountain battery. This little army was divided into two columns, one advancing from Cáchár and the other from the Chittagong side. Both columns were completely successful. The resistance of the Lusháis, though obstinate in parts, was completely overcome, and the chiefs made their personal submission and accepted the terms offered them. Upwards of one hundred British subjects were liberated from captivity. The actual British loss in fighting was very small, but a large number of soldiers and camp-followers died from cholera. Since this expedition, the Lusháis have remained quiet along the entire frontier, and active measures have been taken to open commercial intercourse between them and the people of the plains. Many *bázárs* have been established for this purpose, and trade by barter is now freely carried on.

LUSTRATION is a term that includes all the methods of purification and expiation among the Greeks and Romans. Among the Greeks there are two ideas clearly distinguishable—that human nature must purify itself from guilt before it is fit to enter into communion with God or even to associate with men (καθαίρω, κάθαρσις), and that guilt must be expiated voluntarily by certain processes which God has revealed in order to avoid the punishment that must otherwise overtake it (ἱλασμός). It is not possible to make such a distinction among the Latin terms *lustratio*, *piacula*, *piamenta*, *cærimoniæ*, and even among the Greeks it is not consistently observed. The conception of sin never reached a high moral standard, and the methods of lustration are purely ritualistic. Guilt and impurity arose in various ways; among the Greeks, besides the general idea that man is always in need of purification, the species of guilt most insisted on by religion are incurred by murder, by touching a dead body, by sexual intercourse, and by seeing a prodigy or sign of the divine will. The last three of these spring from the idea that man had been without preparation and in an improper manner brought into communication with God, and was therefore guilty. The first, which involves a really moral idea of guilt, is far more important than the others in Hellenic religion. Among the Romans we hear more of the last species of impurity; in general the idea takes the form that after some great disaster the people become convinced that some guilt has been incurred somewhere and must be expiated. The methods of purification consist in ceremonies performed with water, fire, air, or earth, or with a branch of a sacred tree, especially of the laurel, and also in sacrifice and other ceremonial. Before entering a temple the worshipper dipped his hand in the vase of holy water (*περιρραντήριον*, *aqua lustralis*) which stood at the door; before a sacrifice bathing was a common kind of purification; salt-water was more efficacious than fresh, and the celebrants of the Eleusinian mysteries bathed in the sea (*ἅλαδε μύσται*); the water was more efficacious if a firebrand from the altar were plunged in it. The torch, fire, and sulphur (*τὸ θεῖον*) were also powerful purifying agents. Purification by air was most frequent in the Dionysiac mysteries; puppets suspended and swinging in the air (*oscilla*) formed one way of using the lustrative power of the air. Rubbing with sand and salt was another excellent method. The sacrifice chiefly used for purification by the Greeks was a pig; among the Romans it was always, except in the Lupercalia, a pig, a sheep, and a bull (*suovetaurilia*). In Athens a purificatory sacrifice and prayer was held before every public meeting; the Maimacteria in honour of Zeus Meilichios was an annual festival of purification, and several other feasts had the same character. On extraordinary occasions lustrations were performed for a whole city. So Athens was purified by Epimenides after the Cylonian massacre, and Delos in the Peloponnesian War. In Rome, besides such annual ceremonies as the *Ambarvalia*, *Lupercalia*, *Cerealia*, *Paganalia*, &c., there was a lustration of the fleet before it sailed, and of the army before it marched. Part of the ceremonial always consisted in leading or carrying the victims round the impure persons or things. After any disaster the *lustratio classium* or *exercitus* was often again performed, so as to make certain that the gods got all their due. The *Amburbium* was a similar ceremonial performed for the whole city on occasions of great danger or calamity. *Ambilustrium* was the purificatory ceremony, consisting in sacrifice and prayer, performed after the regular quinquennial census of the Roman people.

LUTE. The European lute is derived in form and name from the Arabic "el 'ûd," "the wood," the consonant of the article "el" having been retained in the European languages for the initial of the name (French, *luth*; Ital., *liuto*; Span., *laud*; German, *Laute*; Dutch, *luit*). The Arab instrument, with convex sound-body, pointing to the resonance board or membrane having been originally placed upon a gourd, was strung with silk and played with a plectrum of shell or quill. It was adopted by the Arabs from Persia, the typical instrument being the two-stringed "tanbur," and ultimately found its way to the West at the time of the crusades. The modern Egyptian "'ûd" is the direct descendant of the Arabic lute, and, according to Lane, is strung with seven pairs of catgut strings played by a plectrum. A specimen at South Kensington, given by the Khedive, has four pairs only, which appears to have been the old stringing of the instrument. When frets are employed they are of catgut disposed according to the Arabic scale of seventeen intervals in the octave, consisting of twelve limmas, an interval rather less than our equal semitone, and five commas, which are very small but quite recognizable differences of pitch.

The lute family is separated from the guitars, also of Eastern origin, by the formation of the sound body, which is in all lutes pear-shaped, without the sides or ribs necessary to the structure of the flat-backed guitar and cither. Observing this distinction, we include with the lute the little Neapolitan mandoline of 2 feet long, and the large double-necked Roman chitarrone, which not unfrequently attains to a length of 6 feet. Mandolines are partly strung with wire, and are played with a plectrum, indispensable for metal or short strings. Perhaps the earliest lutes were so played, but the large lutes and theorbos strung with catgut have been invariably touched by the fingers only, the length permitting this more sympathetic means of producing the tone.

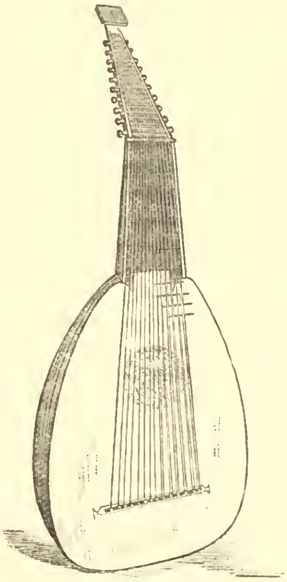
The Neapolitan is the best known mandoline; it was indicated by Mozart in the score of *Don Giovanni*, to accompany the famous serenade. The four pairs of strings are tuned like the violin, in fifths :—

The Milanese is larger, and has five and six pairs :—

or, as in a specimen at South Kensington,

The mandola or mandore is larger than either, with eight pairs of strings. This name has been derived from the Italian word, similarly spelled but differently accented, signifying almond, which the mandola is supposed to resemble in shape, but *ban*, *man*, *pan*, and *tan* are first syllables of lute and guitar instruments met with all over the world, the oldest form of which is the borrowed Greek "*πανδοῦρα*," an Asiatic word, which the Arabs changed to "tanbur." Prætorius (*Organographia*, Wolfenbüttel, 1619, a scarce work, of which the only copy in Great Britain is in the Advocates' Library, Edinburgh), writing when the lute was in universal favour, mentions seven varieties distinguished by size and tuning. The smallest would be larger than a mandoline, and the melody string, the "chanterelle," often a single string, lower in pitch. Prætorius calls this an octave lute, with the chanterelle C or D. The two discant lutes have respectively B and A, the alto G, the tenor E, the bass D, and the great octave bass G, an octave below the alto lute which may be taken as the model lute cultivated by the amateurs of the time. The bass lutes were most likely theorbos, that is, double-necked lutes, as described below. The accordance of an alto lute was

founded upon that of the original eight-stringed European lute, to which the highest and lowest notes had, in course of time, been added. A later addition was the  also on the finger-board, and bass strings, double or single, known as diapasons, which, descending to the deep C of the violoncello, were not stopped with the fingers. The diapasons were tuned as the key of the piece of music required. The illustration represents an Italian instrument made by one of the most celebrated lute makers, Venere of Padua, in 1600; it is 3 feet 6 inches high, and has six pairs of unisons and eight single diapasons. The finger-board, divided into approximately equal half tones by the frets, as a rule eight in number, was often further divided on the higher notes, for ten, eleven, or, as in the woodcut, even twelve, semitones. The head, bearing the tuning pegs, was placed at an obtuse or a right angle to the neck, to increase the bearing of the strings upon the nut, and be convenient for sudden requirements of tuning during performance, the trouble of keeping a lute in tune being proverbial.


Lute, by Venere of Padua.

The lute was in general use during the 16th and 17th centuries. In the 18th it declined; still the great J. S. Bach wrote a "partita" for it, which remains in manuscript. The latest date we have met with of an engraved publication for the lute is 1760.

The large double-necked lute, with two sets of tuning pegs, the lower for the finger-board, the higher for the diapason strings, was known as the theorbo; also, and especially in England, as the archlute; and, in a special form, the neck being then very long, as the chitarrone. Theorbo and chitarrone appear together at the close of the 16th century, and their introduction was synchronous with the rise of accompanied monody in music, that is, of the oratorio and the opera. Peri, Caccini, and Monteverde used theorbos to accompany their newly-devised recitative, the invention of which in Florence, from the impulse of the Renaissance, is well known. The height of a theorbo varied from 3 feet 6 inches to 5 feet, the Paduan being always the largest, excepting the Roman 6-feet long chitarrone. These large lutes had very deep notes, and doubtless great liberties were allowed in tuning, but the strings on the finger-board followed the lute accordance already given, or another quoted by Baron (*Untersuchung des Instruments der Lauten*, Nuremberg, 1727) as the old theorbo or "violway" (see Mace, *Musick's Monument*, London, 1676):—

We find again both these accordances varied and transposed a tone higher, perhaps with thinner strings, or to accommodate local differences of pitch; Prætorius recommends the chanterelles of theorbos being tuned an octave lower on account of the great strain. By such a change, another authority, the Englishman Thomas Mace, says, the life and spruceness of airy lessons were quite lost. The theorbo or archlute had at last to give way to the violoncello and double bass, which are still used to accompany the "recitativo secco" in oratorios and operas. Handel wrote a part for a theorbo in *Esther* (1720); after that date it appears no more in orchestral scores, but remained in private use until nearly the end of the century.

We cannot refrain from admiring the beauty of decoration of ivory, mother of pearl, and tortoiseshell, the characteristic patterning of the "knots" or "roses" in the sound-boards, all of which was so well allied with the extremely artistic forms of the different lutes, rendering them, now their musical use is past, objects of research for collections and museums. The present direction of musical taste and composition is adverse to the cultivation of such tenderly sensitive timbre as the lute possessed. The lute and the organ share the distinction of being the first instruments for which the oldest instrumental compositions we possess were written. It was not for the lute, however, in our present notation, but in tablature, "lyrawise," a system by which as many lines were drawn horizontally as there were pairs of strings on the finger-board, the frets being distinguished by the letters of the alphabet, repeated from A for each line. This was the English manner; the Italian was by numbers instead of letters. The signs of time were placed over the stave, and were not repeated unless the mensural values changed.

Consult Grove's *Dictionary of Music*, arts. "Lute," "Frets"; Stainer and Barrett's *Dictionary of Music*, "Tablature"; and the admirable museum catalogues of Carl Engel (South Kensington), G. Chouquet (Paris), and Victor Mahillon (Brussels). (A. J. H.)

LUTHER (1483–1546). *First Period* (1483–1517).—Martin Luther (Lyder, Lüder, Ludher—from Lothar, some say) was born at Eisleben in the county of Mansfeld, in Thuringia, on the 10th of November 1483. His father Hans Luther, a slate-cutter by trade, belonged to a family of free peasants. His mother was Margaret Lindeburn. Hans Luther had left Möhra, his native village, and had come to Eisleben to work as a miner. When Martin was six months old he went to Mansfeld and set up a forge, the small profits of which enabled him to send his son to the Latin school of the place. There the boy so distinguished himself that his father determined to make him a lawyer, and sent him for a year to a Franciscan school at Magdeburg, and then to Eisenach near Möhra. There Luther, with other poor scholars, sang for alms in the streets, and his fine tenor voice and gentle manners attracted the attention and gained for him the motherly care of Ursula Cotta, the wife of the burgomaster of Eisenach. From Eisenach he went in his eighteenth year to the high school of Erfurt, where his favourite master was the humanist Trutwetter, who taught him classics and philosophy. He took his bachelor's degree in 1502, and his master's in 1505. At Erfurt the preaching of the town's pastor Weisemann made a deep impression on his mind, as did the preacher's frequent exhortations to study the Scripture. Luther tells us that he sought in vain for a whole Bible, and that he could only get portions to read. A dangerous illness, the death of a near friend, together with other circumstances, so wrought on his pious, sensitive nature that in spite of father and family he resolved to give up all his prospects and become a monk. He entered the Augustinian convent at Erfurt in June 1505, taking with him Plautus and Virgil, the solitary mementos of the life he had abandoned. His first years of monastic life were spent in fierce mental struggle. He had found a whole Bible and read it diligently, but it did not bring him peace. The feeling of universal human sinfulness, and of his own, was burnt into him both by his dogmatic studies and by his reading of the Scripture. He lived a life of the severest mortification, and invented continually new forms of penance, and all the while heart and head alike told him that outward acts could never banish sin. "I tormented myself to death," he said, "to make my peace with God, but I was in darkness and found it not." The vicar-general of his order, Staupitz, who had passed through somewhat similar experiences, helped him greatly. "There is no true repentance," he said, "but that which begins with the love of righteousness and of God. Love Him then who has first loved thee." Staupitz had been taught heart religion by the mystics, and he sent Luther to the sermons of Tauler and to the *Theologia Germanica*.

When Luther regained his mental health, he took courage to be ordained priest in May 1507, and next year, on the recommendation of Staupitz, the elector of Saxony appointed him professor in the university of Wittenberg, which had been founded in 1502. While in the monastery Luther had assiduously pursued his studies, and his severe mortifications and penances had never interrupted his theological work. He read all the great scholastic theologians, but Augustine was his master in theology, while Erfurt studies under Trutwetter doubtless made him pore over Occam ("mein lieber Meister," as he afterwards fondly called him) till he got his bulky folios by heart. He began by lecturing on Aristotle; and in 1509 he gave Biblical lectures, which from the very first were a power in the university. His class-room was thronged; his fellow-professors were students. Staupitz forced him also to preach; and his marvellous eloquence, felt to be from the heart, attracted great crowds of hearers. The year 1511 brought an apparent interruption, but in fact only a new development, of Luther's character and knowledge of the world. He went to Rome, probably in fulfilment of an old vow, and the journey was a marked event in his life. He went up in true pilgrim spirit, a mediæval Christian, and he came back a Protestant. The pious German was horrified with what he saw in Rome, and he afterwards made telling use of what he had seen in various tracts, and notably in his address to the German nobles. He tells us that at Wittenberg he had pondered over the text, "The just shall live by faith," that while in Rome the words came back to him, and that on his return journey to Germany the evangelical meaning of the phrase rushed into his mind. On his return to the university he was promoted to the degree of doctor of divinity, in October 1512. The oath he had to take on the occasion "to devote his whole life to study, and faithfully to expound and defend the holy Scripture," was to him the seal of his mission. He began his work with lectures on the Psalms, and then proceeded to comment on the epistles of Paul to the Romans and Galatians, enforcing especially his peculiar views of the relations between law and gospel. His lectures and his sermons were attended by great audiences, and disciples gathered round him. As early as 1516 his special principles were publicly defended at academical disputations. Staupitz made him district-vicar of his order for Meissen and Thuringia. He made short preaching tours, and his influence was felt far beyond Wittenberg. When the plague came to that university town he remained at his post when others fled. Then came 1517, the year of the Reformation. The new pope, Leo X., had sent agents through Germany to sell indulgences, and had chosen John Tetzel, a Dominican monk, for Saxony. Luther, who had passed through deep soul-struggles ere he won pardon, knew that God's forgiveness could not be purchased for money, and thundered against Tetzel and his indulgences from Wittenberg pulpit. He wrote anxiously to the princes and bishops to refuse the pardon-seller a passage through their lands. When Tetzel got to Jüterbogk near Wittenberg, Luther could stand it no longer. He wrote out ninety-five propositions or theses denouncing indulgences, and on the eve of All Saints, October 31, nailed the paper to the door of the Castle church. In a short time all Germany was ablaze.

The Wittenberg theses

These ninety-five theses are one continuous harangue against the doctrine and practice of pardon-selling, but they do not openly denounce indulgence in every form. They make plain these three things:—(1) there may be some good in indulgence if it be reckoned one of the many ways in which God's forgiveness of sin can be proclaimed; (2) the external signs of sorrow are not the real inward repentance, nor are they as important as that is, and no permission to neglect the outward expression can permit the neglect of true repentance; (3) every Christian who feels true sorrow for sin is there and then pardoned by God for Christ's sake without any indulgence ticket or other human contrivance. And in his sermons on indulgence Luther declared that repentance consisted in contrition, confession, and absolution, and that contrition was the most important, and in fact the occasion of the other two. If the sorrow be true and heartfelt, confession and pardon will follow. The inward and spiritual fact of sorrow for sin, he thought, was the great matter; the outward signs of sorrow were good also, but God, who alone can pardon, looks to the inward state. These theses, with the sermons explaining them, brought Germany face to face with the reality of blasphemy in the indulgences. Luther's public life had opened; the Reformation had begun.

Luther preaching.

Second Period (1517–1524).—Pilgrims who had come to Wittenberg to buy indulgences returned with the theses of Luther in their hands, and with the impression of his powerful evangelical teaching in their hearts. The national mind of Germany took up the matter with a moral earnestness which made an impression, not only upon the princes, but even upon bishops and monks. At first it seemed as if all Germany was going to support Luther. The traffic in indulgences had been so shameless that all good people and all patriotic Germans had been scandalized. But Luther had struck a blow at more than indulgences, although he scarcely knew it at the time. In his theses and explanatory sermons he had declared that the inward spiritual facts of man's religious experience were of infinitely more value than their expression in stereotyped forms recognized by the church, and he had made it plain too that in such a solemn thing as forgiveness of sin man could go to God directly without human mediation. Pious Christians since the day of Pentecost had thought and felt the same, and all through the Middle Ages men and women had humbly gone to God for pardon trusting in Christ. They had found the pardon they sought, and their simple Christian experience had been sung in the hymns of the mediæval church, had found expression in its prayers, had formed the heart of the evangelical preaching of the church, and had stirred the masses of people in the many revivals of the Middle Ages. But those pious people, hymn-writers, and preachers had not seen that this inward experience of theirs was really opposed to a great part of the ecclesiastical system of their day. The church had set such small store by that inward religious experience that the common speech of the times had changed the plain meanings of the words "spiritual," "sacred," "holy." A man was "spiritual" if he had been ordained to office in the church; money was "spiritual" if it had been given to the church; an estate, with its roads, woodlands, fields, was "spiritual" or "holy" if it belonged to a bishopric or abbey. And the church that had so degraded the meaning of "spiritual" had thrust itself and its external machinery in between God and the worshipper, and had proclaimed that no man could draw near to God save through its appointed ways of approach. Confession was to be made to God through the priest; God spoke pardon only in the priest's absolution. When Luther attacked indulgences in the way he did he struck at this whole system.

Compelled to examine the ancient history of the church, he soon discovered the whole tissue of fraud and imposture by which the canon law had from the 9th century downwards been foisted upon the Christian world. There is scarcely any essential point in ancient ecclesiastical history bearing upon the question of the invocation of saints, of clerical priesthood, of episcopal and metropolitan pretensions, which his genius did not discern in its true light. Whatever Luther denounced as fraud or abuse, from its contradiction to spiritual worship, may be said to have been openly or tacitly admitted to be such. But what produced the greatest effect at the time were his short popular treatises, exegetical and practical—his *Interpretation of the Magnificat or the Canticle of the Virgin Mary*, his *Exposition of the Ten Commandments, and of the Lord's Prayer.* The latter soon found its way into Italy, although without Luther's name, and has never been surpassed either in genuine Christian thought or in style. He resolved also to preach throughout Germany, and in 1518 appeared at a general meeting of his order at Heidelberg. There he held a public disputation on certain theses called by him paradoxes, in which he strove to make apparent the contrast between the external view of religion taught by the schoolmen and the spiritual view of gospel truth based upon justifying faith. He made many disciples on this occasion, of whom perhaps the most notable was Martin Bucer. On his return to Wittenberg in May 1518, Luther wrote and published an able and moderate exposition of the theses, and sent it to some of the German bishops. He proclaimed the need for a thorough reformation of the church, which he thought could only be effected, with the aid of God, by an earnest co-operation of the whole of Christendom. This energy awakened opponents. Conrad Wimpina at Frankfort, Hoogstraten at Cologne, Sylvester Trierias at Rome, and above all John Eck, an old fellow student, at Ingolstadt, attacked his theses, and discovered heresy in them. The result was that Luther was summoned to appear before the pope at Rome, but the elector of Saxony intervened, and got the matter so arranged that Luther was cited to appear before the pope's legate at Augsburg.

t Augsburg before the legate.

The pope was unwilling to quarrel with Germany, where the whole people seemed to be supporting Luther, and the cardinal legate James de Vio of Gaeta, commonly called Cajetan, was told to be conciliatory. Luther went to Augsburg on foot, and presented himself before the legate, but the interview was not a successful one. The cardinal began by brow-beating the monk, and ended by being somewhat afraid of him. "I can dispute no longer with this beast," he said; "it has two wicked eyes and marvellous thoughts in its head." Luther could not respect either the learning or the judgment of Cajetan. He left Augsburg by stealth, afraid of capture, condemned, but appealing "from the pope ill-informed to the pope to-be-better-informed." On his return to Wittenberg he found the elector in great anxiety of mind, in consequence of an imperious letter from the cardinal, and offered to leave Saxony for France. The elector, however, allowed him to remain, and the pope sent another legate to settle the affairs of Germany. This was Carl von Miltitz, a native of Saxony, a man of the world, and no great theologian. He resolved to meet Luther privately, and did so in the house of Spalatin, court preacher to the elector of Saxony. In his interview with Cajetan Luther had refused to retract two propositions—that the treasury of indulgences is not filled with the merits of Christ, and that he who receives the sacrament must have faith in the grace offered to him. Miltitz made no such demands. He apparently gave up Tetzel and the indulgences, agreed with much of Luther's theology, but insisted that he had not been respectful to the pope, and that such conduct weakened the authority which rightly belonged to the church. He wished Luther to write to the pope and apologize. Luther consented. It was further arranged that both parties were to cease from writing or preaching on the controverted matters, and that the pope was to commission a body of learned theologians to investigate. Luther accordingly wrote to the pope, telling him that he "freely confessed that the authority of the church was superior to everything, and that nothing in heaven or on earth can be preferred before it save only Jesus Christ, who is Lord over all." This was in March 1519. Meanwhile Luther had appealed from the pope to a general council to be held in Germany. In the end of 1518 a papal bull concerning indulgences had appeared, confirming the old doctrine, without any reference to the late dispute.

The years 1519, 1520, 1521 were a time of fierce but triumphant struggle with the hitherto irresistible Church of Rome, soon openly supported by the empire. The first of these years passed in public conferences and disputations. Luther had promised Miltitz to refrain from controversy, on the understanding that his adversaries did not attack him, and he kept his word. But his old antagonist John Eck published thirteen theses attacking Luther, and challenged Andrew Bodenstein of Carlstadt, a friend and colleague of Luther, to a public disputation. Luther instantly replied to Eck's theses, and the disputation between Carlstadt and Eck was immediately followed by one between Eck and Luther. In this famous Leipsic disputation the controversy took a new shape. It was no longer a theological dispute; it became a conflict between two opposing sets of principles affecting the whole round of church life. Luther and Eck began about indulgences and penance, but the debate soon turned on the authority of the Roman Church and of the pope. Eck maintained the superiority of the Roman Church and of the pope as successor of St Peter and vicar-general of Christ. His argument was "no pope no church." Luther denied the superiority of the Roman Church, and supported his denial by the testimony of eleven centuries, by the decrees of Nicæa, by the Holy Scriptures. He maintained that the Greek Church was part of the church of Christ, else Athanasius, Basil, and the Gregories were outside Christianity. The pope has more need of the church, he said, than the church has of the pope. Eck retorted that these had been the arguments of Wickliffe and of Huss, and that they had been condemned at the council of Constance. Luther refused to admit that the condemnation was right; Eck refused to debate with an opponent who would not abide by the decision of œcumenical councils; and so the disputation ended. But Luther immediately afterwards completed his argument and published it. He asserted that he did not mean to deny the bishop of Rome's primacy, provided the pope kept his own place as servant of the church, but that he did mean to deny that there could be no church apart from the pope. The church, he said, is the communion of the faithful, and consists of the elect, and so never can lack the presence of the Holy Spirit, who is not always with popes and councils. This church, he declared, is invisible, but real, and every layman who is in it and has Holy Scripture and holds by it is more to be believed than popes or councils, who do not. This Leipsic disputation had very important consequences. On the one hand, Eck and his associates felt that Luther must now be put down by force, and pressed for a papal bull to condemn him; and Luther himself, on the other hand, felt for the first time what great consequences lay in his opposition to the indulgences. He saw that his Augustinian theology, with its recognition of the heinousness of sin, and of the need of the sovereign grace of God, was incompatible with the whole round of mediæval ceremonial life, proved it to be impossible for men to live perfectly holy lives, and so made saints and saint worship and relics and pilgrimages

Leipsic disputation.

impossible things. He saw the uselessness of the monastic life, with its vigils and fasts and scourgings. These things were not helps, he saw, but hindrances to the true religious life. The Leipsic disputation made Luther feel that he had finally broken with Rome, and it made all Germany see it too, and raised the popular enthusiasm to a white heat. The people of the towns declared their sympathy with the bold monk. Ulrich von Hutten and the German humanists saw that this was more than a monkish quarrel, and recognized Luther as their leader. Franz von Sickingen and the free knights hailed him as a useful ally. Even the poor down-trodden peasants hoped that he might be a luckier leader than Joss Fritz, and that he might help them to free themselves from the unbearable miseries of their lot. Luther became the leader of the German nation after the Leipsic disputation.

During 1520 the first great political crisis occurred, on the occasion of the death of Maximilian, and ended fatally, in consequence of the want of patriotic and political wisdom among the German princes. Ranke has pointed out the political elements which then existed for creating a Germany as free and independent as France or England; and Justus Möser of Osnabruck had long before truly declared, "If the emperor at that time had destroyed the feudal system, the deed would have been, according to the spirit in which it was done, the grandest or the blackest in the history of the world." Möser means that if the emperor had embraced the Reformed faith, and placed himself at the head of the lower nobility and cities, united in one body as the lower house of a German parliament, this act would have saved Germany. Probably some such idea was in the mind of the archbishop of Treves when he proposed that Frederick, the elector of Saxony, should be chosen emperor. Frederick might have carried out this policy, just because, if elected, he had nothing to rely upon except the German nation, then more numerous and powerful than it has been since; but he had not the courage to accept a dignity which he supposed to require for its support a more powerful house than his own. Charles, the son of Maximilian, was elected emperor, and that election meant the continuation of a mediæval policy in Germany.

Meanwhile Luther was at Wittenberg continuing his course of preaching, lecturing, and writing. The number of matriculated students had increased from 232 in 1517 to 458 in 1519, and to 579 in 1520; but large numbers besides these came to hear Luther. The study of Greek and Hebrew was diligently carried on, and the university was in a most flourishing state. Some of the finest productions of Luther's pen belong to this period,—his *Sermons* on the sacraments, on excommunication, on the priesthood, on good works, his *Address to the Christian Nobility of the German Nation on the Reformation of Christendom*, and *The Babylonian Captivity of the Church*. The address to the German nobles, published on June 26, 1520, created a great deal of excitement not only in Germany but beyond it. It was this appeal which first made Zwingli feel in sympathy with Luther, who showed in this little book that the Romish doctrine of two estates, one secular and the other spiritual, was simply a wall raised round the church to prevent reform. *All* Christians are spiritual, he said, and there is no difference among them. The secular power is of God as well as the spiritual, and has rule over all Christians without exception,—pope, bishops, monks, and nuns. He also appealed to the people to prevent so much money going out of the kingdom to Italy. "Why," he said, "should 300,000 florins be sent every year from Germany to Rome?" His address raised the cry of Germany for the Germans, civil government uncontrolled by ecclesiastics, a married clergy, while he called for a national system of education as the foundation of a better order of things. The most important work of the time, however, was the *Babylonian Captivity of the Church of God* (October 1520), in which he boldy attacked the papacy in its principles. The main thought in the book is expressed in the title. The catholic church had been taken into bondage by the papacy, as the Jewish people were taken to Babylon, and ought to be brought back into freedom. Luther described the sacraments, real and pretended, and showed how each had been carried into captivity and ought to be delivered. He concluded in a very characteristic fashion. "I hear that bulls and other papistical things have been prepared, in which I am urged to recant or be proclaimed a heretic. If that be true, I wish this little book to be part of my future recantation." The printing press sent thousands of these books through Germany, and the people awaited the bull, armed beforehand against its arguments. The bull was published at Rome on July 15, 1520. It accused Luther of holding the opinions of Huss, and condemned him. Eck brought it to Leipsic, and published it there in October. It was posted up in various German towns, and usually the citizens and the students tore it down. At last it reached Luther. He answered it in a pamphlet, in which he called it the execrable bull of Antichrist, and at last he proclaimed at Wittenberg that he would publicly burn it. On December 10, 1520, at the head of a procession of professors and students, Luther passed out of the university gates to the market-place, where a bonfire had been laid. One of the professors lighted the fuel, and Luther threw the bull on the flames; a companion flung after it a copy of the canon law. Germany was henceforth to be ruled by the law of the land, and not by the law of Rome. The news flashed over all Germany, kindling stern joy. Rome had shot its last bolt; if Luther was to be crushed, only the emperor could do it. On December 17th Luther drew up before a notary and five witnesses a solemn protest, in which he appealed from the pope to a general council. This protest, especially when we take it along with other future acts of Luther, meant a great deal more than many historians have discerned. It was the declaration that the Christian community is wider than the Roman Church, and was an appeal from later mediæval to earlier mediæval ideas of catholicity. In the times immediately preceding the Reformation, the common description of Christian society was social life in communion with the bishop of Rome, but in the earlier Middle Ages Christian society had also been defined to be social life within the holy Roman empire. For the Roman empire had imposed on all its subjects a creed, and to that extent had made itself a Christian community. The œcumenical council was the ecclesiastical assembly and final court of appeal for this society, whose limits were determined by the boundaries of the mediæval empire, and Luther by this appeal not only declared that he could be a catholic Christian without being in communion with Rome, but secured an ecclesiastical standing ground for himself and his followers which the law could not help recognizing. It was an appeal from the catholic church defined ecclesiastically to the catholic church defined politically, and foreshadowed the future political relations of the Lutheran Church.

Luther excommunicated.

He burns the pope's bull.

The pope had appealed to the emperor to crush heresy in Germany, and Charles V., with his Spanish training and his dreams of a restored mediæval empire, where he might reign as vicar of God *circa civilia*, had promised his aid. He had declared, however, that he must pay some regard to the views of Frederick of Saxony, from whom he had received the imperial crown, and had in the end resolved to summon Luther before the diet to be held at Worms. The diet was opened by Charles in January 1521, and the ɩefore he mperor t Vorms.

papal nuncio Hieronymus Alexander (afterwards archbishop of Brindisi and cardinal) urged first privately and then publicly in the diet that Luther should be condemned unheard, as one already tried and convicted by the papal bull. He threatened the Germans with extermination, it is said, in case of their refusal to accede to his requests,—"We shall excite the one to fight against the other, that all may perish in their own blood,"—a threat to which the whole subsequent history of Germany offers the commentary. But the princes had their own quarrel with Rome, and urged besides that it would be unfair to condemn a man unheard and untried. A committee appointed by the diet presented a list of one hundred grievances of the German nation against Rome. This startled the emperor, who, instead of ordering Luther's books to be burned, issued only a provisional order that they should be delivered to the magistrate. He then sent to summon Luther before him, and granted him a safe conduct to and from the diet. In April Luther set out for Worms. Before leaving Wittenberg he had devised with his friend Lucas Cranach the artist what he called "a good book for the laity," a series of woodcuts depicting contrasts between Christ and the pope, with explanations in pithy German:—Christ washing the disciples' feet on one page, the pope holding out his toe to be kissed, on the other; Christ bearing his cross, the pope carried in state through Rome on men's shoulders; Christ driving money-changers out of the temple, the pope selling indulgences, with piles of money before him; and so on. Luther went to Worms, believing that he was going to his death. Everywhere on the road he saw the imperial edict against his books posted up, yet his journey was in some sort a triumphal progress; the people came out in crowds to meet him, and at Erfurt the herald gave way to the universal request, and, against his instructions, permitted Luther to preach. On the 16th Luther entered the imperial city amidst an immense concourse of people. Next day he was brought before the diet. When the hour approached he fell on his knees, and uttered in great agony a prayer such as can only be pronounced by a man filled with the spirit of Him who prayed in Gethsemane. When he appeared before the diet he was asked by John Eck, an official of the archbishop of Treves (to be distinguished from Eck the theologian), whether the books piled on a table were his, and whether he would retract what was written in them. Luther acknowledged his writings, and requested that as the matter written concerned the highest of all subjects, the word of God and the welfare of souls, he might have time for consideration before he answered the second question. His request was granted, and he retired. Luther's resolution had been taken before he appeared at the diet; he only desired to convince friends as well as foes that he did not act with precipitation at so decisive a moment. The next day he employed in prayer and meditation, making a solemn vow upon a volume of Scripture to remain faithful to the gospel, should he have to seal his confession with his blood. When he was again brought before the diet, he answered at great length, dividing his writings into three kinds:—(1) those in which he had written about faith and morals in such fashion that even his opponents admitted that what he had said was worth reading: he could not retract these; (2) those in which he had condemned the papacy and popish doings, which had ruined Christendom body and soul: to retract these would be mean and wicked, and he would not; (3) those in which he had attacked private persons with perhaps more vehemence than was right: he would not retract, but would readily listen to any one who pointed out errors. He spoke in German with earnestness and force, but the emperor and his followers scarcely understood him, and he was asked to repeat his answer in Latin. He did so, and the papal party were irritated; the official declared that they were not there to make distinctions or to discuss things which had been long ago settled by councils; let the accused say whether he recanted or not. Luther answered, "Well then, if your imperial majesty and your graces require a plain answer, I will give you one of that kind without horns and teeth. It is this. I must be convinced either by the witness of Scripture or by clear arguments, for I do not trust either pope or councils by themselves, since it is manifest that they have often erred and contradicted themselves—for I am bound by the Holy Scriptures which I have quoted, and my conscience is held by the word of God. I cannot and will not retract anything, for to act against conscience is unsafe and unholy. So help me God. Amen." Eck asked him whether he actually meant to say that general councils had erred. He answered that he declared, and that openly, that councils had erred several times, that the council of Constance had erred. Eck replied that he surely did not mean to say that general councils had erred. Luther persisted that he could prove that they had erred in many places. The emperor made a sign to end the matter, and Luther said, "I can do nought else. Here stand I. God help me. Amen." He went back to his lodgings in deep depression of spirit, but was comforted on learning that the elector had told Spalatin, "Doctor Martin has spoken well in Latin and in German before the emperor and all the princes and estates of the empire; only he is too keen for me." Luther's answer created very various feelings among those who heard him. The Italians and Spaniards wished the safe conduct revoked, and Luther burnt at once. Most of the Germans resolved to protect him at all hazards. The emperor deliberated for a day, and then declared that he meant to permit Luther to return safely from the council, but that his opinions were to be condemned, and all who clung to them punished for the future. But the proposal to cancel the safe conduct had roused the people. There were threatenings of insurrections of the peasants, and of Sickingen and the knights; and the emperor, to allay the feeling, resolved that three days should be given to Luther to reconsider what he had said. Theologians came to argue with him, and to induce him to make some recantation, but in vain. At last the edict of the diet was pronounced, in which Luther was condemned in the severest terms, and placed under the ban of the empire. This meant that when his safe conduct expired he was an outlaw, and that all people were forbidden to give him food or fire or shelter. His books were to be burnt, his goods confiscated, and his adherents punished. Whoever disobeyed the edict incurred the ban of the empire.

At the Wartburg.

Frederick the elector of Saxony thought that Luther's life was no longer safe, as in twenty-one days his safe conduct would expire. Luther was hurried away from Worms, and as he travelled back to Wittenberg he was stopped near Eisenach by a band of armed knights, and carried to the fortified castle of the Wartburg above Eisenach by Frederick's orders. The elector's fears, as matters turned out, were exaggerated. Germany was in no mood to give Luther up, and there were threatenings of risings when he disappeared, only appeased when it was whispered about that he was in friendly keeping. Luther remained at the Wartburg, dressed as a knight, ordered to let his beard grow, and bearing the name Junker George, for ten months, and made use of his enforced leisure to begin what was perhaps his greatest literary work, his translation of the Scriptures from the original texts. The New Testament was almost entirely his own work. He used for the text Erasmus's fourth edition, and took incredible pains with his work. Some of his MS. still survives, and shows that he corrected and recorrected with great pains. Some passages were altered at least fifteen times. He often felt at a loss for want of technical knowledge, and laid all his friends under contribution. Thus, when in difficulty about the translation of Rev. xxi. he wrote to Spalatin to ask for names and descriptions of all the precious stones mentioned. When engaged in the translation of the descriptions of the slaughter of beasts for sacrifice, he got a butcher to kill some sheep for him, that he might learn what every part of a sheep was called. His aim was to reproduce the tone and spirit of the original as far as he possibly could. No fine courtly words, he said to Spalatin; this book can only be explained in a simple popular style. It must be understood by the mother in the house, by the children in the streets, and by the "common man in the market." The translation of the New Testament was first published on September 21, 1522, and a second edition appeared in October. By choosing the Franconian dialect in use in the imperial chancery, Luther made himself intelligible to those whose vernacular dialect was High German or Low German, and his Bible is still the standard of the German tongue, and has preserved unity of language, literature, and thought to the German nation during its political disintegration. The translation of the Old Testament, begun in the same year, was a much more tedious task, and Luther was assisted in it by what Matthesius calls a private Sanhedrim. The friends met once a week, several hours before supper, in the old Augustinian monastery at Wittenberg, which had become Luther's house. Bugenhagen, Justus Jonas, Melanchthon, Aurogallus, Roser, and several Jewish rabbis made the "Sanhedrim." Luther thus describes the work: "We are labouring hard to bring out the prophets in the mother-tongue. Ach Gott! what a great and difficult work it is to make the Hebrew writers speak German! They resist it so, and are unwilling to give up their Hebrew existence and become like Germans." At the Wartburg Luther was ill in health and somewhat troubled in mind. He had been ill before he was summoned to Worms, and his long journey in the waggon with its cloth tent, the excitement at Worms, and the solitude at the Wartburg had enfeebled him; but his literary activity was untiring. He wrote short commentaries on the 68th Psalm and on other portions of Scripture, and a set of homilies intended to guide evangelical preachers, the *Kirchen-postille*. He also wrote one or two short treatises on worship, on the mass, on confession, and on monkish vows, intended to guide the reformed churches in the rejection of superstitious usages. Up to this time there had been no change in the church services. The true doctrine of the gospel had been preached in Germany, and Romish rites and ceremonies had been exhibited as abuses, but not a single word or portion of these ceremonies had been changed, and Luther felt that the time had come to bring the preaching and the usages into harmony with each other. In the midst of these labours news came to him that Germany was threatened with a new sale of indulgences. The cardinal archbishop of Mainz, Albert of Brandenburg, unable to pay the 26,000 ducats due to Rome for his pallium, had resolved to raise the money by indulgences. Luther wrote a fierce tractate *Against the New Idol at Halle*. The archbishop getting word of this, sent to Frederick asking him to restrain Luther from attacking a brother-elector, and Frederick wished Luther to desist. He was indignant, but at the request of Melanchthon he agreed to lay the treatise aside until he had written to the archbishop. "Put down the idol within a fortnight, or I shall attack you publicly," he wrote; and the archbishop in reply thanked Luther for his Christian brotherly reproof, and promised, "with the help of God, to live henceforth as a pious bishop and Christian prince."

Back to Wittenberg.

Luther's absence from his congregation, his students, and his friends and books at Wittenberg weighed heavily upon him, and he began to hear disquieting rumours. Carlstadt and other friends at Wittenberg were urging on the Reformation at too rapid a rate. Their idea was that everything in worship not expressly enjoined in the Bible should at once be abolished. The churches were to be stripped of crucifixes, images of saints, and the ritual of the mass; the festivals of the Christian year were to be neglected, the monastic life put down by force; and some even wished it ordained that all clergymen should be married. To Luther all this seemed dangerous, and sure to provoke a reaction; the changes insisted upon were to him matters of indifference, which might be left to the individual to do or leave undone as he pleased. Auricular confession, the reception of the Lord's Supper under both forms, pictures in churches, the observance of festivals and fasts, and the monastic life were *adiaphora*. He wrote earnestly warning his friends against rashness and violence, and he was anxious and distressed. Still he held out patiently till events occurred which called for his presence. Certain men claiming to be prophets, Nicolaus Storch, a weaver, and his disciple Thomas Münzer, belonging to the village of Zwickau, near the Erzgebirge on the borders of Bohemia, preached wildly a thorough-going reformation in the church and the banishment of priests and Bibles. All believers were priests, they said, and all the faithful had the Holy Spirit within them, and did not need any such external rule as Holy Scripture. They were banished from Zwickau, and came to Wittenberg, where Carlstadt joined them. Fired by their preaching, the people tore down the images in the churches and indulged in various kinds of rioting. Luther felt he could remain no longer in hiding. He wrote to the elector telling him that he must quit the Wartburg, and at the same time declaring that he left at his own peril. "You wish to know what to do in the present troublesome circumstances," he said. "Do nothing. As for myself, let the command of the emperor be executed in town or country. Do not resist if they come to seize and kill me; only let the doors remain open for the preaching of the word of God." He was warned that Duke George of Saxony, a violent enemy of the Reformation, was waiting to execute the sentence of the ban. "If things were at Leipsic as they are at Wittenberg," he said, "I would go there, if it rained Duke Georges for nine days running, and every one of them nine times as fierce as he." He left the Wartburg, suddenly appearing in Wittenberg on March 3, 1522, and plunged at once into the midst of struggles very different from those which he had hitherto so victoriously overcome. He found things in a worse state than he had feared; even Melanchthon had been carried away. Luther preached almost daily for eight consecutive days against Carlstadt and the fanatics from Zwickau, and in the end he prevailed and the danger was averted. His theme was that violence does no good to God's word; there are in religion matters of indifference. "The Word created heaven and earth and all things; the same Word must also now create, and not we poor sinners. *Summa summarum*, I will preach it, I will talk of it, I will write about it, but I will not use force or compulsion with any one." "In this life every one must not do what he has a right to do, but must forego his rights, and consider what is useful to his brother. Do not make a 'must be' out of a 'may be,' as you have now been doing, that you may not have to answer for those whom you have misled by your uncharitable liberty." Storch and Münzer, sincere though misguided men, sought an interview with him. They laid their claims for support before him; they said that they were inspired and could prove it, for they would tell him what then passed through his mind. Luther challenged them to the proof. "You think in your own heart that my doctrine is true," said one of them impressively. "Get thee behind me, Satan," exclaimed Luther, and dismissed them. "They were quite right," he said to his friends afterwards; "that thought crossed my mind about some of their assertions. A spirit evidently was in them; but what could it be but the evil one?"

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When Charles V. had laid Luther under the ban of the empire, he had undoubtedly been greatly influenced by political considerations. Francis I. of France and Charles of Spain were rivals, and the whole of the European policy of the time turns on this rivalry. The opponents schemed to attract to themselves and to divert from their neighbour the two outside powers of England and the papacy, and in 1521 it was the policy of Charles to win alliance with the pope. The Germans saw that they were being sacrificed in this game of statecraft, and there was no great willingness even among Roman Catholics to put the edict of Worms in force. Luther at the Wartburg and at Wittenberg was protected by the national feeling of Germany from attack. The diet of the empire met in 1522 at Nuremberg, and the new imperial council, which ruled in the emperor's absence, and very fairly represented the popular feeling in Germany, was in no mood to yield to the papacy. Leo X. had died, and his successor Adrian VI., an orthodox Dominican and an advocate for reformation in the cloisters and in the lives of the clergy, proposed to begin reformation by crushing the German heresy. He instructed his nuncio to the diet to demand the execution of the edict of Worms. The imperial council refused until the grievances of Germany were heard and redressed. They spoke of concordats broken and papal pledges unfulfilled, and finally they demanded a free œcumenical council to be held in Germany within a year, which should settle abuses, and until it met they wished the creed to be an open question. The nuncio found that the pulpits of the free imperial city were filled with preachers, mostly monks, who were making the city resound with gospel preaching. He asked the diet at least to arrest the preachers; the diet pleaded incompetence. He proposed to seize them himself in the pope's name; the magistrates threatened to release them by force, and the nuncio had to desist. The diet then presented a hundred gravamina or subjects of complaint which the German nation had against the papacy, including in the list indulgences, dispensations bought for money, absentee bishops and other ecclesiastics, the use of bans and interdicts, pilgrimages, excessive demands for money, and the decisions of matrimonial cases in ecclesiastical courts. The complaint was an expansion of Luther's address to the German nobles. The nuncio could do nothing, and was forced to accept by way of compromise a decision from the diet that only the *verum, purum, sincerum, et sanctum evangelium* was to be preached in Germany. Nuremberg reversed the edict of Worms. Next year the diet met again at Nuremberg, and the new pope, Clement VII., sent the celebrated cardinal-legate Lorenzo Campeggio to demand the execution of the edict of Worms. The diet asked in return what had become of the hundred grievances of the German nation, to which Rome had never deigned to return an answer. Campeggio declared that at Rome the document had been considered merely as a private pamphlet; on which the diet, in great indignation, insisted on the necessity of an œcumenical council, and proceeded to annul the edict of Worms,—declaring, however, in their communication to the pope, that it should be conformed to as much as possible, which with respect to many cities and princes meant not at all. Finally it was resolved that a diet to be held at Spires was to decide upon the religious differences. But between Nuremberg and Spires an event occurred, the revolt of Sickingen and the knights, which was destined to work harm to the Reformation. The diet of Spires met, and, many of the members being inclined to connect Sickingen and Luther, there was a strong feeling against the Reformation, but the feeling was not strong enough to induce the diet to comply with the demands of the legate Campeggio and revoke the decisions of Nuremberg, and it refused to execute the edict of Worms. Campeggio, however, was able to separate Germany into two parties, and this separation became apparent at the convention of Ratisbon, where Bavaria, Austria, and other South-German states resolved to come to separate terms with the papacy. The curia promised to stop a number of ecclesiastical extortions and indulgences, to make better appointments to benefices, and to hand over some of the ecclesiastical estates to the Austrian and Bavarian princes; while the states promised to set aside the gravamina, and to permit no toleration of the new doctrines. On the other hand, many states which had kept aloof from the Reformation now joined it, and declared against the seven sacraments, the abuses of the mass, the worship of saints, and the supremacy of the pope. The emperor's brother and successor Ferdinand was a bitter foe to the Reformation, and urged persecution. Four Augustinian monks at Antwerp were the first martyrs; they were burnt on 1st July 1523. Ferdinand began the bloody work of persecution in the hereditary states of Austria immediately after the convention of Ratisbon. At Passau in Bavaria, and at Buda in Hungary, the faggots were lighted. The dukes of Bavaria followed the same impulse.

Luther's writings during this period.

Luther's literary activity during these years was unparalleled. In 1522 he published, it is said, one hundred and thirty treatises, and eighty-three in the following year, among them the famous *Contra Henricum regem Angliæ*, in which, after having dealt mercilessly with the royal controversialist, he exclaims, "I cry 'Gospel! Gospel! Christ! Christ!' and they cease not to answer 'Usages! Usages! Ordinances! Ordinances! Fathers! Fathers!' The apostle St Paul annihilates with a thunderstorm from heaven all these fooleries of Henry." His principal work, however, during these years was the publication of certain short tracts upon worship and its reform, followed by various directories for public worship, which afterwards served as a model for the numerous Lutheran Church ordinances. In 1522, while Luther was still in the Wartburg, Carlstadt had published for the church at Wittenberg an ordinance for directing the government and worship of the church. It was very brief, but very revolutionary (*cf.* Richter's *Evangel, Kirchenordnungen*, vol. ii. p. 484). This was withdrawn after Luther's return; but the Reformer felt that the time had come for a definite reform of public worship and for publishing his views upon the subject. Accordingly, after a series of tracts in 1522 upon religious and monastic vows, the abolition of private masses, the Lord's Supper under both forms, saint worship, the so-called spiritual estate, and the married life, he published in 1523 *The Order of the Worship of God*. He was, as usual, conservative, and made as few changes as possible in the form of service, caring only to give full place to prayer and the reading and preaching of the word. The order of worship was followed by the *Formula Missæ*, published in Latin, but at once translated into German by Paul Speratus, in which the ancient form was as much preserved as is consistent with evangelical doctrine. Luther was of opinion that the more difficult introits should be removed from the order of the Eucharist, and simpler hymns put in their place, and he also was strongly in favour of the singing of hymns in the common worship. This led to the publication in 1524 of a small collection of church hymns, which was Luther's first *German Church Hymn-book*, and which was the beginning of the wonderfully rich German Protestant hymnology. In the same year Luther translated the order of baptism, and published it under the title of *Das Tauf-Büchlein*. He also drew up a directory for public worship for Leisnig (*cf.* Richter, *op. cit.*, vol. i.). The hymn-book was followed by a prayer-book, and by the publication of a short summary of the heads of Christian truth fitted for the instruction of the "rude common man." Luther's catechism for children completed this series of works, intended to aid worship, public and private. Notwithstanding this immense amount of literary work, Luther found time to make preaching tours, and visited in this way Altenburg, Zwickau, Eilenburg, Erfurt, Weimar, and many other places, and was cheered by the progress of the Reformation throughout North Germany. About this time also he sent a powerful address to the municipal councils of the German towns, exhorting them to establish everywhere Christian schools, both elementary and secondary. "Oh my dear Germans," he exclaimed, "the divine word is now in abundance offered to you. God knocks at your door; open it to Him! Forget not the poor youth. . . . The strength of a town does not consist in its towers and buildings, but in counting a great number of learned, serious, honest, and well-educated citizens." He tried to impress upon them the necessity for the highest education, the knowledge of Greek and Hebrew, by showing how serviceable such learning had been to him in his attack upon the abuses of Rome. He also appealed to the princes and cities to help the gospel and the Reformed churches; but church rule and church maintenance could not be fixed on a legal basis until much later.

Here we conclude this first glorious period of Luther's life. The problem to be solved was not to be solved by Luther and by Germany; the progressive vital element of reformation passed from Germany to Switzerland, and through Switzerland to France, Holland, England, and Scotland. Before he descended into the grave, and Germany into thraldom, Luther saved, as much as was in him, his country and the world, by maintaining the fundamental principles of the Reformation against Melanchthon's pusillanimity; but three Protestant princes and the free cities were the leaders. The confession was the work of Melanchthon; but the deed was done by the laity of the nation. The German Reformation was made by a scholastically trained monk, seconded by professors; the Swiss Reformation was the work of a free citizen, an honest Christian, trained by the classics of antiquity, and nursed in true hard-won civil liberty. Luther's work was continued, preserved, and advanced by the work of the Swiss and French Reformers. The monk began; the citizen finished. If the one destroyed Judaism, the other converted paganism, then most powerful, both as idolatry and as irreligious learning. But as long as Luther lived he did not lose his supremacy, and he deserved to keep it. His mind was universal, and therefore catholic in the proper sense of the word.

Third Period (1525–1546). In this third period the epic of Luther's life was changed into tragedy; the revolt of the knights under Sickingen, the Anabaptist tumults, and the peasants' war in the Black Forest alienated the sympathies of many from the Reformation, and resulted in a divided Germany (see vol. x. p. 498, vol. i. p. 786). From Sickingen's rising Luther sedulously kept himself aloof, but the insurgent had more than once proclaimed himself on Luther's side, and that was enough to make many of the princes resolve to have nothing to do with reform. The convention of Ratisbon was the result of Sickingen's abortive revolt. The Anabaptists have to do with Luther's history mainly in so far as his contact with them modified and gave final shape to his doctrine of baptism. In his tract on the *Sacrament of Baptism*, 1519, Luther distinguishes carefully between the sign and the thing signified. The ordinance is just the sign, the thing signified is the death to sin, the new birth, and a new life in Christ. This new life goes on here on earth, so does the death to sin. Believers die daily to sin, not once for all in baptism, and their life in Christ is not a full life whilst earth's life lasts; and so baptism is merely a sign of what is never really accomplished till after death. In the *Babylonian Captivity of the Church of God*, 1520, Luther adopted a view not unlike Calvin's. He said that God's word was always more than a statement, it was also a promise. Baptism was therefore a seal or pledge, a promise that what was signified by the ordinance would be bestowed. Only unbelief can rob the baptized of the benefits of their baptism and make the ordinance of none effect. But after Luther came in contact with the Anabaptists he departed from this simple theory, for he thought that he could not justify infant baptism upon it, and so in his *Sermon on Baptism*, 1535, he introduced a third theory, which approached much nearer to mediæval views. He explained that in the ordinance of baptism God through His word so works on the water in the sacrament that it is no longer mere water, but has the power of the blood of Christ in some mysterious fashion. Luther then asked if faith was required for the worthy partaking of the sacrament, and he felt obliged to confess that the faith of the recipient was not needed. This sermon marks Luther's reaction towards ideas he had abandoned in 1519–20.

Revolt under Sickingen.

Anabaptist tumults.

Peasants' war.

More important was the connexion between the Lutheran movement and the peasant revolt. The first coalitions of the peasants against the intolerable rapacity and cruelty of the feudal aristocracy had begun before the close of the 15th century. But all the oppressed inclined towards Luther, and the oppressors, most of whom were sovereigns, bishops, and abbots, towards the pope. The struggle in the peasants' war was really between the reforming and the papist party, and it could easily be foreseen that Luther would be dragged into it. As early as January 1525 the revolutionary movement had extended from the Black Forest into Thuringia and Saxony, and the peasants were eagerly looking to Luther for help. The more moderate party published their programme in twelve articles, with a very remarkable preface, in which they stated that they did not wish for war, and asked nothing that was not in accordance with the gospel. These articles were the following:—(1) the whole congregation to have power to elect their minister, and if he was found unworthy to dismiss him; (2) the great tithe, *i.e.*, the legal tithe of corn, to be still payable for the maintenance of the pastor, and what is over to go to support the poor; the small tithes to be no longer payable; (3) serfdom abolished, since Christ has redeemed us all by His precious blood; (4) game, fish, and fowl to be free as God created them; (5) the rich have appropriated the forests, this to be rearranged; (6) compulsory service to be abolished—wages for work; (7) peasant service to be limited by contract, and work done above contract to be paid for; (8) fair rents; (9) arbitrary punishments abolished; (10) the commons restored; (11) the right of heriot, *i.e.*, the right of the lord to take the vassal's best chattel, to be abolished; (12) all these propositions to be tested by Scripture, and what cannot stand the test to be rejected. Most impartial historians have declared that their demands were on the whole just, and most of them have become law in Germany. The words of Scripture brought forward by the peasants prove clearly that Luther's preaching of the gospel had acted, not as an incentive, but as a corrective. The peasants declared their desire to uphold the injunctions of the gospel, peace, patience, and union. Like the Puritans in the following century, the peasants say that they raise their voice to God who saved the people of Israel; and they believe that God can save them from their powerful oppressors, as he did the Israelites from the hand of Pharaoh. Luther evidently felt himself appealed to. The crisis was difficult, and, in spite of what has been said in his defence, he failed, as he failed afterwards in the conference with the Swiss deputies at Marburg. Had Luther thrown the weight of his influence into the peasants' scale, and brought the middle classes, who would certainly have followed him, to the side of the peasants, a peaceful solution would in all probability have been arrived at, and the horrors of massacre averted. But Luther, bold enough against the pope or the emperor, never had courage to withstand that authority to which he was constantly accustomed, the German prince. He began by speaking for the peasants in his address to the lords, and had courage enough to tell them some plain truths, as when he said that some of the twelve articles of the peasants are so equitable as to dishonour the lords before God and the world, when he told them that they must not refuse the peasants' demands to choose pastors who would preach the gospel, and when he said that the social demands of the peasants were just, and that good government was not established for its own interest nor to make the people subservient to caprice and evil passion, but for the interest of the people. "Your exactions are intolerable," he said, "you take away from the peasant the fruit of his labour in order to spend his labour upon your finery and luxury." He was courageous enough also in asking the peasants to refrain from violence, and in telling them that they would put themselves in the wrong by rebellion. But what Luther did not see was that the time for good advice had gone by, and that he had to take his stand on one side or the other. He trusted too much in fine language. His advice that arbiters should be chosen, some from the nobility and some from towns, that both parties should give up something, and that the matter should be amicably settled by human law, came ten months too late. The bloody struggle came; the stream of rebellion and destruction rolled on to Thuringia and Saxony, and Luther apparently lost his head, and actually encouraged the nobles in their sanguinary suppression of the revolt, in his pamphlet entitled *Against the Murdering, Robbing Rats of Peasants*, where he hounds on the authorities to "stab, kill, and strangle." The princes leagued together, and the peasants were routed everywhere. One army, with neither military arms nor leaders, was utterly routed at Frankenhausen, another in Würtemberg. Fifty thousand were slain or butchered by wholesale executions. Among this number many of the quietest and most moderate people were made victims in the general slaughter, because they were known or suspected to be friends of the Reformation and of Luther, which indeed all the citizens and peasants of Germany were at that time. None felt more deeply, when it was too late, this misery, and what it involved in its effects on the cause of the gospel in Germany, than Luther; and he never recovered the shock. He thus unburdens his soul at the close of this fatal year, which crushed for centuries the rights and hopes of the peasants and labourers, and weakened the towns and cities, the seats of all that was best in the national life,—"The spirit of these tyrants is powerless, cowardly, estranged from every honest thought. They deserve to be the slaves of the people;" and in the next year—"I fear Germany is lost; it cannot be otherwise, for they will employ nothing but the sword."

The prospect was dark enough for the Reformer. Ferdinand of Austria and the duke of Bavaria were imprisoning and slaying Christians on account of the gospel. The emperor, fresh from his victory at Pavia, and the pope were combining to crush the Reformation, and it was rumoured that the kings of France and England were to lend their aid. The convention of Ratisbon had resulted in a Roman Catholic league in which Duke George of Saxony, Albert elector-archbishop of Mainz, and the duke of Brunswick were the leaders. Luther also found that the war had demoralized the Protestant congregations, and that they were becoming ignorant and savage. And in May 1525 the elector Frederick died.

Luther's marriage.

It was under such auspices that Luther decided at last to take a wife, as he had long advised his friends among the priests and monks to do. He married Catherine von Bora, a lady twenty-four years of age, of a noble Saxon family, who had left her convent together with eight other sisters in order to worship Christ without the oppression of endless ceremonies, which gave neither light to the mind nor peace to the soul. The sisters had lived together in retirement, protected by pious citizens of Torgau. Luther married her on June 11, 1525, in the presence of Lucas Cranach and of another friend as witnesses. Catherine von Bora had no dowry, and Luther lived on his appointment as professor; he would never take any money for his books. His marriage was a happy one, and was blessed with six children. He was a tender husband, and the most loving of fathers. In the close of the year 1525 Luther was engaged in controversy with Erasmus on the freedom of the will.

Progress of the Reformation.

The princes who were friendly to the Reformation gradually gained more courage. The elector John of Saxony established the principle in his state that all rites should be abrogated which were contrary to the Scriptures, and that the masses for the dead be abolished at once. The young landgrave Philip of Hesse gained over the son of the furious Duke George to the cause of the Reformation. Albert, duke of Prussia, had established it at Königsberg, as hereditary duke, abolishing the vows of the order whose master he had been, saying:—"There is only one order, and that is Christendom." At the request of the pope, Charles placed Albert under interdict as an apostate monk. The evangelical princes found in all these circumstances a still stronger motive to act at Augsburg as allies in the cause of the evangelical party; and when the diet opened in December 1525 they spoke out boldly:—"It is violence which brought on the war of the peasants. If you will by violence tear the truth of God out of the hearts of those who believe, you will draw greater dangers and evils upon you." The Romanist party was startled. "The cause of the holy faith" was adjourned to the next diet at Spires. The landgrave and the elector made a formal alliance in February 1526 at Torgau.

Luther, being consulted as to his opinion, felt helpless. "You have no faith; you put not your trust in God; leave all to Him." The landgrave, the real head of the evangelical alliance, perceived that Luther's advice was not practical—that Luther forsook the duty of self-defence and the obligation to do one's duty according to the dictates of reason, in religious matters as well as in other political questions. But the alliance found no new friends. Germany showed all her misery by the meanness of her princes and the absence of any great national body to oppose the league formed by the pope, the emperor, and the Romanists throughout Europe. The archbishop of Treves preferred a pension from Charles to the defence of the national cause. The evangelically-disposed elector of the palatinate desired to avoid getting into trouble. The imperial city of Frankfort, surrounded by open enemies and timid friends, declined to accede to the alliance. There was more national feeling and courage in the Anglo-Saxon north of Germany. The princes of Brunswick, Luxemburg, Mecklenburg, Anhalt, and Mansfeld assembled at Magdeburg, and made a solemn and heroic declaration of their resolution "to pledge their estates, lives, states, and subjects for the maintenance of the holy word of God, relying on Almighty God, as whose instruments they would act." The town of Magdeburg (which then had about three times as many inhabitants as now) and Duke Albert of Prussia adhered to the alliance. The league doubled its efforts. Charles, strong and rendered safe by the peace of Madrid concluded with Francis, sent word from Seville in March 1526, through the Romish Duke Henry of Brunswick, that he would soon come himself to crush the heresy. Luther saw the dangers crowding around him; his advice was,—"We are threatened with war; let us force our enemies to keep the peace, conquered by the Spirit of God, before whose throne we must now combat with the arms of prayer; that is the first work to be done."

Diet of Spires, 1526.

The emperor commissioned his brother Ferdinand to preside at the diet of Spires and carry out his wishes. But before the diet met Francis and the pope had formed a league against him, and Charles had commissioned Count Frundsberg to levy an army of Germans to fight against the pope, while Ferdinand was called to Hungary to maintain against the Turks and others the kingdoms of Hungary and Bohemia, bequeathed to him by King Louis after the battle of Mohacz. When the diet at Spires met (June 1526), after some deliberation a proposition presented by the free cities was accepted that until a general council met "every state shall live, rule, and bear itself as it shall be ready to answer for to God and his imperial majesty,"—a decision which foreshadowed the famous Augsburg formula *cujus regio ejus religio*, the principle on which the German Protestant church was afterwards legally based. The Reformation had thus the three years, 1526–1529, to organize and consolidate itself. The man of Germany at that time among the princes was Philip, landgrave of Hesse, and he was taught what to do by a citizen James Sturm, the deputy of Strasburg at Spires. Sturm had convinced Philip that the basis of the true evangelical church was the acknowledgment of the self-government of the church by synods composed of the representatives of the whole Christian people; and this was embodied in the first Protestant constitution, the *Reformatio ecclesiarum Hassiæ juxta certissimam sermonum Dei regulam ordinata*.[1] The constitution acknowledged the episcopal element, but not episcopal rule; the *jus episcopale* was invested in the Christian community, and the flock of Christ were to hear only the voice of their shepherd Christ. Bishops and deacons were to be elected by the Christian people; bishops were to be consecrated by imposition of the hands of three bishops, and deacons instituted by the imposition of the hands of elders; while elders were associated with the pastors in the pastoral care of the congregation. A general or land synod was to be held annually, consisting of the pastor of each parish and of pious men elected from the various congregations, and there were provisions made for provincial and congregational synods. Three men were to be elected annually to exercise the right of visitation. This was afterwards found to be inconvenient, and six and then thirteen superintendents for life were substituted. This board of superintendents became afterwards an oligarchy, and at last a mere instrument of state, overriding the original democratic constitutions of the church, a consequence of the disruption of Germany and of the paralysis of all national institutions. Luther had in 1523 and 1524 professed principles almost identical with those established in 1526 in Hesse. His action ceased there; after the peasants' war he abandoned his more liberal ideas, and insisted on leaving everything to the princes, and what could a people do cut up into four hundred sovereignties? Luther never acknowledged Cæsaropapism or Erastianism as a principle and as a right. He considered the rights of the Christian people as a sacred trust provisionally deposited in the hands of the princes their representatives. "Where," he asked, "are the people to form the synods? I cannot find them." It was Melanchthon's influence that facilitated the despotic system and hampered the thorough reform of the forms of worship. Luther withdrew from a sphere which he felt was not his. He busied himself during these years with plans to improve and simplify the church services at Wittenberg. Some portions of the music in the communion service were too difficult for the people. Luther induced the elector to provide music teachers, and also to permit a simpler service. This led to the *German Mass and Order of Worship for Wittenberg*. The churches too throughout electoral Saxony were becoming better attended, and Luther had to consider and devise plans for church extension and supervision. His letters to Philip of Hesse, disapproving of the new constitution of the church there, show how jealous he had become of the entrance of democratic ideas. He asked the elector of Saxony to take charge of the church within his dominions, and Melanchthon's articles for the visitation of the churches in Saxony, which foreshadowed the Lutheran consistorial organization, show that Luther distinctly contemplates the transfer of the *jus episcopale* to the princes and magistrates. It is true that he called these magistrates *Nothebischöfe*, but he could not see any other solution of the difficulty, and undoubtedly from the legal point of view it was easy to transfer the right of supervision from one external authority to another, and difficult to hand it over from the bishops to the congregation. The new ecclesiastical organization adopted in Hesse and electoral Saxony had the effect of making the archbishop of Mainz renounce in 1528 the spiritual jurisdiction he had hitherto exercised over these two districts.

Diet of Spires, 1529.

Meanwhile the emperor had been again successful in his political schemes. His German army under the Constable Bourbon and General Frundsberg had seized upon Italy and had sacked Rome, and again he had brought the pope and Francis to terms. It only remained to subdue the Reformation, and the mediæval empire might be restored. He first sent a dispatch saying that the edict of Worms was to be held as in force. When the diet met at Spires in 1529, the imperial commissioners forbade the celebration of worship according to the reformed usage in churches, and afterwards in the houses of the elector and of the landgrave. The Act of Toleration of 1526 was to be abrogated. The diet appeared to be hopelessly divided, a majority with the emperor and a minority with the elector and the landgrave, and the majority passed an edict which amounted to this that where the edict of Worms could not be executed without fear of revolution no further reforms were to be allowed. The minority prepared a protest. "The diet has overstepped its authority," they said; "our acquired right is that the decree of 1526, unanimously adopted, remains in force until a council can be convened. Up to this time the decree has maintained the peace, and we protest against its abrogation." Ferdinand, who represented his brother, assured the princes that nothing remained for them but to submit; he threatened the free cities with the loss of their privileges

The protest and Protestantism.

[1] See Richter, *Evang. Kirchenordnungen*, i. p. 56; and Lechler, *Gesch. d. Presb. u. Synod. Verfassung*, p. 14.

and with an interdict, and he left the diet while the evangelical members were deliberating. In spite of these threats the protest was signed by John of Saxony, George of Brandenburg, Ernest of Lüneburg, Philip of Hesse, and Wolfgang of Anhalt among the princes, and by the representatives of the free cities of Strasburg, Nuremberg, Ulm, Costnitz (Constance), Lindau, Memmingen, Kempten, Nördlingen, Heilbronn, Reutlingen, Isny, St Gall, Weissenburg, and Windsheim. This celebrated protest of April 15, 1529, from which comes the name Protestant, is one of the noblest documents of Christian history. The protesting princes and cities claimed as their right as Germans the sacred duty freely to preach the word of God and the message of salvation, that all who would hear it might join the community of believers. It was also an earnest of true evangelical union; for it was well known that most of the cities were more inclined towards Zwingli's than towards Luther's view of the sacrament.

If this great act be considered impartially, it is impossible not to see that neither Luther nor Melanchthon was the real leader of the time. Luther had no real comprehension of what had to be done in Germany to preserve the gospel from destruction. He had shown little sympathy with the first attempt made in Hesse at the self-government of the church; still less did he see the importance of the protest at Spires, and of the unity it gave to the evangelical cause. It was evident that nothing but the inroad of the Turks had saved the Protestant princes after the diet, and that Charles was so far master of Germany as to make it impossible for Germany to become a Protestant nation. The Protestants were lost unless they strengthened the alliance which they had just founded at Spires. But Luther disliked such alliances; he dissuaded the elector from sending deputies to the meeting agreed to be held at Smalkald, and when the Saxon deputies prevented any business being done he was proud of the result. This apparent blindness and perversion of mind requires explanation. Luther lived under the shadow of the Middle Ages, and had been trained in scholastic law as well as in scholastic theology. To the mediæval jurist the emperor was the impersonation of all social order and moral law; he was the vicar of God. In the later Middle Ages the jurists had exaggerated this sacredness of the emperor, and had done so quite naturally in order to protect civil law from canon law, and to uphold the state against the church. Luther could throw off scholastic theology, but he could not throw off that scholastic jurisprudence that all his mediæval heroes, Occam, Wickliffe, and Huss had found so useful in their attacks on the papacy, and that Luther himself had found so serviceable when he appealed from the church defined by the pope to the church defined by the empire. He could not bear to think of an alliance against the holy Roman empire. Luther too had been trained in the school of Tauler and the *Theologia Germanica*, and partook greatly of their quietism. "Suffer God to do His work in you and about you" was their motto. There was a theological scruple also at the bottom of Luther's opposition to a vigorous Protestant alliance and a national attitude. This betrayed itself, first, in an uneasiness about Zwingli's rising influence in Germany, and, secondly, as a doctrinal idiosyncrasy respecting the sacrament of the Eucharist. Philip of Hesse saw through this instantly, and said, "I see they are against the alliance on account of these Zwinglians; well, let us see whether we cannot make these theological differences disappear."

uther nd wingli n the u- iarist.

When Luther was raised above himself by the great problem before him in that glorious period of action from 1518 to 1524, he had considered the sacrament as a part of the services of the church, and a secondary matter compared with the right view of faith or the inward Christianity which implies necessarily an unselfish believing and thankful mind. He was convinced that there was no virtue inherent in the elements apart from the communion, and it was a matter indifferent how the spirituality of the action and the real presence, even the transubstantiation, might be reconciled with faith. But the peasants' war and Carlstadt's mystical enthusiasm alarmed him. Where was this to lead to, he asked, and he seems to have settled down into a great resolve to abide by the tradition of the church, and alter as little as possible provided room was found for the exercise of living faith. So when he felt called upon to form a theory of the doctrine of the sacrament of the Eucharist he went back to his scholasticism to find there some theory which should be traditional and yet afford room for the spiritual priesthood of all believers, and for the exercise of faith on the promises of God. He found it in the writings of that schoolman whom he more than once calls "his dear master," the daring Englishman William of Occam. Transubstantiation, the Romish doctrine, offended Luther in his two essential requirements: it demanded a miracle which could be performed by a priest only, and this miraculous power so separated clergy from laity that it denied the spiritual priesthood of all believers; and, when the elements had been made by the priest's creating word the body and blood of the Lord, their supernatural efficacy, apart from the faith of the communicant, imparted grace. Occam had championed a theory which in some form or other had been in the church since the 10th century at least, and which openly rejected one of these stumbling blocks, and, as Luther saw, really did away with the other also. According to Occam's scholastic distinctions, matter can be present in two ways—(1) when it occupies a distinct place by itself, excluding every other body, *e.g.*, two stones mutually exclude each other, and (2) when it occupies the same space as another body at the same time. Everything which is omnipresent or ubiquitous must be able to occupy the same space as other things, else it could not be ubiquitous. Christ's resurrection body, said Occam, had this power when our Lord appeared among His disciples while they were in a room with the doors shut; at a certain moment of time it and a portion of door or wall must have been in the same place at the same time; and besides Christ's body is ubiquitous. It is therefore in the elements bread and wine, in, with, and under them. Luther took over this doctrine from Occam without alteration. The very illustrations he uses in his *Bekenntniss vom Abendmahl* are taken almost verbatim from Occam, *De Altaris Sacramento*. From this it followed that consubstantiation involved no miracle. Christ's body was not brought into the elements by the priest; it was there naturally. But its presence in these elements on sacramental occasions brought with it a blessing, and imparted grace, not because of the presence, but because God had promised that this particular presence of the everywhere present body of Christ would bring blessings to the faithful partaker. Occam's theory of consubstantiation fulfilled all Luther's wants, and above all it involved no explaining away of the plain meaning of the sentence, "This is my body," such as had offended him in Carlstadt. It is easy to see therefore how Luther was alarmed at Zwingli. The Swiss Reformer seemed to attack everything that Luther prized. He did not care for tradition or church usage; he seemed engaged in a rationalistic attack on the presence of Christ in the church, and on the word of God, and so he was guilty, in Luther's estimation, both of self-confidence and of a rationalism. On the other hand, Zwingli could not understand what Luther meant; and yet he was anxious to unite with him, and was willing to leave this one difficulty an open question. It was in these circumstances—suspicion on the part of Luther, blank amazement on the part of

Marburg conference.

Zwingli—that Philip of Hesse induced the Swiss and the German theologians to meet at Marburg. Luther was gloomy and suspicious, "as he had never been seen before," a friend said. The frank declarations of the Swiss Reformers soon cleared away all shadows of difference and dissent on all points but one, and fourteen articles defining the chief heads of Christian doctrine were adopted by both parties. Then came the discussion on the fifteenth, the doctrine of the Eucharist. Luther took a piece of chalk and wrote upon the table *Hoc est corpus meum*, and when worsted in argument, as he usually was, appealed to the sentence. The discussion, which lasted four days, however, resulted in the parties recognizing exactly where the point of difference lay, and in reducing it to its smallest dimensions. Both declared that they agreed in recognizing the Eucharist to be a sacrament of the true body and blood of Christ, and that a spiritual partaking of this body was a means of grace. They differed whether the true body and blood of Christ were *corporeally* in the sacrament. It was hoped that time would bring about alliance if not agreement, but Luther was obstinate. "Submit yourselves, believe as we do, or you cannot be acknowledged as Christians." He refused Zwingli's hand; "You have another spirit from us," he said, meaning that there was no objective basis of faith between them owing to what he thought to be Zwingli's rationalism. The result was a sad one, but Zwingli was to some extent a gainer; his view became naturalized in Germany, where Swabia adopted it, as did many of the imperial cities, and Philip of Hesse indicated that he preferred it.

Diet of Augsburg and the Augsburg confession.

The Marburg conference was a sad prelude to the decisive diet to be held at Augsburg in 1530. The new diet was anxiously awaited. Charles had made known his intention to be present, and that he intended to enforce obedience to the edict of Worms. He entered Augsburg with great magnificence, and was in fact at the zenith of his power. He had broken the might of France, humbled the papacy, been crowned at Bologna, reorganized Italy, and driven back the Turk. His only remaining task, and it seemed easy, was to crush the Reformation. He first summoned before him the protesting princes and asked them to withdraw the protest. This they refused to do; they had a clear constitutional right, founding on the decision of Spires, to resist the emperor, and they resolved to exercise it. Divine service after Lutheran fashion was held at their quarters, and they refused to join in the procession of the host at the festival of Corpus Christi. Meanwhile Luther, Melanchthon with him, was at Coburg, near enough at hand for consultation and yet beyond the emperor's reach. Melanchthon was preparing a confession with a defence, the so-called *Apology*, in case the emperor should require a statement of their doctrines. Luther was writing commentaries on the Psalms and the prophets, and was also preparing a popular edition of *Æsop's Fables.* He also wrote comforting letters to the elector, and addressed one of his most powerful writings to the Roman Catholic clergy assembled in the diet at Augsburg. Melanchthon was sent for to consult about the confession which the emperor had asked for, and Luther remained alone at Coburg full of anxiety, for he knew his friend's helplessness in the actual bustle of life. When Melanchthon got to Augsburg he really became a source of weakness. He induced the elector for the sake of peace to give up the services in the Franciscan church, and the Protestant preachers left the town in despair. Luther all the while had been quiet, waiting in patience; but this was too much for him, and he wrote to encourage the elector to resist. At length the Protestants were asked to present their confession. The emperor ordered it to be read in Latin. "No," said the elector, "we are Germans and on German ground. I hope therefore your majesty will allow us to speak German." When the vice-chancellor of the elector, Dr Christian Baier, had read the first part of the confession, which expounds the principles of the Reformation, and in particular the doctrine of justification by faith, "that faith which is not the mere knowledge of an historical fact, but that which believes, not only the history, but also the effect of that history upon the mind," it is said that an indescribable effect was produced upon the assembly. The opponents felt that there was a reality before them which they had never imagined; and others said that such a profession of faith by such princes was a more effectual preaching than that which had been stopped. "Christ," said Jonas, "is in the diet, and he does not keep silence; the word of God is indeed not to be bound." The Roman Catholic theologians present answered the confession, and then the emperor engaged Protestant and Roman Catholic theologians in negotiations in which Melanchthon soon showed his yielding character, even granting that the Protestants might acknowledge the jurisdiction of the bishops and the supremacy of the pope. At this critical moment Luther's indignation found vent. "I understand," he wrote to Melanchthon, "that you have begun a marvellous work, to make Luther and the pope agree together, but the pope will say that he will not, and Luther begs to be excused. Should you, however, after all succeed in your affair, I will follow your example and make an agreement between Christ and Belial. Take care that you give not up justification by faith; that is the heel of the seed of the woman to crush the serpent's head. Take care not to acknowledge the jurisdiction of the bishops; they will soon take all. In short, your negotiations have no chance of success unless the pope will renounce papacy." The Romanists fortunately demanded too much. Not even Melanchthon could yield the acknowledgment of private masses, of auricular confession, and of the meritorious character of good works; and the negotiations ceased. While they were in progress the emperor tried to intimidate the princes by calling the imperial troops into the free city of Augsburg and closing the gates. The landgrave escaped, and this frightened the Catholics. Unfortunately the Protestants had confessed their want of union by presenting three confessions of faith:—the Lutherans had presented the Augsburg confession; Strasburg, Constance, Memmingen, and Lindau, which sympathized to some extent with Zwingli, presented the Confessio Tetrapolitana; and Zwingli had sent a confession which was not, however, laid before the diet. The diet broke up with the final decision that the Protestants should have till next spring to consider whether they would voluntarily return to the church, and that, if they proved obstinate, then measures would be taken for their extermination.

To the student of Luther's life the diet of Augsburg is noteworthy chiefly because it was the occasion of the composition of the Augsburg confession, or *Augustana*, which afterwards became the symbol or confession of faith for the Lutheran Church. It was prepared by Melanchthon, founding on the fifteen articles of the Marburg conference, on the seventeen articles of Schwabach, and on the articles of Torgau. These various sets of articles had been written by Luther, and therefore the Augsburg confession was strictly Luther's own. It consists of two parts—one dogmatic, in twenty-one articles, which states the principal doctrines of the evangelical church, beginning with the Trinity and ending with the worship of saints; and the other in seven articles, rejecting the celibacy of the clergy, the sacrifice of the mass, auricular confession, ceremonial feasts and fasts, monastic vows, and the secular jurisdiction of bishops. It was signed at Augsburg by John of

Saxony, George of Brandenburg, Ernest of Lüneburg, Philip of Hesse, and Wolfgang of Anhalt, and by the representatives of the towns of Nuremberg and Reutlingen, and during the sitting of the diet by the representatives of Kempten, Heilbronn, Windsheim, and Weissenburg.

Smalkald league.

The edict of the diet was published on November 19, and the Protestant princes, after having overcome the resistance of Luther, met for conference at Smalkald on Christmas 1530, and formed an armed league for mutual defence. It had been declared that the edict would be put into execution in the spring of 1531, but when the time came the emperor had other work on hand: France had become troublesome, and the Turks were again moving. He found also that he could not count on the support of the Roman Catholic princes in the suppression of the Protestants. In presence of danger the Zwinglians and Lutherans showed a united front, and the Smalkald league grew to be a formidable power. The emperor resolved to come to terms with his Protestant subjects, and the result was the religious peace or rather truce of Nuremberg, which left things as they were until a general council should settle matters. The years following this peace of Nuremberg were comparatively prosperous to the Reformation. The Smalkald league was the only organized power in Germany, and very effectually prevented the oppression of Protestants by Roman Catholics. Year by year their numbers increased, and Luther saw the evangelical cause prospering. First Würtemberg was won back for young Duke Christopher, who had become a Protestant, and found on his entry to his dukedom that his people were already secret Protestants. In northern and central Germany whole districts embraced the evangelical doctrines. Electoral Brandenburg and ducal Saxony had received Protestant rulers, who found their people more than willing to accept the creed of their new sovereigns. At last the only large states that were able to maintain a firm front against the Lutheran doctrines were Austria, Bavaria, the Palatinate, and the great ecclesiastical provinces on the Rhine, and even in these regions visitations of the churches had shown that the people were forsaking the old faith. It appeared that a more serious defection than any might at any moment be made. The elector-archbishop of Cologne showed signs of abandoning the Roman Catholic faith and secularizing his vast episcopal territories, and this threatened defection made Charles bestir himself. If the elector became a Protestant the Lutherans would be in a majority in the electoral college, and a Protestant emperor might be elected.

Work of Luther's later years.

During all these years Luther was quietly at work at Wittenberg, lecturing, preaching, and writing. At first he felt anxious lest civil war should break out, and he had scruples about many of the doings, and even about the very existence, of that league which was really giving the land peace. Under Philip of Hesse the Reformation was assuming a national and political shape which alarmed Luther, who was more than ever content to keep out of public life and keep himself to his books. He began publishing his lectures on various portions of Scripture, on the Epistle to the Galatians and on the Psalms of Degrees. He wrote one or two controversial tracts, mainly to show how the Reformed could not accept the conditions offered by the Roman Catholics at Augsburg. In 1534, to his great joy, the first complete translation of the whole Bible was published, and next year appeared a new edition of the Wittenberg hymn-book, containing several new hymns. Philip of Hesse, notwithstanding the failure of the conference at Marburg, still thought that something might be done to remove the theological differences between Switzerland and Saxony, or at least between Swabia, Strasburg, and Wittenberg. The divines of Switzerland and of South Germany had by their publications made this somewhat easier. The confession of Basel, drafted by Œcolampadius (1531), revised by Myconius, and published by the magistracy of Basel, had declared that in the Lord's Supper Christ is the food of the soul to everlasting life, and Bucer and the other South-German divines were anxious for a union. Philip of Hesse, Bucer, and Melanchthon met in conference at Cassel to arrange preliminaries, not without suspicion on Luther's part, for he could not trust Melanchthon at a conference, and, as he remarked to Justus Jonas, he hated trimmers above all men on the earth's round. The result, however, was better than he had hoped for. Bucer drew up a short confession which was to be submitted to the Wittenberg theologians, and was favourably received by them, and the South German theologians were invited to a further conference at Wittenberg. The meeting very fairly represented all the German states, and the result was the document known as the *Wittenberg Concordia.* This document, mainly drawn up by Bucer and Melanchthon, contains a statement of the doctrine of the sacrament of the supper expressed according to the Lutheran formula, with the declaration that unworthy or faithless partakers really do not participate in the sacrament. Melanchthon and Bucer had used too much diplomatic skill in drawing up the formula, for the essential differences between the Wittenberg and the Strasburg school were not really faced and explained; they were covered over with ambiguous language. Nor could the document be accepted by the Swiss; but for a time it seemed as if a satisfactory basis of peace had been established. The general satisfaction was increased by the publication of the First Helvetic Confession, which, while stating the doctrine of the sacrament of the supper in a manner essentially Zwinglian, laid special emphasis on the real spiritual presence of Christ in the elements. Luther in a letter to Meyer, burgomaster of Basel, and also in his answer to the Reformed cantons, acknowledged the earnest Christianity of the confession, and promised to do his best to promote union with the Swiss. It is sad to think that only three years later his old animosity to Zwingli and his countrymen broke out again in his book against the Turks, and that he renewed the sacramental controversy with even more than the old fury in his *Short Confession of the Holy Sacrament*, published in 1544. This first Helvetic confession was drawn up, however, for another purpose than to appease the Wittenberg theologians. Charles V. was urging the pope to call a general council to end the disputes within the Christian church, and it seemed so probable that a council would meet that the Protestants were everywhere preparing themselves by doctrinal statements for taking their share in its work. The German princes and their theologians were also greatly exercised about this council, and the thought of it and how Protestants should bear themselves in its presence was filling Luther's mind. He wrote several short papers on the subject in the years 1534–39, beginning with the *Convocatio Concilii liberi* and ending with *Von den Conciliis und Kirchen.* The pope, Paul III., yielding to the pressure of the emperor and of such liberal Roman Catholics as Vergerius, his legate in Germany, called a council to meet in May 1537 at Mantua, and invited the Lutherans to be present. The Lutheran princes and theologians felt compelled to face the question whether they could or could not accept the invitation, and Luther, at the request of the elector of Saxony, prepared a creed to be used as a basis of negotiations. This was submitted to the princes and theologians assembled at Smalkald, and was in substance adopted by them. It is called the Smalkald Articles, and is important because in its statement of the doctrine of the sacrament of the supper it repudiates the Wittenberg Concord. The princes decided that they would have nothing to do with a council which did not meet on German soil. The emperor, alarmed at the progress of Protestantism, and at the united front shown by German Protestants, and troubled by the refusal of the pope to consent to a council to be held out of Italy, strove to bring Protestants and Roman Catholics together by means of religious conferences. The first of these, held at Hagenau, came to nothing. Next year (1541) the conference was renewed at Worms, when the Roman Catholic party promised reforms on condition that the Protestants first submitted to the pope. This condition could not be accepted. Representatives met the same year at Ratisbon, and here the conference was wrecked on the doctrine of transubstantiation, but the diet renewed the terms of the edict of Nuremberg of 1532—the Ratisbon Interim. It was felt by all parties that this provisional state of matters must come to an end some time, and that the Protestants must either be allowed to have their own way or win it by fighting. The emperor was not ready for war, and at the diet at Spires in 1544 it was agreed that the Protestants were to maintain their rights until a general council met. Whatever hopes they might have from such a council were soon dissipated. The council of Trent was opened that year, and its earliest acts were to refuse to pass the conciliatory measures proposed by some of the liberal Roman Catholics. The emperor still temporized and promised reforms, if not by a council then by a national assembly, and many of the Protestants, Luther among them, still hoped that matters might settle themselves without civil war. This hope inspired what was called the *Wittenberg Reformation*, a document setting forth how near the evangelical church might approach the Roman Catholic and still retain the truths it had upheld. The year 1546 began, however, with unmistakable indications that Charles was now ready to strike a decisive blow.

Luther had been suffering much during the last few years, and he felt his end to be near. In the month of January 1546 he undertook a journey to Eisleben in very inclement weather, in order to restore peace in the family of the counts of Mansfeld; he caught a violent cold, but preached four times, and took all the time an active part in the work of conciliation. On the 17th of February he felt that his release was at hand; and at Eisleben, where he was born, he died, in faith and prayer, on the following day. Nothing can be more edifying than the scene presented by the last days of Luther, of which we have the most authentic and detailed accounts. When dying, he collected his last strength and offered up the following prayer:—"Heavenly Father, eternal, merciful God, thou hast revealed to me Thy dear Son, our Lord Jesus Christ. Him I have taught, Him I have confessed, Him I love as my Saviour and Redeemer, whom the wicked persecute, dishonour, and reprove. Take my poor soul up to Thee!" Then two of his friends put to him the solemn question,—"Reverend Father, do you die in Christ and in the doctrine you have constantly preached?" He answered by an audible and joyful "Yes"; and, repeating the verse, "Father, into thy hands I commend my spirit," he expired peacefully, without a struggle, on the 18th of February 1546, at four o'clock in the afternoon.

The books on the life and work of Luther are so very numerous that it is impossible to do more than mention one or two. The best editions of Luther's works are (1) the Wittenberg, 1539-58, 19 vols. folio (7 in Latin and 12 in German; Melanchthon wrote the prefaces, and inserted a life of Luther in the beginning of the 2d vol.); (2) Walch's edition, 24 vols. 4to, 1740-53; (3) the Erlangen edition, 65 vols. and 2 vols. of indices, in all 67 vols., in German, and 33 vols. in Latin, and not yet complete, 1826-73; (4) the last edition is from Frankfort-on-the-Main, publishing at the expense of the Prussian Government.

Luther's letters have been collected and edited by (1) De Wette and Seidemann, *L. Briefe*, 6 vols., 1825-56; (2) this emendated by Burkhardt, *Luther's Briefwechsel*, 1866; (3) Seidemann, *Lutherbriefe*, 1859.

The *Table Talk* was translated (1) by William Hazlitt, 1848, and (2) by Bindseil, *Colloquia*, &c., 3 vols., last published 1866.

Lives of Luther.—(1) J. Mathesius, *Historie von D. M. Luther's*, &c., Nuremberg, 1566; (2) Cochlæus, *Acta et Scripta Lutheri*, Paris, 1565 (Roman Catholic and abusive); (3) Merle d'Aubigné, *Hist. of the Ref.*, vols. i.-iii., 1838, &c.; (4) Michelet, *Life of Luther* (his statements about himself collected), translated by Hazlitt, 1846 and 1862; (5) Croly, *Life of Luther*, 1857; (6) Julius Köstlin, *Martin Luther, sein Leben, &c.*, 2 vols., 1875. The last is the best; it has been summarized for popular reading in one volume, with interesting illustrations, 1882.

The Times of Luther.—(1) Ranke, *Deutsche Geschichte im Zeitalter d. Ref.*, 6 vols., 1st ed. 1839-47, reached a 6th ed., Eng. transl. by Sarah Austin, 1845-47; (2) Löscher, *Reformations Akta*, Leipsic, 1720; (3) Häusser, *The Period of the Reformation*, 2 vols., 1873; (4) Seebohm, *Era of the Protestant Revolution*, 1877 (a very short but good and clear summary of events). (T. M. L.)

LUTHERANS are that body of Christians who adopted the principles of Martin Luther in his opposition to the Roman Church, to the Swiss theologians, and to the sectaries of Reformation times. They called themselves "Evangelical" in distinction from the "Reformed" or followers of Calvin, and formed one of the two great divisions of the Reformation Church. In the early days of controversy the stricter Lutherans held it to be their peculiar function to preserve the *status religionis in Germania per Lutherum instauratus* and to watch over the *depositum Jesu Christi* which Luther had left in their charge. Luther himself was much more fitted to be a reformer and preacher than an exponent of a scheme of theology or the organizer of an ecclesiastical system. His wonderfully sympathetic nature was easily moved, and his own liking and disliking ruled him too strongly to make him able to expound in calm fashion the whole round of theology, giving to each doctrine its proper place in the system. His nominalist training, his quietism got from the mystics of the 14th and 15th centuries, his occasional fits of morbid melancholy, all kept him from looking at the whole system of Christian doctrine, and made him intensify the value and importance of special aspects of truth. The early Lutheran theology reflected the character of its founder. It lacked systematic completeness, more especially in its failure to construct a comprehensive doctrine of the work of the Holy Spirit, and it swayed from side to side in violent controversies, until at length out of the conflicts emerged the Form of Concord, which, it was hoped, would succeed in pacifying the church. The dogmatic symbols of the Lutheran Church are usually said to include nine separate creeds, three of which are taken from the early Christian Church while six are the production of the 16th century. They are the Apostles' Creed, the Nicæo Constantinopolitan Creed in its Western form (*i.e.*, with the *filioque*), the so-called Athanasian Creed, the Augsburg Confession or Confessio Augustana, the Apology for the Augsburg Confession, the Smalkald Articles, Luther's two Catechisms, and the Form of Concord. These nine confessions together make up the *Liber Concordiæ* of the Lutheran Church; but only the three pre-Reformation creeds and the Augsburg confession are recognized by all Lutherans. Luther's catechisms, especially the shorter of the two, have been almost universally accepted, but the Form of Concord was expressly rejected by many Lutheran churches. The Augsburg Confession and Luther's Shorter Catechism may be said to contain the distinctive principles of Lutheranism which all Lutherans unite to maintain, but, as the principal controversies of the Lutheran Church all arose after the publication of the Augsburg Confession, and were fought out between men who united in accepting that symbol, it does not contain all that is distinctively Lutheran. The Augsburg Confession itself perhaps owed its universal recognition to the fact that it existed in two forms which vary slightly in the way in which they state the doctrine of the sacrament of the supper, the *variata* and the *invariata*; and this also bears witness to the lack of dogmatic coherence which is a characteristic of Lutheranism. Melanchthon's *Hypotyposes* or *Theological Commonplaces* (first published in 1521) may also rank along with these creeds as an authoritative exposition of Lutheran theology; and the changes it underwent in its successive editions show the incompleteness of the system.

The earliest controversy which divided the Lutheran Church arose in Luther's lifetime and lasted till 1560 (1537–60). It sprang out of differences of opinion about the precise meaning to be attached to the term law in Luther's famous distinction between law and gospel. According to Luther, and the distinction runs through all Lutheranism, law and gospel are the two factors which bring home to the individual experience the knowledge of salvation. Law is the rule of life given by God and accompanied by threatening and promise, which counts on fulfilment from selfish motives, threatens, terrifies, and so produces contrition; while the gospel, which is the message of salvation, comes after the law has done its work, and soothes. In this description the term law has a distinct and definite meaning; it signifies legal injunction or command; and Luther and his followers were accustomed to say, using law in this definite way, that Christ was not under the dominion of the law, and that Christ's people are also free from its restraints. They said that believers ascend to the Christian life only when they have transcended a rule of life which counts on selfish motives for obedience. The word law manifestly means more than Luther put into this definition, and certain Lutherans who accepted Luther's distinction between law and gospel did not understand his limitation of the term law, and taught that believers were not bound by the moral law. These antinomians, of whom Agricola was chief, took Luther's statements about law in the sense of legal injunction, and applied them to law in the sense of ethical rule. The confusion perplexed the Lutheran Church for more than twenty years.

The debates which harassed the Reformed Church in the Arminian controversy, and the Roman Catholic Church in the Jansenist controversy, appeared in the Lutheran Church in three separate disputes lasting from about 1550 to 1580. In these discussions the stricter Lutherans were on the one side and Melanchthon with his followers on the other. The first dispute was about the relation of good works to conversion. George Major, founding on an expression in Melanchthon's *Commonplaces* (ed. 1543), said that good works were both necessary and useful to holiness. He was attacked by Mat. Flacius and Nic. Amsdorf, and after a long and tedious discussion, in the course of which it was made plain that both sides were sadly in want of general principles to guide them, and that important words were used ambiguously, George Major's proposition was condemned because it savoured of Pelagianism. The problem took a new form in the Synergist controversy, which discussed the nature of the first impulse in conversion, and in the controversy about original sin which followed. Pfeffinger taught that the first impulse in conversion came from grace and was due to the Holy Spirit, but he said that this impulse and its effect might be compared with the reviving of a man apparently dead. According to the strict Lutherans the sinner was not apparently but actually dead, and grace was not merely the occasion, it was also the actual cause, of the new life. Flacius, who had made this last assertion, which seemed to be generally approved of, started a fresh controversy by his assertion that sin was part of the substance of man in his present natural condition, and that man was no more able to co-operate with grace in conversion than was a stick or a stone. This was contradicted by Striegel, a follower of Melanchthon, who asserted that sin had not totally destroyed man's ethical nature, but that grace by its action changed what was morally insensible into what was morally living and sensible, so that there could be an actual synergy or co-operation between God's grace and man's will.

The controversy raised by Andrew Osiander was much more important, and revealed the lack in Lutheranism of a systematic doctrine of the work of the Holy Spirit. Osiander felt that Lutheran dogmatic had omitted to make adequate answer to a most important practical question in theology, how Christ's death on the cross could be so brought into connexion with each individual believer as to be the ground of his actual justification. The mediæval church had spanned the centuries by their doctrine of the prolongation of Christ's death throughout time in the sacrifice of the mass, but he could not see any such real connexion of time in Luther's theology. He proposed to get rid of the difficulty by saying that justification is a real work in the believer done by that same Christ who had died so many centuries before. He distinguished between redemption, which he said was the result of the historical work of Christ upon the cross, and justification, which was another work of the same Redeemer within the individual, and was the influence renewed daily of the Saviour upon each believer. The controversy which followed was full of ambiguities and misunderstandings, but out of it rose two distinct theories, one of which was generally adopted by the Lutherans, while the other has become a characteristic of Reformed or Calvinist theology. Striegel declared that the principal effect of the work of Christ upon the cross was to change the attitude of God towards the whole human race, and that in consequence whenever men come into being and have faith they can take advantage of that change of attitude, the ground of their assurance being that because of what Christ did God regards all men benevolently. Calvinist divines, on the other hand, found in Osiander's criticism the starting point of that close connexion between Christ's work and His redeemed which is expressed in the doctrine of the limited reference in the atonement.

These controversies all implied more or less vagueness in the earlier dogmatic teaching of Luther. Others, however, arose from what may be called the distinctive teaching of Luther upon the sacrament of the Lord's Supper and what was implied therein. In the article LUTHER it is stated that Luther, at least after the peasants' war, held strongly a theory of the connexion between the elements (the bread and wine) and the body and blood of Christ in the sacrament of the supper which has been called *consubstantiation*, and that this theory depended not merely on certain scholastic definitions of bodily presence but also on the supposition that the attribute of ubiquity belonged to the glorified body of Christ. A large number of Lutherans, followers of Melanchthon, were inclined to depart from these views and approach the more reasonable opinions of Calvin, and this occasioned controversies about Crypto-Calvinism and about Christology. The university of Jena was the theological headquarters of the stricter Lutherans, while Wittenberg was the centre of the Philippists or Crypto-Calvinists, as the followers of Melanchthon were called. At first the controversy mainly gathered round the questions of the corporeal presence, the oral manducation, and the literal eating of Christ's body by unbelievers as well as by the truly faithful, but it soon included discussions on the person of Christ, and into these discussions Reformed theologians were brought. The result was various conferences at Maulbronn (1564), which only confirmed both parties in their peculiar opinions; at Dresden (1571), where the Lutheran theologians of Wittenberg and Leipsic renounced the doctrine of the ubiquity of Christ's body and agreed with the Calvinists; and elsewhere. It seemed as if the Lutheran Church was about to fall in pieces.

Out of these disputes came the Form of Concord, due principally to Jacob Andreæ of Tübingen, to Martin Chemnitz of Brunswick, and to Nicolas Selnecker of Leipsic. Various theological conferences were held, and various articles of agreement more or less successful were framed, of which the most notable was the *Torgau Book* of 1576; and at last in 1577 the Form of Concord was published, and after much discussion and negotiation was adopted by most of the Lutherans in Germany. Its recognition was mainly due to the exertions of Augustus, elector of Saxony It was also adopted by the Lutheran churches of Sweden in 1593, and of Hungary in 1597. It was rejected by the Lutheran Church of Denmark and by the churches of Hesse, of Anhalt, of Pomerania, and of several imperial cities. It was at first adopted and afterwards rejected by Brunswick, by the Palatinate, and by Brandenburg. The German churches which refused to adopt it became for the most part Reformed or Calvinist; and the Form of Concord, which ended the more violent theological controversies among the Lutherans, greatly decreased their numbers and territorial extent.

The divided state of Germany in the 16th century, aided by the maxim of the peace of Augsburg which gave Protestantism a legal standing, and by the consistorial system of ecclesiastical rule which followed in consequence, divided the Lutherans in Germany into a number of separate churches as numerous as the principalities. At the peace of Augsburg the adherents to the Augsburg Confession were recognized legally as having a right to exist within the German empire, and the power of determining whether the Roman Catholic or Lutheran confessions should be the recognized creed of the state was left, with some reservation, in the hands of the supreme civil authority in each separate principality (*cujus regio ejus religio*). This virtually gave the direction of the church of each German state into the hands of the supreme civil power therein; it belonged to the princes in the various principalities and to the municipal councils in the free imperial cities. This legal recognition of the supreme authority of the civil power in ecclesiastical affairs was intensified by the adoption in the Lutheran Church of the consistorial system of church government, which was the distinctive mark of the Lutheran as opposed to the Reformed Church. The consistorial system took a great variety of forms, but it had one common characteristic: it simply transferred the *jus episcopale* from the bishops to the civil authorities, and, as the bishops ruled their dioceses in ecclesiastical and other matters by means of councils or consistories appointed by themselves, so in the

Lutheran Church these old episcopal consistories were transformed into councils whose members were appointed by the civil rulers. Thus each petty German state had its own church with its special organization and peculiar regulations. Richter in his *Evangelische Kirchenordnungen des 16ten Jahrhunderts* (2 vols., 1846) has collected more than one hundred and eighty separate constitutions of churches adhering to the Augsburg Confession. This minute subdivision makes it almost impossible to recognize any unity in the Lutheran Church save what comes from the profession of a common creed.

The publication of the Form of Concord drew the strict Lutherans more together, and set over against them in Germany a Calvinist Church, and the divided state of Protestantism greatly weakened its strength in the religious wars of the 17th century. As the smaller German states came together in larger principalities the awkwardness of the separate Protestant churches was more keenly felt. Many attempts were made by conferences, as at Leipsic (1631), Thorn (1645), Cassel (1661), to unite Lutherans and Reformed, though without success. At length the union of the two churches was effected mainly by the force of the civil authority in Nassau (1817), in Prussia (1817), in Hesse (1823), in Anhalt Dessau (1827). These unions for the most part aimed, not at incorporating the two churches in doctrine and worship, but at bringing under one government the two confessions, and permitting every congregation to use at pleasure either the Lutheran or the Heidelberg Catechism. They were sometimes accompanied, as in Prussia, by a separation of the stricter Lutherans, who formed themselves into dissenting churches. The separation in Prussia was caused mainly by a new liturgy which Frederick William III. forced on the church, and which the dissenters or Old Lutherans refused to use. The divisions caused in this way were at first repressed but were afterwards tolerated, and have reproduced themselves in the flourishing Lutheran Church of the United States.

See Ritschl, "Die Entstehung der Lutherischen Kirche" (*Zeitsch. für Kirchengeschichte*, i. 1); Hundeshagen, *Beiträge zur Kirchenverfassungs Geschichte*, &c., 1864; Dorner's *History of Protestant Theology*; Hering, *Geschichte der kirchlichen Unionsversuche seit die Reformation*, 1836–38; Sack, *Die Evangelische Kirche und die Union*, 1861. (T. M. L.)

LUTON, a market-town and municipal borough of Bedfordshire, England, is situated in a fine valley near the source of the Lea, 31 miles north-west of London. The parish church of St Mary, dating from the 14th century, a very fine building in the Decorated Norman and Later English styles, contains a large number of old monuments and brasses. Its entire length is 182 feet, the width of nave and aisles 57 feet, and the width of the transepts from north to south 101 feet. On the process of restoration, begun in 1865, £6000 has been expended. The other principal public buildings are the town-hall, the corn exchange, the court-house, and the plait hall. Luton is the principal seat of the straw-plait manufacture in England. The industry originated in the colony of straw-plaiters transplanted by James I. from Scotland, whither they had been brought from Lorraine by Queen Mary. Though the town is very ancient, it was first incorporated in February 1876. The population, which in 1871 was 17,317, was 23,959 in 1881.

LUTZK, a district town of Russia, in the government of Volhynia, on the Styr, 162 miles west-north-west of Szitomir, and 5 miles from the Kivertzy station of the railway between Kieff and Brest-Litovsky. It is a very old town, supposed to have been founded in the 7th century; in the 11th century it was known under the name of Luchesk, and was the chief town of an independent principality. In the 15th century it was the seat of a bishop, and became a wealthy town, but during the wars between Russia and Poland in the second half of the 16th century, and especially after the extermination of its 40,000 inhabitants, it lost its importance. In 1791 it was taken by Russia. It is now a rather poor town, situated in an unfertile district, and its 11,500 inhabitants, many of them Jews, live mainly by shipping goods on the Styr.

LUXEMBOURG, FRANÇOIS HENRI DE MONTMORENCY-BOUTTEVILLE, DUC DE (1628–1695), marshal of France, the comrade and successor of the great Condé, was born at Paris on January 8, 1628. His father, the Comte de Montmorency-Boutteville, had been executed six months before his birth for killing the Marquis de Beuvron in a duel, but his aunt, the Princesse de Condé, recognizing in him the last male heir of her great family De Montmorency, took charge of him, and educated him with her son, the Duc d'Enghien. The young Montmorency attached himself enthusiastically to his cousin, and shared his successes and reverses throughout the troubles of the Fronde. He returned to France in 1659 and was pardoned, and Condé, who was then much attached to the Duchesse de Châtillon, Montmorency's sister, contrived the marriage of his adherent and cousin to the greatest heiress in France, the Princesse de Tingry, after which he was created Duc de Luxembourg and peer of France. At the opening of the war of the devolution, 1667–68, Condé, and consequently Luxembourg, had no command, but in the second campaign he served as one of Condé's lieutenants in the conquest of Franche Comté. During the four years of peace which followed the peace of Aix-la-Chapelle, Luxembourg diligently cultivated the favour of Louvois, and in 1672 received orders to commence hostilities with the Dutch. He defeated the prince of Orange, whom he was to beat again and again, at Woerden, and ravaged Holland, and in 1673 made his famous retreat from Utrecht with only 20,000 men in face of 70,000, an exploit which placed him in the first rank of generals. In 1674 he was made captain of the gardes du corps, and in 1675 was made marshal of France. In 1676 he was placed at the head of the army of the Rhine, but failed to keep the duke of Lorraine out of Philipsburg; in 1677 he stormed Valenciennes; and in 1678 he defeated the prince of Orange, who attacked him at St Denis after the signature of the peace of Nimeguen. His reputation was now at a great height, and it is commonly reputed that he quarrelled with Louvois, who managed to mix him up in the confessions of the poisoners, and get him sent to the Bastille. Rousset in his *Histoire de Louvois* has, however, shown that this quarrel is probably apocryphal. There is no doubt that Luxembourg spent some months of 1680 in the Bastille, but on his release took up his post at court as *capitaine des gardes*, and was in no way disgraced. When the war of 1690 broke out, the king and Louvois also recognized that Luxembourg was the only general they had fit to cope with the prince of Orange, and accordingly he was put in command of the army of Flanders. On July 1, 1690, he defeated the prince of Waldeck at Fleurus with the loss of 14,000 men and 49 pieces of cannon. In the following year he commanded the army which covered the king, who was besieging Mons, and defeated William III. of England at Leuze on September 18, 1691. Again in the next campaign he covered the king's siege of Namur, and utterly defeated William at Steenkerk on June 5, 1692; and on July 29, 1693, he won his greatest victory over his old adversary at Neerwinden, in which he took 76 pieces of cannon and 80 flags. No wonder he was received with enthusiasm at Paris by all but the king, who looked coldly on a relative and adherent of the Condés. He conceived himself strong enough to undertake an enterprise which St Simon describes at length in the first volume of his *Memoirs*: instead of ranking as eighteenth peer of France according to his patent of 1661, he claimed through his wife to be Duc de Piney of an old creation of 1571, which would place him second on the roll. The whole affair is described with St Simon's usual keen interest in all that concerned the peerage, and was chiefly checked through his assiduity. In the campaign of 1694, possibly owing to this check, Luxembourg did but little in Flanders, except his well-known march from Vignamont to Tournay in face of the enemy. On his return to Versailles for the winter he fell ill, and died on January 4, 1695. In his last moments he was attended by the famous Jesuit priest Bourdaloue, who said on his death, "I have not lived his life, but I would wish to die his death." The holy father certainly had not lived like Luxembourg, whose morals were conspicuously bad even in those times, and whose life had shown very slight signs of religious conviction. But as a general he was Condé's grandest pupil. Utterly slothful, like Condé, in the management of a campaign, and therein differing from Turenne, at the moment of battle he seemed seized with happy inspirations, against which no ardour of William's and no steadiness of Dutch or English soldiers could stand. His death and Catinat's disgrace close the second period of the military history of the reign of Louis XIV., and Catinat and Luxembourg, though inferior to Condé and Turenne, were very far superior to Tallard and Villeroi. He was distinguished for a pungent wit. One of his best retorts referred to his deformity. "I never can beat that cursed hump-back," William was reputed to have said of him. "How does he know I have a hump?" retorted Luxembourg, "he has never seen my back." He left four sons, the youngest of whom was a marshal of France as Maréchal de Montmorency.

See the various memoirs and histories of the time. There are some interesting facts in Desormeaux's *Histoire de la Maison de Montmorency*. Camille Rousset's *Louvois* should also be studied.

LUXEMBURG, a grand-duchy of Europe, governed under a special constitution by the king of the Netherlands, is bounded on the N. and E. by Rhenish Prussia, S. by Lorraine and the French department Meurthe-et-Moselle, and W. by Belgian Luxemburg. It measures 32 miles from Hartelingen to Rosport, both on the Sure, and 50 miles from Rumelange in the south to Weiler in the north. The surface contains 639,000 acres (998 square miles), of which 293,554 acres are arable, 61,033 meadow-land, 143,812 woodland, 54,135 coppice, and 540 vineyards. The hills in the south of the duchy are a continuation of the Lorraine plateau; and the northern districts are crossed in all directions by outrunners from the Ardennes. With the exception of the Chiers, which flows into the Meuse near Sedan after a course of 50 miles, the streams all drain into the Moselle, which forms the boundary between Luxemburg and the Rhine province for about 20 miles. The Sure or Sauer, the most important stream in the duchy, rises at Vaux-les-Rosières in Belgian Luxemburg, crosses the duchy, and forms the eastern boundary from the confluence of the Our till it joins the Moselle after a course of 50 miles, during which it receives the Wiltz, the Woltz, the Alzet, &c. At Mondorf there are mineral wells and a bathing establishment. The soil of Luxemburg is generally good; the southern districts are on the whole the most fertile as well as the most populous. Building materials of all sorts are obtained throughout the duchy, and in the south there is iron-ore of fair quality—the mining area at present occupying from 8000 to 10,000 acres. Galena is worked on the frontier between Oberwampach and Longville, and antimony at Gösdorf near Wiltz. Since 1842 Luxemburg has been included in the Zollverein, and its principal dealings are, consequently, with Germany. Besides the iron furnaces,—situated all of them in the south near the Lorraine plateau,—the industrial establishments of the country comprise a large number of tanneries, a dozen weaving factories, an important glove-making factory, a pottery, paper-mills for all sorts of paper, breweries and distilleries, and two sugar refineries. A German patois mixed with French words is spoken throughout the country; but French, which is universally employed by the commercial community, is also the common speech of all classes on the French and Belgian frontiers. Though perfect liberty of worship prevails, Roman Catholicism is almost the sole form of religion in the duchy, the only dissenters worthy of note being the Protestant Prussian employés and about three hundred Jewish families. The government is in the hands of the grand-duke, who sanctions and promulgates the laws. Between 1850 and 1879 the king of the Netherlands was represented in his grand-ducal functions by his brother Prince Henry; but since the prince's death he has resumed the personal direction of affairs. The grand-duchy is a neutral and independent state, and its crown hereditary in the Nassau family (Treaty of London, March 11, 1867). A house of representatives and a council of state, named by the grand-duke, compose the administrative body. The representatives, to the number of forty-four, are chosen by the people in the proportion of one for from 4000 to 5500 inhabitants. No law can be passed without the consent of the house of representatives. Bills are introduced by the grand-duke, but the house has also the right of initiative. A single battalion (150) of Luxemburg chasseurs composes the grand-ducal army,—all voluntary recruits. The gendarmerie also consists of about 150 men. There are two courts of first instance in the duchy,—one at Luxemburg, the other at Diekirch,—and a high court and a court of appeal, both at Luxemburg. Criminals appear before the court of assize at Luxemburg. By grand-ducal decree the order of the Crown of Oak was instituted for the duchy, December 29, 1841, and that of the Golden Lion, February 5, 1858. The communal councils are under the supervision of the district commissioners, who are subject in turn to the minister of the interior. The administration of the town of Luxemburg depends immediately on the Government. Education is in a flourishing state: there are 642 primary schools attended by 31,000 pupils; Luxemburg has a normal school and an athenæum; Diekirch and Echternach have each a gymnasium. The bishopric of Luxemburg, containing 13 diaconates, subdivided into 253 parishes, holds its authority directly from the Holy See. From 6,000,000 to 7,000,000 francs is the annual amount of the state budget, and the public debt was 12,000,000 francs in 1863. Since 1854 there has been a grand-ducal bronze coinage.

The following table shows the administrative divisions and the population (total, 205,158) according to the census of 1875.

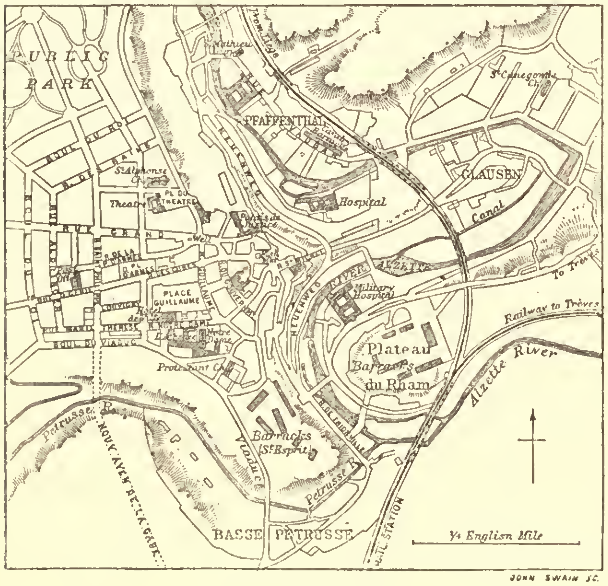
Districts.	Cantons.	Communes.	Population.
Luxemburg	Luxemburg	13	42,066
	Capellen	11	16,363
	Esch	13	24,158
	Mersch	11	14,264
Grevenmacher	Echternach	8	13,136
	Grevenmacher	9	14,918
	Remich	10	13,796
Diekirch	Clerf	10	13,899
	Diekirch	13	18,254
	Redingen	13	15,042
	Vianden	3	3,350
	Wiltz	13	15,972

Next to the capital come Echternach with 3920, and Diekirch with 3130 inhabitants,—both worthy of note for their blast furnaces. At Echternach an annual procession is held in honour of St Willibrord, dating from 1374. Grevenmacher is the centre of a great wine district.

The Luxemburg territory as well as the country of Ardenne was included in Belgica Prima at the first division of Gaul by Augustus in 27 B.C.; during the Frankish period it formed part first of Austrasia, then of Lorraine, and then of Lower Lorraine. On the dismemberment of ancient Austrasia the countship of Ardenne fell to Ricuin; and, when after Ricuin's death his children divided his possessions, Ardenne proper was obtained by Count Sigfried (Sigefroi). The county of Luxemburg, as Ardenne came to be called after the chief town, was raised to be a duchy in 1354, and existed as an independent state till 1451, when it was seized by Philip, duke of Burgundy. The dynasty which he displaced had been ambitious and active, and had, in the person of Henry VII., attained the imperial dignity, and in that of John ascended the throne of Bohemia. As a Burgundian possession Luxemburg came to the house of Austria, and, after forming part of the archduchy governed by Albert and Isabella, 1598–1632, followed the fate of the Spanish Netherlands till it was ceded by the treaty of Utrecht to the house of Hapsburg. It was deprived of Thionville, Montmedy, Damvilliers, Ivoix, and Marville by the treaty of the Pyrenees (1659) in favour of France; and Louis XIV. occupied the town and great part of the province from 1684 till the treaty of Ryswick (1697). Seized by the French in 1793, it went in the main to form the department of Forêts. On the 16th March 1815 William I. declared himself king of the Netherlands and duke of Luxemburg, and his claims were sanctioned by the treaty of Vienna,—Luxemburg being considered compensation for the loss of the small principalities of Hadamar, Siegen, Dietz, and Nassau-Dillemburg, the surrender of which to Prussia had deprived William of his place in the Germanic confederation. The fortress was assigned to the confederation itself, and was garrisoned by six thousand men, of whom one-fourth belonged to the grand-duke and three-fourths to the confederation. From the recognition of Belgian independence in 1830 to the treaty of London in 1839, matters were still more complicated; there were two governments in Luxemburg—one at Luxemburg, acting for the grand-duke, and the other at Arlon, acting for Belgium. By the treaty of London about 1218 square miles of the duchy with 149,571 inhabitants were transferred to Belgium, the German confederation and King William being compensated with parts of Limburg. On the dissolution of the confederation the duchy became free from its connexion with Germany, but the fortress remained in the hands of Prussia. A diplomatic contest for possession of the duchy took place between France and Prussia; and the matter became the object of a special conference of the plenipotentiaries of the great powers, Holland, Belgium, and Italy, in 1867. The result was that the neutrality of Luxemburg was guaranteed and the military importance of the town destroyed. The actual demolition of the fortifications evacuated by the Prussians in September 1867 did not take place till 1872.

See Bertholet, *Hist. du duché de Luxembourg*, Luxemburg, 1741–43; Vandermaelen, *Dict. géogr. du Luxembourg*, Brussels, 1838; Schötter, *Krit. Erörterungen über die früh. Gesch. der Grafschaft Luxemburg*, Luxemburg, 1859; Grövig, *Luxemburg, Land und Volk*, Luxemburg, 1867.

LUXEMBURG, the capital of the grand-duchy, lies 34 miles north of Metz and 25 south-west of Treves, in a position as remarkable for natural beauty as for military strength. The main part of the town is built on a rocky table-land terminating precipitously towards the north-east and south;



Plan of Luxemburg.

the modern portions, known as Pfaffenthal, Clausen, and Grund, lie 200 feet below, in the valley of the Alzette. Till their demolition in terms of the treaty of 1867 the fortifications, on which the engineers of three centuries had expended their skill, were the great feature of the place; in point of strength they ranked, according to Carnot, second only to those of Gibraltar, and like them they were to a great extent hewn out of the solid rock. The site is now occupied partly by a fine public park, partly by new districts of handsome houses, which give the city more of the outward appearance of a capital. Among the buildings of historical interest are the cathedral of Notre Dame, erected by the Jesuits in 1613; the church of St Michel, dating from 1320; the Government-house, built in 1443, and still regularly occupied by the legislative assemblies; the town-house, built in 1830; the law courts, dating from 1565, but serving till 1795 as the residence of the governor of Luxemburg; and the athenæum, built in 1594, and now (1882) attended by 500 to 600 pupils. The population of the city and suburbs, which was 15,930 in 1875, is now estimated at 19,000.

Luxemburg (formerly called Lützelburg) appears in 738 as a castle presented to the abbey at Treves by Charles Martel. The town grew up in the course of the 10th century, and soon began to surround itself with walls; but it was not till 1503 that a regular system of fortifications was commenced, and the principal features of the modern fortress were due to Vauban, who accompanied Créqui in his capture of the place in 1664. Extensive additions were made to the works in 1728–34.

See Coster, *Gesch. der Festung Luxemburg*, Luxemburg, 1869.

LUXEMBURG, a province of the kingdom of Belgium, lying at the south-eastern extremity of the country, and bounded N. and W. by the provinces of Liége and Namur, S. by France, and E. by Prussia and by the grand-duchy of Luxemburg, from which it was separated in 1839. It is the largest and most thinly populated of the Belgian provinces,—75 miles in length, 30 in breadth; the population is 204,000. The ground is high, averaging 1200 feet above sea-level, and rising in parts over 2000. The soil is dry and slaty, with occasional sand and limestone. The aspect of the country is a succession of broad tracts of table-land or plateaus covered with wood or heather, and intersected by wide and deep valleys; these contain streams, half-dry during the summer, but quickly changed to sweeping torrents by rain or melting snow. Peat is found on the hills, and occasional morasses, known by the name of "hautes fanges," are to be met with on the tops of the highest mountains. The whole district is comprised within the region of Ardennes. The agricultural produce is poor; the various breeds of horses, cattle, sheep, &c., are remarkably small, though they all possess individual qualities of endurance or their flesh of flavour; the hams are renowned. The forests abound in game of all kinds; red deer are plentiful, and wild boars have of late become so abundant as to be a serious nuisance. The mineral productions are worthy of note. Iron is found in the valley of the Ourthe, and also farther south near Arlon; lead is extracted at Longwilly, manganese at Biham, zinc at Longwilly and Bleid. Building stone is to be had throughout the province, and is generally employed, brick houses being the exception. There are quarries of grey and rose-coloured marble at Wellin, and extensive slate quarries on the banks of the Semois, the Sure, and the Salm. The trade in wood and bark is considerable, and there are some important tanneries, as well as iron works, paper-mills, and limekilns. The principal rivers are the Semois, the Lesse, and the Ourthe, affluents of the Meuse, and the Sure, which flows into the Rhine; of these the Ourthe alone is navigable for a few miles down from Barvaux. There are no canals in the province, so that Luxemburg is entirely dependent on railways for its traffic. The Brussels and Basel line runs through the whole province, with a station at Arlon, the capital; and branch lines have been established to connect the principal markets, Marche, Durbuy, Bastogne, Virton, &c., with the main artery. The language spoken by the inhabitants is French, with an admixture of Walloon dialect and an inferior kind of German on the borders of the grand-duchy. The king of the Belgians and his brother the count of Flanders possess summer residences, with extensive forest lands, in the province of Luxemburg.

LUXOR, more properly El-Aksur, "The Castles" (*plur. pauc.* of kaṣr), a village on the Nile, 450 miles above Cairo, occupies part of the site of the ancient Thebes, and has its name from the ruins described in vol. vii. p. 777. The village is also called Abu'l Ḥajjáj from the patron saint whose tomb is mentioned by Ibn Baṭuṭa, i. 107, ii. 253. See also Yáḳút, i. 338. Luxor is the centre for visitors to the ruins of and about Thebes, and is increasingly frequented by travellers and invalids in the winter season, being the only place above Osyûṭ (Sayûṭ) provided with hotel accommodation suitable for Europeans. The district is the seat of an extensive manufacture of forged antiques, often very skilfully made.

LUZON, or LUÇON. See PHILIPPINE ISLANDS.

LYCANTHROPY is a term used comprehensively to indicate a belief, firmly rooted among all savages, and lingering in the form of traditional superstition among peoples comparatively civilized, that men are in certain circumstances transformed temporarily or permanently into wolves and other inferior animals. In the European history of this singular belief, wolf transformations appear as by far the most prominent and most frequently recurring instances of alleged metamorphosis, and consequently in most European languages the terms expressive of the general doctrine have a special reference to the wolf. Examples of this are found in the Greek λυκάνθρωπος, Russian *volkodlák*, English *were-wolf*, German *währwolf*, French *loup-garou*. And yet general terms (*e.g.*, Latin, *versipellis*; Russian, *ôboroten*; Scandinavian, *hamrammr*; English, *turnskin*, *turncoat*) are sufficiently numerous to furnish some evidence that the class of animals into which metamorphosis was possible was not viewed as a restricted one. It is simply because the old English general terms have been long diverted from their original signification that the word "lycanthropy" has recently been adopted in our language in the enlarged sense in which it has been defined above.

There are two unfailing characteristics of lycanthropous belief:—(1) there can nowhere be a living belief in contemporary metamorphosis into any animal which has ceased to exist in the particular locality; (2) belief in metamorphosis into the animal most prominent in any locality itself acquires a special prominence. These characteristics apart, the phenomena of lycanthropy exhibit a very considerable diversity in their nature.

Throughout the greater part of Europe the were-wolf is preferred on the principles just noted. There are old traditions of his existence in England, in Wales, and in Ireland. In southern France, the Netherlands, Germany, Lithuania, Bulgaria, Servia, Bohemia, Poland, and Russia he can hardly be pronounced extinct now. In Denmark, Sweden, Norway, and Iceland the bear competes with the wolf for pre-eminence. In Persia the bear is supreme, in Japan the fox; in India the serpent vies with the tiger, in Abyssinia and Bornou the hyæna with the lion, in eastern Africa the lion with the alligator; in western Africa the leopard is perhaps most frequently the form assumed by man, among the Abipones the tiger, among the Arawaks the jaguar, and so on. In none of these cases, however, is the power of transformation limited exclusively to the prominent and dominant animal.

The most familiar phase of the superstition is also the latest and most sophisticated. It was no belief in mere transformation; the transformation here was accomplished by Satanic agency voluntarily submitted to, and that for the most loathsome ends, in particular for the gratification of a craving for human flesh. "The were-wolves," writes Richard Verstegan (*Restitution of Decayed Intelligence*, 1628), "are certayne sorcerers, who having annoynted their bodies with an oyntment which they make by the instinct of the devill, and putting on a certayne inchaunted girdle, doe not onely unto the view of others seeme as wolves, but to their owne thinking have both the shape and nature of wolves, so long as they weare the said girdle. And they do dispose themselves as very wolves, in wourrying and killing, and most of humane creatures." Such were the views about lycanthropy current throughout the continent of Europe when Verstegan wrote. France in particular seems to have been infested with were-wolves during the 16th century, and the consequent trials were very numerous. In some of the cases,—*e.g.*, those of the Gandillon family in the Jura, the tailor of Châlons, and Roulet in Angers, all occurring in the year 1598,—there was clear evidence against the accused of murder and cannibalism, but none of association with wolves; in other cases, as that of Gilles Garnier in Dôle in 1573, there was clear evidence against some wolf, but none against the accused; in all the cases, with hardly an exception, there was that extraordinary readiness in the accused to confess and even to give circumstantial details of the metamorphosis, which is one of the most inexplicable concomitants of mediæval witchcraft. Yet, while this lycanthropy fever, both of suspectors and of suspected, was at its height, it was decided in the case of Jean Grenier at Bordeaux, in 1603, that lycanthropy was nothing more than an insane delusion. From this time the *loup-garou* gradually ceased to be regarded as a dangerous heretic, and fell back into his pre-Christianic position of being simply a "man-wolf-fiend," as which he still survives among the French peasantry. In Prussia, Livonia, and Lithuania, according to the bishops Olaus Magnus and Majolus, the were-wolves were in the 16th century far more destructive than "true and natural wolves," and their heterodoxy appears from the assertion that they formed "an accursed college" of those "desirous of innovations contrary to the divine law." In England, however, where at the beginning of the 17th century the punishment of witchcraft was still zealously prosecuted by James I., the wolf had been so long extinct that that pious monarch was himself able (*Demonologie*, lib. iii.) to regard "warwoolfes" as victims of delusion induced by "a naturall superabundance of melancholie." Only small creatures, such as the cat, the hare, and the weasel, remained for the malignant sorcerer to transform himself into; but he was firmly believed to avail himself of these agencies. Belief in witch-animals still survives among the uneducated classes in parts of the United Kingdom.

The were-wolves of the Christian dispensation were not, however, all heretics, all viciously disposed towards mankind. "According to Baronius, in the year 617, a number of wolves presented themselves at a monastery, and tore in pieces several friars who entertained heretical opinions. The wolves sent by God tore the sacrilegious thieves of the army of Francesco Maria, duke of Urbino, who had come to sack the treasure of the holy house of Loreto. A wolf guarded and defended from the wild beasts the head of St Edmund the martyr, king of England. St Oddo, abbot of Cluny, assailed in a pilgrimage by foxes, was delivered and escorted by a wolf."[1] Many of the were-wolves were most innocent and God-fearing persons, who suffered through the witchcraft of others, or simply from an unhappy fate, and who as wolves behaved in a truly touching fashion, fawning upon and protecting their benefactors. Of this sort were the "Bisclaveret" in Marie de France's poem (*c.* 1200), the hero of "William and the Were-wolf" (translated from French into English about 1350), and the numerous princes and princesses, knights and ladies, who appear temporarily in beast form in the *Mährchen* of the Aryan nations generally. Nay the power of transforming others into wild beasts was attributed not only to malignant sorcerers, but also to Christian saints. "Omnes angeli, boni et mali, ex virtute naturali habent

[1] A. de Gubernatis, *Zoological Mythology*, 1872, vol. ii. p. 145.

potestatem transmutandi corpora nostra," was the dictum of St Thomas Aquinas. A Russian story tells how the apostles Peter and Paul turned an impious husband and wife into bears; St Patrick transformed Vereticus, king of Wales, into a wolf; and St Natalis cursed an illustrious Irish family, with the result that each member of it was doomed to be a wolf for seven years. In other tales the divine agency is still more direct, while in Russia, again, men are supposed to become were-wolves through incurring the wrath of the devil.

There is thus an orthodox as well as a heterodox were-wolf; and, if a survey be taken of the lycanthropous beliefs of non-Christian peoples, this distinction among shape-changers will be equally obvious. The gods of ancient mythology, Hindu, Persian, Greek, and Teutonic, had an apparently unlimited power of assuming animal forms. These gods, moreover, constantly employed themselves in changing men and women into beasts, sometimes in punishment of crime, sometimes out of compassion, and sometimes from pure voluptuousness. Thus Kabandha was changed by Indra into a monster, Trisanku by the sons of Vasishtha into a bear, Lycaon by Zeus into a wolf, Callisto into a bear, Io into a heifer; the enemies of Odin became boars, and so on. It is admittedly difficult to trace the original meaning of these legends, but the alleged metamorphosis of a god is at times clearly associated with his worship under the form of the animal he turned into in the region where the metamorphosis was said to have occurred. Indra in the form of a bull encountered the monster Vritra, and released the cows he had stolen; Indra was invoked as a bull, and to him the bull and the cow were sacred among the Hindus. Derketo became a fish near Ascalon; a fish-goddess identified with her was worshipped in Syria, and the fish sacred to her were not eaten. Poseidon, the inventor of horses, was, as a horse, the father of the steeds Arion and Pegasus, and the horse was sacred to him. Jupiter Ammon appeared as a ram in the deserts of Libya; in Libya he had an oracle where the ram was sacred to him, and his image wore ram's horns. So too metamorphosis by gods is in some cases connected with local traditions. The Arcadians, or bear-tribe, sprang from the were-bear Callisto; the Lycians, or wolf-tribe, were wolves when they conducted to the river Xanthus the were-wolf Leto, mother of the Lycian Apollo. Turning from the gods to the heroes of classical romance, we find traditions more interesting and more instructive, because they must have some real historical foundation. Yet they also abound in episodes of beast mothers and beast fathers, and also of lycanthropy proper. Cyrus was suckled by a bitch, the Servian hero Milosh Kobilitch by a mare, the Norse Sigurd by a hind, the German Dieterich and the Latin Romulus by wolves; the progenitor of the Merovingian kings was a bull, of the Danish royal race a bear; Sigmund and Sinfiotli in the *Volsunga Saga* become wolves, Nagli in the *Eyrbyggia Saga* a boar. The Berserkir of Iceland asserted their ability to become bears and wolves, and dressed themselves in the skins of these animals; their existence, their garb, and their pretensions are historical facts. In the Sanskrit epic, the *Mahabharata*, the hero Puloman becomes a wild boar to carry off the wife of Bhrigu; the house of Brabant traced its origin to a transformed swan. Beast-form is, however, in mythology proper far oftener assumed for malignant than for benignant ends; indeed the heroes and anthropomorphic gods of the great religious systems are principally distinguished for their victories over the semi-human semi-bestial demons. The bull Indra fights the demon serpent Vritra, and so forth; the Theban Cadmus, the Russian Ivan, the Norse Sigurd, all encounter dragons or serpents, which possess human characteristics. In most of such cases indeed the human as well as the beast form is distinctly attributed to the demon.

It is because they may after all be properly associated with the undoubted phenomena of modern savage life that these facts of ancient mythology are here alluded to. Among savages there is the most confident belief in metamorphosis,—metamorphosis effected for the most salutary and for the most baneful ends. In the neighbourhood of Tette on the Zambesi every chief is credited with the power of assuming lion shape; every lion is respected as being a transformed chief or the spirit of a chief departed. Moreover, there is a special class of "doctors" or medicine-men, known as "pondoros," scattered through the villages, who pretend to powers of metamorphosis, and thus are regarded with both respect and dread; their kindly disposition they display by hunting for the community in lion shape, and then bringing home the game. Among the Arawaks of Guiana, the Kandhs of Orissa, and the Jakuns of the Malay peninsula, beast form is said to be assumed by those desiring to avenge themselves justly on enemies. Beast-parents and cases of women alleged to have borne beast children are also familiar to savages. But this is only one side of the picture. The "kanaima-tiger" (*i.e.*, man-jaguar) of Arawak may be possessed by the spirit of a man devoted to bloodshed and cannibalism; "there is," writes the Rev. Mr Brett, "no superstition more prevalent among the Indians than this, and none which causes more terror." In Ashango-land, where there are distinct traces of animal worship, a were-leopard was at the time of Du Chaillu's visit charged with murder and metamorphosis, and, confessing both, was slowly burnt to death, quite in the style of mediæval Europe. Similar occurrences have been known among the Kols (of Chútiá-Nágpúr) and among the Arabs.

The expedients supposed to be adopted for effecting change of shape may here be noticed. One of the simplest apparently was the removal of clothing, and in particular of a girdle of human skin, or the putting on of such a girdle,—more commonly the putting on of a girdle of the skin of the animal whose form was to be assumed. This last device is doubtless a substitute for the assumption of an entire animal skin, which also is frequently found. In other cases the body is rubbed with a magic salve. To drink water out of the footprint of the animal in question, to partake of its brains, to drink of certain enchanted streams, were also considered effectual modes of accomplishing metamorphosis. Olaus Magnus says that the Livonian were-wolves were initiated by draining a cup of beer specially prepared, and repeating a set formula. Mr Ralston in his *Songs of the Russian People* gives the form of incantation still familiar in Russia. Various expedients also existed for removing the beast-shape. The simplest was the act of the enchanter (operating either on himself or on a victim); another was the removal of the animal girdle. To kneel in one spot for a hundred years, to be reproached with being a were-wolf, to be saluted with the sign of the cross, or addressed thrice by baptismal name, to be struck three blows on the forehead with a knife, or to have at least three drops of blood drawn were also effectual cures. The last-mentioned was quite essential to the subsistence of the superstition. Its absurdity would have much sooner appeared, but for the theory that, directly the were-wolf was wounded, he resumed his human shape; in every case where one accused of being a were-wolf was taken, he was certain to be wounded, and thus the difficulty of his not being found in beast form was satisfactorily disposed of.

The foregoing types of lycanthropy, in which the divine or diabolical agency is always emphasized, are presumably less primitive than those cases in which superhuman agency is not so prominent. The following cases, therefore, seem to be more intimately connected with the origin of the belief. (1) The Kandhs believe "natural tigers to kill game only to benefit men, who generally find it but partially devoured and share it; while the tigers which kill men are either Tari (a goddess), who has assumed the form of a tiger for purposes of wrath, or men who, by the aid of a god, have assumed the form of tigers, and are called 'mleepa tigers.'" A distinction was previously drawn between friendly and hostile lycanthropists; here a distinction is drawn between friendly and hostile tigers, and lycanthropy is introduced to explain the cases of hostility. Again (2) in the native literature of modern savages there constantly occur stories of the "Beauty and the Beast" type, so distinctly resembling those of the Aryan *Mährchen* as to indicate identity of origin; but, while in the Aryan story the beast-form of the hero or heroine is generally at last removed, in the savage story the incongruity of the beast-form is scarcely realized, and the Indian lover lives happily with his beaver bride, the Zulu maiden with her frog husband. And (3) in many instances the power or necessity of transformation is ascribed, not to individuals, but to clans or nations. Thus the aboriginal Naga tribes of India seemed to the Aryans to take the form of serpents; the Neuri seemed to the Scythians, and the Hirpini to the Romans, to become wolves, as also did the native Irish of Ossory to the early Christian priests; the Abyssinians credit the Buda caste (blacksmiths and potters of alien stock) with ability to become hyænas at pleasure; the Berserkr-rage of Iceland is perpetuated in the modern Scandinavian belief that Lapps and Finns can take the form of bears. In mediæval times Blois had a special celebrity for were-wolves, and persons named Garnier or Grenier were generally assumed to be lycanthropists.

When we find that these three distinct classes of primitive facts regarding lycanthropy are all referable to a common origin, there seems good reason for regarding that as being in truth the origin of lycanthropous belief. And thus we are led to refer lycanthropy to the more general facts of primitive TOTEMISM (*q.v.*), for the facts recited are as undoubtedly characteristic of the latter as of the former. Where the totem is an animal, it is regarded as the ancestor of the tribe; all animals of its species are revered, and are never willingly killed; however dangerous to life, they are feigned by the tribe to be friendly to them, and hostile only to their enemies. Applying these facts to the foregoing lycanthropous phenomena in order, we observe (1) that the tiger is a totem god among the Kandhs; consequently he reserves his wrath for their enemies.[1] Individual enemies would, however, be created whenever an individual Kandh had the blood-feud against another, for then his totem was bound to aid him. Such we saw was in fact the Kandh explanation of the wrath of the totem. The development of sorcery would naturally lead to the utilization of the totem as assistant in it also. The Arawak "kanaima" is both lawful avenger and cruel sorcerer; and from a similar reason probably did the wolf or were-wolf in Europe become a synonym for outlaw. The outlaw was at first simply the peaceless man—the man who preferred vendetta to money composition for injuries,—as he was originally *bound* to do, subsequently *entitled* to do, and finally *prohibited* from doing. (2) The beast-hero of savage story ceases to be strange when we learn that "a beaver," "a dog," "a grizzly bear," mean respectively a person of a tribe having the animal in question for totem. And so too (3) with the third class of phenomena which contemplates tribes turned into beasts. The Nagas had the serpent for totem; apparently the Hirpini, and the native Irish in many districts, had the wolf; they certainly venerated and worshipped that animal. The Lapps are known to worship the bear. Blois means the "city of wolves." Doubtless all cases of this sort admit of similar explanation.

The doctrine of lycanthropy or metamorphosis of living men must be distinguished from the doctrine of metempsychosis or transmigration of souls. It no doubt was usual to conclude that the souls of cataleptic and epileptic patients sojourned temporarily in animals, while the patients were unconscious; but this phase of lycanthropy is too rare and too abnormal to be associated with the origin of the superstition. Transmigration after death, involving the belief in a future state, raises questions as puzzling as does lycanthropy itself, and questions quite of a different kind, because in normal lycanthropy the change effected is an actual corporeal one. Mr Tylor therefore throws little light on the origin of lycanthropy when he connects it with metempsychosis. In the form familiar to us it doubtless involves the doctrine of "animism"—the doctrine that animals, plants, and things are prompted to action by spirits similar to those possessed by men; but, whether lycanthropy is simply a special application of a general doctrine of animism, and is not rather one of the earliest advances from a blind totemism to a general animistic theory, may fairly be questioned. This at least seems plain: animism, apart from totemism, is not itself sufficient to explain lycanthropy, for even animistic beliefs are not developed abnormally, but along lines predetermined by circumstances. Mr Tylor's views are, however, so cautiously and so suggestively expressed as to deserve close study. Hardly so satisfactory are the other theories on the subject, which, passing over variations in detail, fall into two classes—the mythological and the rationalistic. On the former view, now upheld by a large school of inquirers, the ancient Aryan myths, and their modern representatives the *Mährchen*, are regarded as imaginative descriptions (principally due to the use of metaphorical language) of the great elemental powers and changes of nature. On such a view the occurrence of shape-changing gods and heroes is simple and natural, so long as the persons are purely mythical, because thus far nothing need be deemed strange or unnatural. But the theory breaks down when it ventures on elucidation of historical facts. It seems vain to contend,—although it is contended,—that "the terrible delusion of lycanthropy arose from the mere use of an equivocal word" (λύκος, "wolf," for λευκός, "shining"). Attempt to substantiate in detail this explanation of history is absolutely fatal. "Whence," it is asked, "came the notions that men were changed into wolves, bears, and birds, and not into lions, fishes, or reptiles?" and the triumphant reply is that the first-named animals were selected for glossiness or luminosity of coat.[2] Consequently, if transformation into the other animals was also believed in, the theory stands self-refuted. Now Hippomenes and Atalanta were for impiety turned into lion and lioness, Cadmus and Harmonia into serpents; and these cases of transformation have almost as intimate an association with the historical belief in men-lions and men-serpents as the case of Lycaon (mythologically = the shiner, the sun) has with lycanthropy. Cognate to the mythological doctrine is the doctrine of the personification as demons of all obstacles which men have encountered in the long struggle for existence,—among these the wilder and more savage animals. This is just a one-sided animism; it is inadequate to explain how the savage beasts so often became mild and gentle men. The rationalistic theories are open to the same objections: to account for divine and benignant lycanthropists they have to be supplemented by the mythological theories; they themselves deal exclusively with the more repulsive characteristics. The most recent exponent of the rationalistic theory is Mr Baring Gould, who rests his case on a proof of the facts that there is "an innate craving for blood implanted in certain natures, restrained under ordinary circumstances, but breaking forth occasionally, *accompanied with hallucination*, leading in most cases to cannibalism." That cannibalism and craving for blood had a natural (though not a necessary) connexion with lycanthropy, if it originated among savages, need not be disputed; but Mr Baring Gould's instances, drawn from mediæval European history, are undoubtedly exceptional. Hallucination, however, has been accepted as sufficient explanation of lycanthropy by many eminent authorities, besides Mr Gould, and raises a graver question. Belief in transformation into beasts has been acknowledged as a distinct type of monomania by medical men since the days of Paulus Ægineta (7th century) at least; but even in madness there is method, and insane delusions must reflect the usages and beliefs of contemporaneous society. Here the weakness of the case appears. Mr Gould, for instance, merely states that the victims were rustics, and wolves the chief terror of their homesteads, an explanation valid only on the assumption that the idea of metamorphosis was already familiar,—an assumption, that is, of the whole matter at issue. Besides, it is the popular, not the individual, belief in transformation that is strange; to trace its origin to insane delusion makes it stranger still, for sane men are particularly sceptical regarding the reality of the impressions of the insane. Sane men, moreover, believed in transformation, not only into malignant wolves, but also into harmless cats and hares, which in consequence became malignant and dangerous. How can the rationalistic theory account for a phenomenon like this? On the whole, there seems little doubt that, whether the origin of lycanthropy rests in totemism or not, Mr

[1] The Watusi of East Africa distinctly describe all wild beasts save their own totem-animals as enemy-scouts.

[2] Sir G. W. Cox, *The Mythology of the Aryan Nations*, London, 1870, vol. i. pp. 63 note, 231, 363, 459; vol. ii. p. 78 note.

Tylor is right in referring lycanthropous insane delusions to an antecedent belief in lycanthropy, instead of ascribing lycanthropy to insane delusions.

Literature.—In the numerous mediæval works directed to the study of sorcery and witchcraft, the contemporaneous phases of lycanthropy occupy a prominent place. In addition to the authors who have been already mentioned, the following may be named as giving special attention to this subject:—Wier, *De Præstigiis Dæmonum*, Amsterdam, 1563; Bodin, *Démonomanie des Sorciers*, Paris, 1580; Boguet, *Discours des Sorciers*, Lyons, 2d ed. 1608; Lancre, *Tableau de l'Inconstance de Mauvais Anges*, Paris, 1613; Psellus, *De Operatione Dæmonum*, Paris, 1615; see also Glanvil, *Saddücismus Triumphatus*, for the English equivalents of lycanthropy. Treatises solely confined to lycanthropy are rare both in mediæval and in modern times; but a few are well known, as, for instance, those of Bourquelot and Nynauld, *De la Lycanthropie*, Paris, 1615; Hartz, *De Werwolf*, Stuttgart, 1862; Baring Gould, *The Book of Were-wolves*, London, 1865. Incidentally, however, lycanthropy has engaged the attention of a large number of writers, most of whom theorize regarding its origin. An exhaustive enumeration of these cannot be here attempted; but the following works will be found particularly instructive:—Grimm, *Deutsche Mythologie*, vols. ii. and iii., 4th ed., Berlin, 1878; Welcker, *Kleine Schriften*, vol. iii., Bonn, 1850; Waitz, *Anthropologie*, vol. ii., Leipsic, 1860; Dasent, *Popular Tales from the Norse* (Introduction), Edinburgh, 1859; Afanasief, *Poeticheskiya Vozzryeniya Slavyan na Prirodu*, vol. iii., Moscow, 1869; Tylor, *Primitive Culture*, vol. i., London, 1871, and *Anthropology*, chap. xiv. and xv., London, 1881; Gubernatis, *Zoological Mythology* (especially chaps. xi. and xii.), London, 1872; Ralston, *Songs of the Russian People*, London, 1872; Laisnel de la Salle, *Croyances et Legendes du Centre de la France*, Paris, 1875; Conway, *Demonology and Devil Lore*, vol. i., London, 1879. For the medical aspects of lycanthropy, consult the *Asylum Journal of Mental Science*, vol iii. p. 100 (Dr D. H. Tuke), and authorities there cited. (J. F. M'L.)

LYCAON, son of Pelasgus or of Aizeus, was the mythical first king of Arcadia, who founded the first city Lycosoura and the worship of Zeus on Mount Lycæus. He, or his fifty impious sons, entertained Zeus and set before him a dish of human flesh; the god pushed away the dish in disgust and overturned the table at a place called Trapezus. In punishment either lightning slew the king and his sons, or they were turned into wolves. Pausanias (viii. 2) says that Lycaon sacrificed a child to Zeus, and was during the sacrifice turned into a wolf. Henceforth the story ran—a man was turned into a wolf at each annual sacrifice to Zeus Lycæus, recovering his human form after ten years if he had not during that time eaten human flesh. Lycaon is evidently the Lycæan form of a very common conception, viz., the divine first man, whose life is the heavenly fire, who comes to earth and returns to heaven as the lightning. The oldest city, the oldest cultus, and the first civilization of Arcadia are attributed to him. The mysterious cultus and the human sacrifices, which continued apparently through the historical period (Paus., viii. 38), of Zeus Lycæus have moulded the legends of the Lycæan first man and first king. Moreover his name, which is connected with that of the mountain, suggested a derivation from λύκος, wolf; and legends analogous to those of the Teutonic were-wolf (see LYCANTHROPY) naturally grew round him.

Plate II. LYCAONIA, in ancient geography, was the name given to a province in the interior of Asia Minor, north of Mount Taurus. It was bounded on the E. by Cappadocia, on the N. by Galatia, on the W. by Phrygia and Pisidia, while to the S. it extended to the chain of Mount Taurus, from which it was, however, in part separated by Isauria, though some writers included that district in Lycaonia. Its boundaries appear indeed to have varied at different times, as was the case with all the nations of Asia Minor. The name is not found in Herodotus, but Lycaonia is mentioned by Xenophon as traversed by Cyrus the younger on his march through Asia. That author, however, describes Iconium, one of the principal cities of Lycaonia, as included in Phrygia. But in Strabo's time the limits of the province were more clearly recognized, though Isauria was by some authors considered as a part of Lycaonia, by others as a distinct province. Ptolemy, on the other hand, includes Lycaonia as a part of Cappadocia, with which it may have been associated by the Romans for administrative purposes; but the two countries are clearly distinguished both by Strabo and Xenophon.

Lycaonia is well described by Strabo as a cold region of elevated plains, affording pasture to wild asses and to sheep. It in fact forms a part of the great table-land which constitutes the whole interior of Asia Minor, and has throughout its whole extent an elevation of more than 3000 feet above the sea. It suffers, moreover, severely from the want of water, aggravated by the abundance of salt in the soil, so that the whole northern portion of the province, extending from near Iconium to the salt lake of Tatta, and the frontiers of Galatia, was almost wholly barren. Other portions of the country, however, notwithstanding the deficiency of water, were well adapted for feeding sheep, so that Amyntas, king of Galatia, to whom the district was for a time subject, maintained there not less than three hundred flocks, which brought him in a large revenue.

Though the greater part of Lycaonia is a broad open plain, extending as far as the underfalls of the Taurus, its monotonous character is interrupted by some minor ranges, or rather groups of mountains, of volcanic character, of which the Kara Dagh in the southern portion of the district, a few miles north of Karaman, rises to a height of above 8000 feet, while the Karadja Dagh, to the north-east of the preceding, though of very inferior elevation, presents a striking range of volcanic cones. The mountains in the north-west of the province, near Iconium and Laodicea, on the other hand, are the termination of the great range of the Sultan Dagh, which traverses a large part of Phrygia.

The Lycaonians appear to have been in early times to a great extent independent of the Persian empire, and were like their neighbours the Isaurians a wild and lawless race of freebooters; but their country was traversed by one of the great natural lines of high road through Asia Minor, from Sardis and Ephesus to the Cilician gates, and a few considerable towns would naturally grow up along this line of route. The most important of these was Iconium, in the most fertile spot in the province, of which it has always continued to be the capital. It is still called Konieh. A little farther north, immediately on the frontier of Phrygia, stood Laodicea (Ladik), called Combusta, to distinguish it from the Phrygian city of that name; and in the south, near the foot of Mount Taurus, was Laranda, now called Karaman, which has given name to the province of Karamania. Derbe and Lystra, which appear from the Acts of the Apostles to have been considerable towns, were apparently situated in the same part of the district, but their sites have not been identified. The other towns mentioned by ancient writers were insignificant places.

The Lycaonians appear to have still retained a distinct nationality in the time of Strabo, but we are wholly in the dark as to their ethnical affinities, or relations to the tribes by which they were surrounded. The mention of the Lycaonian language in the Acts of the Apostles (xiv. 11) is evidently only intended to designate the vernacular tongue, as opposed to Greek, and cannot be regarded as any proof that they spoke a different language from their neighbours the Phrygians or Cappadocians.

LYCIA, in ancient geography, was the name given to a Plate II.
district in the south-west of Asia Minor, occupying the portion of the coast between Caria and Pamphylia, and extending inland as far as the ridge of Mount Taurus. The region thus designated is one strongly marked by nature, as constituting a kind of peninsula or promontory projecting towards the south from the great mountain masses of the interior. It was also inhabited from a very early period by a distinct people, known to the Greeks as Lycians, but whose native name, according to Herodotus, was Termilæ, or (as it is written by Hecatæus) Tremilæ, and this is confirmed by native inscriptions, in which the name is written Tramilæ. Herodotus tells us also that they were not the original inhabitants of the country, which was previously occupied by the Milyans, and this is rendered probable by the fact that a people of that name was still found in the rugged mountainous district in the north-east, who appear to have always continued distinct from the Lycians. But

LYCAONIA, LYCIA, LYDIA, &c.

the statement of the same historian that they originally came from Crete is in the highest degree improbable; and the attempts to connect them with the Greek legendary history through Sarpedon and Lycus, a son of Pandion, may be safely rejected as mere fictions.

The Lycians alone among the nations in the west of Asia Minor preserved their independence against the kings of Lydia; but after the fall of the Lydian monarchy (in 546 B.C.) they were subdued by Harpagus, the general of Cyrus, though not till after an obstinate resistance in which Xanthus, their chief city, was utterly destroyed. But, though they were from this time nominally subject to Persia, they appear to have enjoyed a considerable amount of independence, which they afterwards maintained by joining the Athenian maritime league. They were conquered almost without resistance by Alexander, and thus passed under the Macedonian dominion, sometimes of the Ptolemies, sometimes of the Seleucidans. But through all these vicissitudes, as well as after their ultimate submission to the Roman power, they continued to preserve their federal institutions, which remained unimpaired, in form at least, as late as the time of Augustus. Strabo, who has preserved to us an account of their constitution, which he regards as the wisest form of federal government with which he was acquainted (a judgment confirmed by the high authority of Montesquieu), tells us that the league consisted of twenty-three cities in all, of which the six principal were Xanthus, Patara, Pinara, Olympus, Myra, and Tlos. These six had each three votes in the general assembly; of the remaining cities the more considerable had each two votes, and the rest only one. The payment of taxes and other public burthens were apportioned in the same manner, and the choice of the supreme magistrate, who was styled Lyciarch, and the other magistrates of the league rested with the federal assembly. At the same time the internal affairs of each city were managed by a senate or council (Boule), and a general assembly of the people (Demos), in the same manner as was usual with Greek cities. This system of government continued to subsist under the Roman empire, though of course subject to the control as well as protection of the sovereign power; but in the time of Claudius dissensions among the separate cities afforded a pretext for the intervention of Rome, and Lycia became formally annexed to the Roman empire. It was at first united in the same province with Pamphylia; but in the reign of Theodosius it was constituted a separate province.

Almost the whole of Lycia is a rugged mountainous country, traversed by offshoots and branches of the great range of Mount Taurus, which occupies the whole interior or northern part of the district, and sends down to the sea great arms or branches, constituting lofty promontories. The consequence is that the coast, though less broken and irregular than that of Caria, is indented by a succession of bays,—the most marked of which is that called in ancient times the Glaucus Sinus, now the Gulf of Macri, in the extreme west of the province, and separating Lycia from Caria. A number of smaller bays, and broken rocky headlands, with a few small islets lying off them, constitute the coast-line from thence to the south-eastern promontory of Lycia, formed by a long narrow tongue of rocky hill, known in ancient times as the Sacred Promontory, with three small adjacent islets, called the Chelidonian islands, which was regarded by some ancient geographers as the commencement of Mount Taurus—an opinion justly controverted by Strabo. But it really forms an important point in the geography of Asia Minor, where the coast trends abruptly to the north till it reaches the confines of Pamphylia. It was believed by Strabo to be directly opposite to Canopus in Egypt, and to be the point where the interval between the two continents was the shortest.

Though the mountain ranges of Lycia may all be considered as in reality offshoots of Mount Taurus, several of them in ancient times were distinguished by separate names. Such were Mount Dædala in the west, adjoining the Gulf of Macri, Mount Cragus on the sea-coast, west of the valley of the Xanthus, and Mount Massicytus nearly in the centre of the region, rising to a height of 10,000 feet, while Mount Solyma in the extreme east, above Phaselis, rises abruptly from the sea to an elevation of 7800 feet. The steep and rugged pass between this mountain and the sea, called the Climax, or Ladder, was the only direct communication between Lycia and Pamphylia.

The only two considerable rivers in Lycia are (1) the Xanthus, which descends from the central mass of Mount Taurus, and flows through a narrow valley till it reaches the city of the same name, below which it forms a plain of some extent before reaching the sea, and (2) the Limyrus, which enters the sea near Limyra. The Arycandus and the Andriacus, which are intermediate between the two, are much less considerable streams, and do not flow from the central chain. The small alluvial plains at the mouths of these rivers are the only level ground in Lycia; but the slopes of the hills that rise from thence towards the mountains are covered with a rich arborescent vegetation of the most beautiful character. (See the description of it by Forbes, quoted in Asia Minor, vol. ii. p. 709.) The upper valleys and mountain sides afford good pasture for sheep, and the main range of Mount Taurus encloses several extensive *yailahs* or upland basin-shaped valleys of the peculiar kind so characteristic of that range throughout its extent (see Asia Minor, p. 704).

It is very difficult to determine the limits of Lycia towards the interior; and the boundary seems to have varied repeatedly at different times. The high and cold upland tract to the north-east, called Milyas (which was supposed to retain some remains of the aboriginal population of Lycia), was by some writers included in that province, though it is naturally more connected with Pisidia. A similar tract to the west of this, and also situated to the north of the watershed of Mount Taurus, was termed Cabalia; but this had no natural connexion with Lycia, nor was in early times ever politically united with it, the four cities that were situated in this region—Cibyra, with its dependent towns of Œnoanda, Balbura, and Bubon—having always formed a separate league or Tetrapolis, which had no connexion with the Lycian league. It was not till after their annexation to Rome that Cibyra, with the district adjoining it, termed the Cibyratis, was united to Phrygia, while the three other towns above enumerated were annexed to Lycia.

According to Artemidorus (whose authority is followed by Strabo), the towns that formed the Lycian league in the days of its integrity were twenty-three in number; but Pliny tells us that Lycia once possessed seventy towns, of which only twenty-six remained in his day. Recent researches have fully confirmed the fact that, notwithstanding its rugged character, the sea-coast and the valleys that ran up into the interior were thickly studded with towns, which in many cases are proved by existing remains to have been places of considerable importance. The names have been for the most part identified by means of inscriptions, and we are thus enabled to fix the position of the greater part of the cities that are mentioned in ancient authors. On the Gulf of Glaucus, near the frontiers of Caria, stood Telmessus, an important place, while a short distance from it in the interior were the small towns of Dædala and Cadyanda. At the entrance of the valley of the Xanthus were Patara, Xanthus itself, and, a little higher up, Pinara on the west and Tlos on the east side of the valley, while Araxa stood at the head of the valley, just at the foot of the pass leading into the interior. Sidyma, on the slope of Mount Cragus, seems also to have borne the name of the mountain, as was also the case with Massicytus, if there was really a city of the name at all. Myra, one of the most important cities of Lycia, occupied the entrance of the valley of the Andriacus; on the coast between this and the mouth of the Xanthus stood Antiphellus, while in the interior, at a short distance, were found Phellus, Cyaneæ, and Candyba. In the alluvial plain formed by the outlets of the rivers Arycandus and Limyrus stood Limyra, and encircling the same bay the three small towns of Rhodiapolis, Corydalla, and Gagæ. Arycanda commanded the upper valley of the river of the same name. On the east coast stood Olympus, one of the cities of the league, though it could never have been more than a small town, while Phaselis, a little farther north, which was a much more important place, never belonged to the Lycian league, and appears to have always maintained an independent position. We have thus in all twenty-one towns of which the sites have been ascertained, but the occurrence of other considerable ruins, to which no names can be attached with any certainty, confirms the statement of Pliny as to the great number of the Lycian towns.

The cold upland district of the Milyas appears never to have contained any town of importance. Podalia seems to have been its chief place. Between the Milyas and the Pamphylian Gulf was the lofty mountain range of Solyma, which was supposed to derive its name from the Solymi, a people mentioned by Homer in connexion with the Lycians and the story of Bellerophon. No such name was known in historical times as an ethnic appellation, but they were supposed by some writers to be the same people with the Milyans, while others regard them as a distinct people of Semitic origin. It was in the flank of this mountain, near a place called Deliktash, that the celebrated fiery source called the Chimæra, which gave rise in ancient times to so many fables, was found. It has been visited in modern times by Captain Beaufort, Messrs Spratt and Forbes, and other travellers, but is merely a stream of inflammable gas issuing from crevices in the rocks, such as are found in several places in the Apennines. No traces of recent volcanic action exist in Lycia.

Few parts of Asia Minor were less known in modern times than Lycia until a very recent period. Captain Beaufort was the first to visit several places on the sea-coast, and the remarkable rock-hewn tombs of Telmessus had been already described by Dr Clarke, but it was Sir Charles Fellows who first discovered and drew attention to the extraordinary richness of the district in ancient remains, especially of a sepulchral character. His two visits to the country, in 1838 and 1840, were followed by a more regular expedition sent out by the British Government in 1842 for the purpose of transporting to England the valuable monuments now in the British Museum, while Lieutenant (now Admiral) Spratt and Professor Edward Forbes explored the interior of the district, and laid down its physical features on an excellent map. The monuments thus brought to light are certainly among the most interesting of any that have been discovered in Asia Minor, and, while showing the strong influence of Greek art, both in their architecture and sculpture, prove also the existence of a native architecture of wholly distinct origin, especially in the rock-cut tombs, some of which present a strange resemblance to our English Elizabethan style, while others distinctly evince their derivation from the simple construction of the mud and timber built cottages of the natives. But the theatres that are found in almost every town, some of them of very large size, are alone sufficient to attest the pervading influence of Greek civilization; and this is confirmed by the sculptures, which are for the most part wholly Greek. None of them, indeed, can be ascribed to a very early period, and hardly any trace can be found of the influence of Assyrian or other Oriental art.

One of the most interesting results of these recent researches has been the discovery of numerous inscriptions in the native language of the country, and written in a character, or at least an alphabet, before unknown, and which appears to have been peculiar to Lycia. A few of these inscriptions are fortunately bilingual, in Greek and Lycian, which has afforded a clue to their partial interpretation, and the investigations of Mr Daniel Sharpe in the first instance, followed by the more mature essays of Moritz Schmidt and Savelsberg, have established the fact that the Lycian language belonged to the great Aryan family, and had close affinities with the Zend. The alphabet in which the inscriptions are written is obviously derived from the Greek, no less than twenty-four of the letters being identical, while most of the additional letters appear to have been invented in order to express vowel sounds which were not distinguished in Greek. None of the Lycian inscriptions, however, any more than the sculptures, can lay claim to a high antiquity. It is remarkable that the Greek alphabet upon which it was founded appears not to have been the Ionic alphabet which was in general use in Asia Minor, but was more akin to the Doric alphabet in use in the Peloponnese.

For these modern researches see *A Journal written during an Excursion in Asia Minor*, London, 1839, by Sir Charles Fellows; *An Account of Discoveries in Lycia*, by the same author, London, 1841; *Travels in Lycia, Milyas, and the Cibyratis*, by Lieutenant Spratt and Professor Edward Forbes, 2 vols., London, 1847; Moritz Schmidt, *Neue Lykische Studien*, Jena, 1869; Savelsberg, *Beiträge zur Entzifferung der Lykischen Sprachdenkmäler*, Bonn, 1874. (E. H. B.)

LYCOPHRON was a Greek poet who flourished at Alexandria in the time of Ptolemy Philadelphus (285–47 B.C.). He was born at Chalcis in Eubœa, and was the son of Lycus. He wrote a number of tragedies, forty-six or sixty-four, and Suidas gives the title of twenty of them. Only a few lines are preserved of these works, which gained him a place in the Pleiad of Alexandrian tragedians. He was entrusted by Ptolemy with the task of arranging the comedies in the Alexandrian library, and out of this work grew his treatise περὶ κωμῳδίας, in at least eleven books. It seems to have treated of the history of comedy, of the lives of the comic poets, and of various topics subsidiary to the proper understanding of their poems, but nothing has been preserved of the work. One of his poems called *Cassandra*, containing 1474 lines of iambic, has been preserved entire. It is in the form of a prophecy uttered by Cassandra, and relates the later fortunes of Troy and of the Greek and Trojan heroes. References to various events of mythic and of later time are introduced, and the poem ends with a reference to Alexander the Great, who was to unite Asia and Europe in his world-wide empire. The style, as befits a prophecy, is so enigmatical as to have procured for Lycophron, even among the ancients, the title of the "obscure" (ὁ σκοτεινός). The poem is evidently intended to display the writer's knowledge of obscure names and uncommon myths; it is full of unusual words of doubtful meaning gathered from the older poets, along with many long-winded compounds coined by the author. It has none of the qualities of poetry, and was probably written not for the enjoyment of the public but as a show-piece for the Alexandrian school. It was very popular in the Byzantine period, and was read and commented on very frequently; the collection of scholia by I. and J. Tzetzes is very valuable, and the MSS. of the *Cassandra* are numerous. A few neat and well-turned lines which have been preserved from Lycophron's tragedies show a much better style; they are said to have been much admired by Menedemus of Eretria, although the poet had ridiculed him in a satyric drama. Lycophron is also said to have been a skilful writer of anagrams, a reputation which does not speak highly for his poetical character.

Two passages of the *Cassandra*, 1446–50 and 1226–82, in which the career of the Roman people and their universal empire are spoken of, could evidently not have been written by an Alexandrian poet of 250 B.C. Hence it has been maintained by Niebuhr and others that the poem was written by a later poet mentioned by Tzetzes, but the opinion of Welcker is generally counted more probable, that these paragraphs are a later interpolation: a prophetic poem is peculiarly liable to have additions inserted, and the Roman rule was the most natural subject to add.

See Welcker, *Griech. Trag.*; Konze, *De Lycophronis Dictione*; and Bernhardy's and other histories of Greek literature.

LYCOPODIUM. This and *Selaginella* are the two chief genera of the order *Lycopodiaceæ* or club mosses. They are flowerless herbs, and mostly creeping; but during the period of the development of coal plants members of this order attained to the dimensions of lofty trees. A remarkable bed of Scotch coal called the "better bed" was found on microscopical examination to be almost entirely composed of the spores and sporanges of some "lycopod." There are one hundred species, which occur in all climates, five being British. The leaves of lycopodium are for the most part small, and thickly cover the stem and branches. The "fertile" leaves are arranged in cones, and bear sporanges in their axils, containing spores of one kind only (of two kinds in *Selaginella*). The prothallium developed from the spore is a subterranean mass of tissue of considerable size, and bears the male and female structures (*antheridia* and *archegonia*). See *Micrographic Dict.*; Le Maout and Decaisne's *Desc. and Anal. Bot.*, Eng. ed., p. 911; and Sach's *Text-book of Bot.*, Eng. ed., p. 400 *sq.* Gerard, in 1597, described two kinds of lycopodium (*Herball*, p. 1373) under the names *Muscus denticulatus* and *Muscus clavatus* (*L. clavatum*, L.) as "Club Mosse or Woolfes Clawe Mosse," the names being in Low Dutch, "Wolfs Clauwen," from the resemblance of the club-like or claw-shaped shoots to the toes of a wolf, "whereupon we first named it *Lycopodion*." Gerard also speaks of its emetic and many other supposed virtues. *L. Selago*, L., and *L. catharticum*, Hook., of South America, have been said to be, at least when fresh, cathartic; but, with the exception of the spores ("lycopodium powder"), lycopodium as a drug has fallen into disuse. The powder is used for rolling pills in, as a dusting powder for infants' sores, &c. It is highly inflammable, and is used in pyrotechny and for artificial lightning on the stage. If the hand be covered with the powder it cannot be wetted on being plunged into water. Another use of lycopodium is for dyeing; woollen cloth boiled with species of lycopodium, as *L. clavatum*, becomes blue when dipped in a bath of Brazil wood.

LYCURGUS, a famous Spartan lawgiver. As even the ancients themselves differed so widely in their accounts of Lycurgus that Plutarch could begin his life by saying that he could assert absolutely nothing about him which was not controverted, it is not surprising that modern historical criticism has been disposed to relegate him wholly into the region of pure myth. One tradition would put him as far back as the age of Troy; another would connect him with Homer; while Herodotus implies that he lived in the 10th century B.C. It is now usual, on the strength of a passage in Thucydides (bk. i. chap. 18), which represents Sparta as having enjoyed a well-established political constitution for as much as four hundred years before the Peloponnesian war, to assign him to the 9th century B.C., and to accept him as a real historical person. But as to the character and result of his legislative work there still remain very conflicting opinions, due to the circumstance that such data as we possess are susceptible of exceedingly diverse inferences and interpretations. Plutarch's life, which is the fullest and most detailed account we have of him, is not merely the compilation at second hand of a late age (2d century), but also abounds in statements which any one with any knowledge of the early growth of political societies feels to be inherently improbable. Grote prefers on the whole to be guided by what may be fairly inferred from the allusions to his legislation in Aristotle, as being one of our earliest sources of information and certainly the most philosophical estimate of his work. With Thirlwall he takes him to have been a real person, and assumes that he was the instrument of establishing good order among the Spartans, hitherto, according to Herodotus, the most lawless of mankind, and of thus laying the foundations of Spartan strength and greatness.

The traditional story was that when acting as guardian to his nephew, Labotas, king of the Spartans, he imported his new institutions from Crete, in which a branch of the Dorian race had for a considerable period settled themselves. It was said that he had travelled widely, and gathered political wisdom and experience in Egypt and even in India. With the support of the Delphic oracle, which was specially reverenced by Dorians, he was able to accomplish his work and to regulate, down to the smallest details, the entire life of Sparta. He lived to see the fruit of his labour, and, having bound his fellow countrymen to change nothing in his laws till his return, he left then for Delphi, and was never seen by them again. The oracle declared that Sparta would prosper as long as she held fast by his legislation, and upon this a temple was built to his honour, and he was worshipped as a god.

It was the fashion with writers like Plutarch, from whom our notions of Lycurgus have been mainly derived, to represent the Spartan lawgiver as the author of a wholly new set of laws and institutions. It need hardly be said that any such view has long been abandoned, and that Lycurgus's work, great as it no doubt was, did not go beyond formulating what already existed in germ, and was in fact the peculiar heritage of the Spartans as members of the Dorian race. It has been contended that the laws of Sparta were the typical Dorian laws, and that Sparta herself was the special representative, politically and socially, of the Dorian race. It appears, however, to have been the general view of the Greeks themselves that many of her most important institutions, more especially the severity of her military training and of her home-discipline, were peculiar to Sparta, and were by no means shared by such states as Corinth, Argos, Megara, all of Dorian origin. Grote lays great stress on this point (*History of Greece*, chap. vi.), and maintains that it was the singularity of the Spartan laws which made such a deep impression on the Greek mind. The truth indeed seems to be that Sparta's political organization in its main lines was of the Dorian type, and resembles the pictures given us in the Homeric poems, but that much in her social life and military arrangements was absolutely unique. It is here that in all probability may be traced the genius and foresight of Lycurgus, and he may thus well deserve the credit of having started Sparta on a new career.

The council of elders (*gerousia*, or senate), a distinctive feature of the Hellenic states generally, must have existed at Sparta long before Lycurgus, nor is it at all certain that he fixed its number at twenty-eight, the two kings who sat and voted in it making it up to thirty members. It was elected from the people from candidates who had reached the age of sixty, and a senator once elected was a senator for life. It united the functions of a deliberative assembly and of a court of justice, and it prepared measures which were from time to time submitted to periodical assemblies of the people, which, however, had simply to accept or reject, without any power of amendment or criticism. So far the constitution of Sparta was distinctly oligarchical. The two kings, whose office was hereditary, and whose descent was from the famous family of the Heraclids, had but very limited political powers, and, with some few exceptions, even little more than ordinary senators. They owed their position and prerogatives to the religious sentiment of the people, which reverenced their noble and quasi-divine origin, and accepted them as legitimately the high priests of the nation, and as specially qualified in great emergencies to consult the Delphic oracle and receive its answers. An ample royal domain was assigned to them, and some rather delicate legal matters, such as the bestowment of the hand of an orphan heiress, were entrusted to their discretion. By far the most important of their duties was the command of the army on a foreign expedition, with, however, the assistance of a council of war. In fact they closely resembled at all points the kings of the heroic age, and the honour and reverence in which they were held was far greater than their actual power, which really was curtailed within such narrow limits that it was not possible for them to establish anything like a tyranny or despotism.

One great check on the kings was a board of magistrates, annually elected by the people, termed ephors, a name not confined to Sparta, whence we may fairly infer that this institution also by no means owed its origin to Lycurgus. A comparison has been suggested between the Spartan ephors and the tribunes at Rome. Both were certainly popular magistrates, and as it was at Rome, so too at Sparta, at any rate in her later days, these magistrates made themselves the great power in the state. There was a form of ancient oaths between the king and the ephors, the king swearing that he would respect the established laws, and the ephors swearing that on that condition he should retain his authority and prerogatives. The unanimous view of antiquity was that it was the special business of the ephors "to protect the people and restrain the kings." We gather from passages in Thucydides that they had in his time great political influence, and in the time of Aristotle they had attained such a position that he says they did not choose to conform themselves to the strict discipline prescribed to Spartan citizens. Although the king took the command in war, it was for the ephors to say when war should be made, and on what terms peace should be concluded. Any public magistrate, the kings not excepted, was liable to be called to account by them, while they themselves seem to have been irresponsible. Of course the fact that they were annually elected necessitated a general conformity in their policy to the popular will. But so great and arbitrary were their powers that Plato hints that the Spartan constitution might be almost described as a tyranny. Indeed they were to Sparta what the House of Commons is to England, "the moving spring," as Arnold says (*Thucy.*, App. II.), of the whole Spartan government.

Of the institutions we have described, not one, as we have seen, was peculiar to Sparta, or, it may be inferred, due to Lycurgus. They were indeed all connected by tradition with his name, and we may believe that he did his best to put them on a sound basis, though, as to the ephors, there is reason to think that they formed no part of the original Spartan constitution. One thing is certain that there was a permanence about Lycurgus's work, whatever it may have been, to which Sparta's long freedom from revolution was unanimously attributed. She owed this no doubt mainly to her peculiar social customs and usages, and it is here that in the opinion of both Grote and Thirlwall we must specially look for the reforming hand of Lycurgus.

It was of the first importance that the Spartan should be an efficient soldier. He was a conqueror in the midst of a subject population, to which he stood in the same relation in which the Norman for a time at least stood to the Saxon. This subject population was made up of two classes, the Periœci (dwellers round the city) and the Helots, the first being freemen and proprietors scattered throughout the townships and villages of Laconia, with some powers of local self-government, but with no voice in the affairs of the state, while the latter were simply serfs, attached to the soil which they cultivated, like the villein of the feudal period, for Spartan proprietors, to whom they paid a rent equivalent, it is said, to half of the entire produce. Their condition, though a humble and in some respects a degraded one, was at least free from the worst incidents of slavery, as they lived with their wives and families, and could not be sold out of the country. Thus they must have felt themselves an integral part of the state, which employed them in military service, and rewarded them from time to time with the gift of freedom. Still, as an oppressed class, they often gave uneasiness to Sparta, and on one memorable occasion, recorded by Thucydides (iv. 80), as many as two thousand of them were treacherously and secretly massacred for reasons of state expediency. There was even a regular and legalized system of thinning their numbers by stealthy assassination, known as the "crypteia," and carried into effect by young Spartans who were annually commissioned to range the country with daggers for this horrible purpose. If under ordinary circumstances the frugal and industrious Helot might exist in tolerable comfort and even hope for freedom, he must have been made to feel that it was exceedingly dangerous to be too aspiring, and the inferiority of his condition was clearly marked by a distinctive dress which he dared not lay aside, any more than he might presume to sing any of the national songs of Sparta.

It was by the toil of the Helots that the Spartan was enabled to live, as we should say, the life of a gentleman, devoting himself to hunting and military exercises along with some slight admixture of mental culture, based mainly on music and poetry. It was not, however, a life of ease and enjoyment. His physical training was proverbially severe. From the age of seven he was put under a rigorous state discipline which inured him to the patient endurance of the most extreme hardships. The ideal at which he was specially taught to aim was a calm passive fortitude, which implied that he lived solely for the state. Spartan youths would compete with each other in submitting themselves to the lash before the altar of the goddess Artemis, and would, it is said, sometimes suffer even to death without any visible emotion. The story that they were habitually trained to theft means that they had licence to roam the country and forage for food, which they were expected to carry off without detection. In every way they were trained to feel themselves at home amid peril and hardship.

The Spartan woman, whose business it was to be the mother of brave and robust children, was naturally held in great honour, and according to Aristotle had at least in his time great influence on public affairs. The maiden was trained in much the same fashion as the youth, and was exercised in running, wrestling, and boxing, and thus at Sparta there was a much freer intermingling of the sexes than in any other Greek state. In this respect Spartan fashions of life seem to have been altogether peculiar to Spartans. The effect of such a training on the women would as a matter of course be to give them masculine sentiments and aspirations, and we can well understand what regard would be paid to their praise or censure. The position of women in Sparta takes us back to the old heroic ages, and reminds us of many passages in the poems of Homer.

One of the features of Spartan life, in thorough harmony with its general purpose and tenor, was the public mess, the "syssitia," according to the Greek phrase. Every citizen was bound to be a member of the mess, which was arranged in a number of joint tables, each providing from his allotment of land a prescribed quota of provisions, with wine and game from the public forests, and the guests being distributed into parties of fifteen persons, and chosen by ballot. Attendance at the mess was strictly enforced, and even the kings were not permitted to excuse themselves. The claims of the state on her citizens, and the duty of obedience to state discipline, were thus kept perpetually present to the Spartan's mind.

With trade and industrial occupations, even agriculture, the Spartan had nothing to do, all this being left to the Periœci and Helots. We might have anticipated that such would be the case with a military aristocracy. The story that Lycurgus restricted Sparta to an iron coinage cannot well be reconciled with the fact that silver money was not in use among the Greeks till a century after his time.

The organization of the Spartan army was always greatly admired by the ancients. Xenophon praises its system of tactics for "an admirable simplicity in the midst of seeming intricacy," and in Thucydides (v. 66) we have it described as based on an elaborate graduation of authority, by means of which the general's orders were transmitted to the rank and file with the utmost promptitude and accuracy. The strength of the army consisted mainly in infantry, every Spartan being a heavy-armed soldier, and the light troops being made up out of the Periœci and Helots. The Spartan cavalry never had much repute, and it was always regarded as a decidedly inferior branch of the service. Nor did they seriously apply themselves to sieges or to sea warfare. Though a brave, they were a very cautious and wary people, and all their military operations were conducted with extreme secrecy. It was a fixed principle with them not to engage the same enemy with needless frequency, and not to carry a pursuit further than victory really required. Anything like cowardice was a disgrace which reduced a citizen to the condition of an outcast. "With it or on it" were the words with which the Spartan mother would bid her son return when he left home with his shield to fight for Sparta.

Lycurgus is fairly described by Grote (*Hist. of Greece*, chap. 6) as "the founder of a warlike brotherhood rather than the lawgiver of a political community." The Spartan was to be almost wholly estranged from home ties, and to live only for the state. His training, though admired both by Plato and Aristotle as directed towards a noble ideal, was felt by them to be very imperfect, inasmuch as it cultivated only one side of human virtue and contemplated the circumstances of a camp or a garrison rather than of a state organized on a really perfect basis.

With the reforms of Lycurgus Plutarch connects a sweeping readjustment of the entire system of landed property, whereby Laconia was parcelled out into 39,000 equal lots, 9000 being assigned to Spartan citizens, and the remainder to their free subjects, the Periœci. It was the fashion with certain ancient writers to assume some such measure in the case of every early legislator or reformer. But it is to be noted that we have no hint of any such repartition of land by Lycurgus till we come to Plutarch, and this fact so much impressed Grote that he utterly rejects the story. All historical evidence, he maintains, points to great inequalities of property among the Spartans from the earliest times, and is therefore irreconcilable with any such belief. Here indeed he seems to be on sure ground, but it may be quite possible that even with equal lots of land there were decided inequalities in wealth. There may have been citizens rich in flocks and herds pastured on common ground, of which, we have reason to believe, there was considerable extent. Plutarch's account is favoured by the fact that equal distributions of land were often made in early days by conquering peoples. The question is one on which it seems impossible to arrive at a certain and definite conclusion. Possibly, as has been suggested by M. Laveleye, some old tradition of an equality of landed property may have been the origin of the belief that a redivision into equal portions was a part of the system of Lycurgus.

There was, however, an equality which he certainly did attempt to establish. Every Spartan, rich or poor, had to submit to the same hard discipline and to aim at the same ideal. The attempt was not altogether unsuccessful, though the subsequent history of Sparta shows that several of her citizens fell so far short of it as to disgrace themselves by actual dishonesty in the public service. But we may fairly credit Lycurgus with a work which laid deep the foundations of a very remarkable and at times a truly noble patriotism both in the men and women of Sparta.

The best accounts of Lycurgus and his legislation will be found in Grote's and Thirlwall's histories, and in Müller's *Dorians*. The chief original sources from which our knowledge of the subject is derived are the writings of Plutarch and Xenophon, and Aristotle's *Politics*. (W. J. B.)

LYCURGUS, one of the ten great Attic orators, was born about 396–93 B.C. His father was named Lycophron, and he belonged to the old Attic family of the Eteobutadæ. He is said to have been a pupil both of Plato and of Isocrates. His early career is quite unknown, but after the real character of the great struggle with Philip of Macedon was becoming manifest he was recognized along with Demosthenes and Hyperides as one of the chiefs of the national party. He left the care of external relations to his colleagues, and devoted himself to the internal organization and the financial administration of the state. He managed the finances of Athens for twelve successive years, being chosen ταμίας τῆς κοινῆς προσόδου, probably in 341 B.C., for a term of four years, and in the two succeeding terms, when the actual office was forbidden him by law, directing it through a nominal official chosen from his party. Part of one of the deeds in which he rendered account of his term of office is still preserved in an inscription (*Corp. Inscr. Gr.*, i. No. 247; *Corp. Inscr. Att.*, ii. pt. 2, No. 289). During this time 18,900 talents passed through his hands, and he raised the public income to 1200 talents yearly. His integrity and his skilful management were highly appreciated by the people, who refused to deliver him up when Alexander the Great demanded his surrender; many private persons deposited money under his charge. He was also appointed to various other offices connected with the preservation and improvement of the city. He was very strict in his superintendence of the public morals, and passed a sumptuary law to restrain extravagance. On the other hand he showed a noble and liberal spirit in all that concerned public expenditure; he did much to beautify and improve the city by fine buildings; and he passed a famous law ordering that statues of the three great tragedians should be erected, and that a careful edition of their tragedies should be made and preserved among the state archives.

Lycurgus was a man of action and not of words: his orations, of which fifteen were published, are criticized by the ancients for their awkward arrangement of matter, harshness of style, and the tendency to digressions about mythology and past history, while the noble spirit and the lofty morality that breathe through them are highly praised. Only one of the orations, that against Leocrates, has been preserved, and fully bears out the criticism of the ancients. He was evidently one of the last examples of the finest Athenian type—full of religious feeling, as became one of the Eteobutadæ, the family in which the priesthood of Athene Polias was hereditary, proud of the history and the religion of his country, and resolved to act worthily of it and to make others do the same, severe and stern in his treatment of offenders and frequently prosecuting them in the public courts, but generous and liberal in all that concerned the glory of Athens.

LYDGATE, JOHN, a monk of Bury St Edmunds, was the most famous English poet of the 15th century. He is a standing refutation of a popular notion that the extraordinary collapse of English poetry after Chaucer disappeared from the stage was due to the unsettled state of public affairs. The exact dates of his birth and death are not ascertained, but he began his occupation as a versemaker before Chaucer's death, and probably ended it several years before the Wars of the Roses broke out. Public affairs were not more unsettled during his lifetime than during the lifetime of Chaucer. Like Chaucer, Lydgate enjoyed the patronage of the royal family. He was the "poet laureate" of his generation. He translated Benoît de St Maure's *History of Troy* "at the commandment" of Henry V.; he wrote a poem on the battle of Agincourt; the coronation of Henry VII. furnished him with another theme; the "Good Duke Humphrey" of Gloucester "commanded" his translation of *Bochas upon the Fall of Princes.* The monk of Bury was in short a professional poet. According to Warton he opened a school in his monastery for teaching the sons of the nobility the arts of versification and the elegancies of composition, and it would seem from the character and the variety of the pieces attributed to him—"disguisings," "mummings," lives of saints, translations of standard works, devotional pieces in metre, metrical paraphrases of proverbs—that he was ready to write to order on any theme submitted to him. Lydgate attracted a good deal of attention from our early printers and antiquaries, his *Fall of Princes* being reprinted four times before the accession of Elizabeth. The fact that it was the largest poem in English of a tragic cast may have had something to do with the popularity of this work. The *Story of Thebes*, based on Statius and Boccaccio, is generally supposed to have been one of his first essays. It is told as one of the Canterbury tales,—the poet in his prologue feigning himself to have joined Chaucer's pilgrims at Canterbury, and recited this tale at the host's command as they rode back. Possibly more than one of two hundred and fifty-one separate poems, most of them short, ascribed to Lydgate by Ritson, have been ascribed to him on very slender authority. But the works undoubtedly his are so commonplace in thought and sentiment, and so clumsy in execution,—with all allowance for transcribers' errors and imperfect editing,—that no injustice can have been done to his reputation by attributing any doggerel to his facile pen. He was evidently a great reader of poetry, a scholar accomplished in amount, had probably a large indiscriminate enjoyment of poetry, and probably also a boisterous enjoyment of his own facility in building up stanzas. His own mental life was probably the reverse of dull. But, like many another self-satisfied versifier, he is the cause of dulness in others. In reading him with his own contented spirit, one catches some faint reflexion of the gleeful happiness with which he seems to have poured out his abundant store of thrice-repeated phrases and images. Of artistic sensibility he was entirely destitute. He claims our sympathy by his warm admiration for Chaucer, but admiration gave him no share of Chaucer's economy of touch, rapid vivacious movement, and subtle wit. His lines are eked out by tautologous and feeble epithets, and garrulous repetitions—"as clerkes can you tell," "in bookes as I rede," "the story saith certain," "the story can devise," "the story can reherse," "the story specifies," "the story maketh mind." Something is expressed in learned terms, and then the same thing is repeated "in plain English." Lydgate is seen at his best in his illustrations of proverbs and maxims of homely morality, and by far his most successful metre is a stave of eight four-beat lines with a rhyme from the first half recurring in the second. *A Satirical Balad on the Times*, with the refrain "So as the crab gothe forwarde"; *A Satirical Description of his Lady*, with the refrain "When she hath on hire hood of green"; *A Lover's Complaint*; *Thonke God of Alle*; and *Make Amendes*—all in this metre—are among the most favourable specimens of his powers. A line of five accents seems always to have driven him into prolixity. *The London Lackpenny*, to the refrain of "But for lack of money I might not speed," the best known of his humorous poems, is also in four-beat lines, though there are seven lines in the stanza. Lydgate's copiousness of detail in describing customs, dresses, architecture, as well as in making literary comparisons, render his verses useful as materials for the historian; but in artistic skill he is a sad falling off from Chaucer. Personally he seems to have been a lively monk enough. In his *Testament* he makes confession to having been a terrible boy, "disposed to many unbridled passions." He fought with his schoolfellows, and scoffed and made mouths at them "like a wanton ape"; he played truant, and "forged leesings" in excuse; neither hedge nor wall could keep him out of orchards; he "told cherry-stones" when he ought to have been at church, and threw his paternoster and his creed at the cock. Highly decorous respectable old men often take a pleasure in looking back, as Justice Shallow did, to the follies of their youth, and perhaps exaggerating them, but there is nothing in Lydgate's confession inconsistent with his poetry. A dull writer is generally a person of high animal spirits; only that could sustain him through platitudes which other people find so dreary. (W. M.)

LYDIA. It is difficult to fix the boundaries of Lydia very exactly, partly because they varied at different times, partly because we are still but imperfectly acquainted with the geography of western Asia Minor. The name is first found, under the form of Luddi, in the inscriptions of the Assyrian king Assur-bani-pal, who received tribute from Gyges about 660 B.C. In Homer we read only of Mæonians (*Il.*, ii. 865, v. 43, x. 431), and the place of the Lydian capital Sardes is taken by Hyde (*Il.*, xx. 385), unless this was the name of the district in which Sardes stood (see Strabo, xiii. p. 626).[1] The earliest Greek writer who mentions the name is Mimnermus of Colophon, in the 37th Olympiad. According to Herodotus (i. 7), the Meiones (called Mæones by other writers) were named Lydians after Lydus, the son of Attys, in the mythical epoch which preceded the rise of the Heraclid dynasty. In historical times, however, the Mæones were a tribe inhabiting the district of the Upper Hermus, where a town called Mæonia (now *Mennen*) existed (Pliny, *N. H.*, v. 30; Hierocles, p. 670). The Lydians must originally have been an allied tribe which bordered upon them to the north-west, and occupied the plain of Sardes or Magnesia at the foot of Tmolus and Sipylus. They were cut off from the sea by the Greeks, who were in possession, not only of the Bay of Smyrna, but also of the country north of Sipylus as far as Temnus, in the Boghaz, or pass, through which the Hermus forces its way from the plain of Magnesia into its lower valley.[2] In an Homeric epigram the ridge north of the Hermus, on which the ruins of Temnus lie, is called Sardene. Northward the Lydians extended at least as far as the Gygæan Lake (Lake Coloe, now *Mermereh*), and the Sardene range (now *Dumanly Dagh*). The plateau of the Bin Bir Tepé, on the southern shore of the Gygæan Lake, was the chief burial-place of the inhabitants of Sardes, and is still thickly studded with tumuli, among which the "tomb of Alyattes" towers to a height of 260 feet. Next to Sardes, Magnesia ad Sipylum was the chief city of the country, having taken the place of the ancient Sipylus, now probably represented by an almost inaccessible acropolis discovered by Mr Humann not far from Magnesia on the northern cliff of Mount Sipylus. In its neighbourhood is the famous seated figure of "Niobe" (*Il.*, xxiv. 614–17), cut out of the rock, and probably intended to represent the goddess Cybele, to which the Greeks attached their legend of Niobe. According to Pliny (v. 31), Tantalis, afterwards swallowed up by earthquake in the pool Sale or Saloe, was the ancient name of Sipylus and "the capital of Mæonia" (Paus., vii. 24; Strabo, xii. p. 579).

Plate I

[1] Pliny (v. 30) makes it the Mæonian name.
[2] See W. M. Ramsay in the *Journal of Hellenic Studies*, ii. 2.

Under the Heraclid dynasty the limits of Lydia must have been already extended, since according to Strabo (xiii. p. 590), the authority of Gyges reached as far as the Troad, and we learn from the Assyrian inscriptions that the same king sent tribute to Assur-bani-pal, whose dominions were bounded on the west by the Halys. But under the Mermnads Lydia became a maritime as well as an inland power. The Greek cities were conquered, and the coast of Ionia included within the Lydian kingdom. The successes of Crœsus finally changed the Lydian kingdom into a Lydian empire, and all Asia Minor westward of the Halys, with the exception of Lycia, owned the supremacy of Sardes. Lydia never again shrank back into its original dimensions. After the Persian conquest the Mæander was regarded as its southern boundary, and in the Roman period it comprised the country between Mysia and Caria on the one side and Phrygia and the Ægean on the other.

Lydia proper was exceedingly fertile. The hill-sides were clothed with vine and fir, and the rich broad plain of Hermus produced large quantities of corn and saffron. The climate of the plain was soft but healthy, though the country was subject to frequent earthquakes. The Pactolus, which flowed from the fountain of Tarne in the Tmolus mountains, through the centre of Sardes, into the Hermus, was believed to be full of golden sand; and gold mines were worked in Tmolus itself, though by the time of Strabo the proceeds had become so small as hardly to pay for the expense of working them (Strabo, xiii. 591). Mæonia on the east contained the curious barren plateau known to the Greeks as the Catacecaumene or Burnt country, once a centre of volcanic disturbance. The Gygæan lake (where remains of pile dwellings have been found) still abounds with carp, which frequently grow to a very large size.

Herodotus (i. 171) tells us that Lydus was a brother of Mysus and Car. The statement is on the whole borne out by the few Lydian, Mysian, and Carian words that have been preserved, as well as by the general character of the civilization prevailing among the three nations. The language, so far as can be judged from its scanty remains, was Indo-European, and more closely related to the western than to the eastern branch of the family. The race was probably a mixed one, consisting of aborigines and Aryan immigrants. It was characterized by industry and a commercial spirit, and, before the Persian conquest, by bravery as well.

The religion of the Lydians resembled that of the other civilized nations of Asia Minor. It was a nature-worship, which at times became wild and sensuous. By the side of the supreme god Medeus stood the sun-god Attys, as in Phrygia the chief object of the popular cult. He was at once the son and bridegroom of Cybele or Cybebe, the mother of the gods, whose image carved by Broteas, son of Tantalus, was adored on the cliffs of Sipylus (Paus., iii. 22). Like the Semitic Tammuz or Adonis, he was the beautiful youth who had mutilated himself in a moment of frenzy or despair, and whose temples were served by eunuch priests. Or again he was the dying sun-god, slain by the winter, and mourned by Cybele, as Adonis was by Aphrodite in the old myth which the Greeks had borrowed from Phœnicia. This worship of Attys was in great measure due to foreign influence. Doubtless there had been an ancient native god of the name, but the associated myths and rites came almost wholly from abroad. The Hittites in their stronghold of Carchemish on the Euphrates had adopted the Babylonian cult of Istar (Ashtoreth) and Tammuz-Adonis, and had handed it on to the tribes of Asia Minor. The close resemblance between the story of Attys and that of Adonis was the result of a common origin. The old legends of the Semitic East had come to the West through two channels. The Phœnicians brought them by sea and the Hittites by land. But though the worship of Makar or Melkarth on Lesbos (*Il.*, xxiv. 544) shows that the Phœnician faith had found a home on this part of the coast of Asia Minor, it could have had no influence upon Lydia, which, as we have seen, was cut off from the sea before the rise of the Mermnads. It was rather to the Hittites that Lydia, like Phrygia and Cappadocia, owed its faith in Attys and Cybele. The latter became "the mother of Asia," and at Ephesus, where she was adored under the form of a meteoric stone, was identified with the Greek Artemis. Her mural crown is first seen in the Hittite sculptures of Boghaz Keui on the Halys, and the bee was sacred to her. A gem found near Aleppo represents her Hittite counterpart standing on this insect. The priestesses by whom she was served are depicted in early art as armed with the double-headed axe, and the dances they performed in her honour with shield and bow gave rise to the myths which saw in them the Amazons, a nation of woman-warriors. The præ-Hellenic cities of the coast—Smyrna, Samorna (Ephesus), Myrina, Cyme, Priene, and Pitane—were all of Amazonian origin, and the first three of them have the same name as the Amazon Myrina, whose tomb was pointed out in the Troad. The prostitution whereby the Lydian girls gained their dowries (Herod., i. 93) was a religious exercise, as among the Semites, which marked their devotion to the goddess Cybele. In the legend of Hercules, Omphale takes the place of Cybele, and was perhaps her Lydian title. Hercules is here the sun-god Attys in a new form; his Lydian name is unknown, since E. Meyer has shown (*Z. D. M. G.*, xxxi. 4) that Sandon belongs not to Lydia but to Cilicia. By the side of Attys stood the moon-god Manes or Men.

According to the native historian Xanthus (460 B.C.) three dynasties ruled in succession over Lydia. The first, that of the Attyads, is wholly mythical. It was headed by a god, and included geographical personages like Lydus, Asies, and Meles, or such heroes of folk-lore as Cambletes, who devoured his wife. To this mythical age belongs the colony which, according to Herodotus (i. 94), Tyrsenus, the son of Attys, led to Etruria. Xanthus, however, puts Torrhebus in the place of Tyrsenus, and makes him the eponym of a district in Lydia. There was no connexion between the Etrurians and Lydians in either language or race, and the story in Herodotus rests solely on the supposed resemblance of Tyrrhenus and Torrhebus. It is doubtful whether Xanthus recognized the Greek legends which brought Pelops from Lydia, or rather Mæonia, and made him the son of Tantalus. The legends must have grown up after the Greek colonization of Æolis and Ionia, though Dr Schliemann's discoveries at Mycenæ have shown a certain likeness between the art of early Greece and that of Asia Minor, while the gold found there in such abundance may have been derived from the mines of Tmolus. The second dynasty was also of divine origin, but the names which head it prove its connexion with the distant East. Its founder, a descendant of Hercules and Omphale, was, Herodotus tells us (i. 7), a son of Ninus and grandson of Belus. The Assyrian inscriptions have shown that the Assyrians had never crossed the Halys, much less known the name of Lydia, before the age of Assur-bani-pal, and consequently the old theory which brought the Heraclids from Nineveh must be given up. But we now know that the case was otherwise with another Oriental people, which was deeply imbued with the elements of Babylonian culture. The Hittites had overrun Asia Minor and established themselves on the shores of the Ægean before the reign of the Egyptian king Ramses II.

The subject allies who then fight under their banners include the Masu or Mysians and the Dardani of the Troad from Iluna or Ilion and Pidasa (Pedasus); and, if we follow Brugsch, Iluna should be read Mauna and identified with Mæonia. At the same time the Hittites left memorials of themselves in Lydia. Mr G. Dennis has discovered an inscription in Hittite hieroglyphics attached to the figure of "Niobe" on Sipylus, and a similar inscription accompanies the figure (in which Herodotus [ii. 106] wished to see Sesostris or Ramses II.) carved on the cliff of Kārabel, the pass which leads from the plain of Sardes to that of Ephesus. We learn from Eusebius that Sardes was first captured by the Cimmerians 1078 B.C.; and, since it was four centuries later before the real Cimmerians appeared on the horizon of history, we may perhaps find in the statement a tradition of the Hittite conquest. Possibly the Ninus of Herodotus points to the fact that Carchemish was called "the old Ninus" (Amm. Marc., xiv. 8), while the mention of Belus may indicate that Hittite civilization came from the land of Bel (see Sayce, *Trans. Soc. Biblical Arch.*, vii. 2). At all events it was when the authority of the Hittite satraps at Sardes began to decay that the Heraclid dynasty arose. According to Xanthus, Sadyattes and Lixus were the successors of Tylon the son of Omphale. After lasting five hundred and five years, the dynasty came to an end in the person of Sadyattes, as he is called by Nicolas of Damascus, whose account is doubtless derived from Xanthus. The name Candaules given him by Herodotus meant "dog-strangler," and was a title of the Lydian Hermes. Gyges, termed Gugu in the Assyrian inscriptions, Gog in the Old Testament, put him to death and established the dynasty of the Mermnads 690 B.C. (Euseb., 698 B.C.). Gyges initiated a new policy, that of making Lydia a maritime power; but his attempt to capture Old Smyrna was unsuccessful. Towards the middle of his reign the kingdom was overrun by the Cimmerians, called Gimirræ in the Assyrian texts, Gomer in the Old Testament, who had been driven from their old seats on the Sea of Azoff by an invasion of Scythians, and thrown upon Asia Minor by the defeat they had suffered at the hands of Esar-haddon. The lower town of Sardes was taken by them, and Gyges turned to Assyria for aid, consenting to become the tributary of Assur-bani-pal or Sardanapalus, and sending him among other presents two Cimmerian chieftains he had himself captured in battle (about 660 B.C.). At first no one could be found in Nineveh who understood the language of the ambassadors. A few years later, Gyges joined in the revolt against Assyria, which was headed by the viceroy of Babylonia, Assur-bani-pal's own brother. The Ionic and Carian mercenaries he despatched to Egypt enabled Psammetichus to make himself independent. Assyria, however, was soon avenged. The Cimmerian hordes returned, Gyges was slain in battle after a reign of thirty-eight years, and Ardys his son and successor returned to his allegiance to Nineveh. The second capture of Sardes on this occasion was alluded to by Callisthenes (Strabo, xiii. p. 627). Alyattes the grandson of Ardys finally succeeded in extirpating the Cimmerians, as well as in taking Smyrna, and thus providing his kingdom with a port. The trade and wealth of Lydia rapidly increased, and the Greek towns fell one after the other before the attacks of the Lydian kings. Alyattes's long reign of fifty-seven years saw the foundation of the Lydian empire. All Asia Minor west of the Halys owned his sway, and the six years' contest he carried on with the Medes was closed by the marriage of his daughter Aryenis to Astyages, and an intimate alliance between the two empires. The Greek cities were allowed to retain their own institutions and government on condition of paying taxes and dues to the Lydian monarch, and the proceeds of their commerce thus flowed into the imperial exchequer. The result was that the king of Lydia became the richest prince of his age. Alyattes was succeeded by Crœsus, who had probably already for some years shared the royal power with his father, or perhaps grandfather, as Floigl thinks (*Geschichte des semitischen Alterthums*, p. 20). He reigned alone only fifteen years, Cyrus the Persian, after an indecisive battle on the banks of the Halys, marching upon Sardes, and capturing both acropolis and monarch before his allies could come to his help (Euseb., 546 B.C.). The place where the acropolis was entered was believed to have been overlooked by the mythical Meles when he carried the lion round his fortress which made it invulnerable; it was really a path opened by one of the landslips which have reduced the sandstone cliff of the Acropolis to a mere shell, and threaten in a few years to carry it altogether into the plain below. The overthrow of Crœsus gave rise to many legends among both Lydians and Greeks, and he was held to have escaped death at the conqueror's hands through the intervention of the gods. The revolt of the Lydians under Pactyas, whom Cyrus had appointed to collect the taxes, caused the Persian king to disarm them, though we can hardly credit the statement that by this measure their former warlike spirit was crushed. Sardes now became the western capital of the Persian empire, and its burning by the Athenians was the indirect cause of the Persian War. After Alexander's death, Lydia passed to Antigonus; then Achæus made himself king at Sardes, but was defeated and put to death by Antiochus. The country was presented by the Romans to Eumenes, and subsequently formed part of the proconsular province of Asia. By the time of Strabo (xiii. p. 631) its old language was entirely supplanted by Greek.

The Lydian empire may be described as the industrial power of the ancient world. The Lydians were credited with being the inventors, not only of games such as dice, huckle-bones, and ball (Herod., i. 94), but also of coined money. The oldest known coins are the electrum coins of the earlier Mermnads (Madden, *Coins of the Jews*, pp. 19-21), stamped on one side with a lion's head or the figure of a king with bow and quiver; these were replaced by Crœsus with a coinage of pure gold and silver. To the latter monarch were probably due the earliest gold coins of Ephesus (Head, *Coinage of Ephesus*, p. 16). Mr Head has shown that the electrum coins of Lydia were of two kinds, one weighing 168·4 grains for the inland trade, and another of 224 grains for the trade with Ionia. The standard was the silver "mina of Carchemish," as the Assyrians called it, which contained 8656 grains. Originally derived by the Hittites from Babylonia, but modified by themselves, this standard was passed on to the nations of Asia Minor during the period of Hittite conquest, but was eventually superseded by the Phœnician mina of 11,225 grains, and continued to survive only in Cyprus and Cilicia. The inns, which the Lydians were said to have been the first to establish (Herod., i. 94), were connected with their attention to commercial pursuits. Their literature has wholly perished, and the only specimen of their writing we possess is on a marble base found by Mr Wood at Ephesus (Schliemann, *Ilios*, p. 698). They were celebrated for their music and gymnastic exercises, and their art formed a link between that of Asia Minor and that of Greece. A marble lion at Achmetly represents in a modified form the Assyrian type, and the engraved gems found in the neighbourhood of Sardes and Old Smyrna resemble the rude imitations of Assyrian workmanship met with in Cyprus and on the coasts of Asia Minor. For a description of a pectoral of white gold, ornamented with the heads of animals, human faces, and the figure of a goddess, discovered in a tomb on Tmolus, see *Academy*, January 15, 1881, p. 45. Lydian sculpture was probably similar to that of the Phrygians as displayed at Doghanly, Kumbet, and Ayazin, a necropolis lately discovered by Mr Ramsay. Phallic emblems, for averting evil, were plentiful; even the summit of the tomb of Alyattes is crowned with an enormous one of stone, about 9 feet in diameter. The tumulus itself is 281 yards in diameter and about half a mile in circumference. It has been partially excavated by Spiegelthal and Dennis, and a sepulchral chamber discovered in the middle, composed of large well-cut and highly polished blocks of marble, the chamber being 11 feet long, nearly 8 feet broad, and 7 feet high. Nothing was found in it except a few ashes and a broken vase of Egyptian alabaster. The stone basement which, according to Herodotus, formerly surrounded the mound has now disappeared. (A. H. S.)

LYELL, Sir Charles (1797–1875), one of the greatest of geological thinkers, was the eldest son of Charles Lyell of Kinnordy, Forfarshire, and was born November 14, 1797, on the family estate in Scotland. His father was a man of literary and scientific tastes, known both as a botanist and as the translator of the *Vita Nuova* and the *Convito* of Dante. From his boyhood Lyell had a strong inclination for natural history, especially entomology, a taste which he was able to cultivate in the New Forest, to which his family had removed soon after his birth. He was educated chiefly at Midhurst, and then at Exeter College, Oxford, where the lectures of Dr Buckland first opened out to him that field of geological study which became the passion of his life. After taking his degree in 1821, he entered Lincoln's Inn, and in 1825, after a delay caused by chronic weakness of the eyes, he was called to the bar, and went on the western circuit for two years. During the whole of this time, though not neglecting his profession, he was slowly gravitating towards the life of a student of science. In 1819 he had been elected a member of the Linnean and Geological Societies, communicating his first paper, "On the Marls of Forfarshire," to the latter society in 1822, and acting as one of the honorary secretaries in 1823. In that year he went to France, with introductions to Cuvier, Humboldt, and other men of science, and in 1824 made a geological tour in Scotland in company with Dr Buckland. In 1826 he was elected a fellow of the Royal Society, from which in later years he received both the Copley and Royal medals; and in 1827 he finally abandoned the legal profession, and devoted himself to geology.

Long prior to this, however, he had already begun the sketch of his principal work, *The Principles of Geology*. The subsidiary title, "An Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes now in Operation," gives the keynote of the task to which Lyell devoted his life, and in pursuance of which he made geological tours over large portions of the Continent, and in later years to Madeira and to the United States and Canada. The journey undertaken with Murchison in 1828 was especially fruitful in results, for not only did it give rise to two joint papers on the volcanic district of Auvergne and the Tertiary formations of Aix-en-Provence, but it was apparently while examining Signor Bonelli's collection of Tertiary shells at Turin, and subsequently when (after parting with Murchison) he studied the marine remains of the Tertiary rocks of Ischia and Sicily, that Lyell conceived the idea of dividing the Tertiaries into three or four principal groups, characterized by the proportion of recent to extinct species of shells. To these groups, after consulting Dr Whewell as to the best nomenclature, he gave the names now universally adopted—Eocene (*dawn of recent*), Miocene (*less of recent*), and Pliocene (*more of recent*) Upper and Lower; and with the assistance of M. Deshayes, who had arrived by independent researches at very similar views, he drew up a table of shells in illustration of this classification. The first volume of the *Principles of Geology* appeared in 1830, and the second in January 1832. Received at first with considerable opposition, at least so far as its leading theory was concerned, the work had ultimately a great success, and it had already reached a second edition in 1833 when the third volume, dealing with the successive formations of the earth's crust, was added.[1]

In August 1838 Lyell published the *Elements of Geology*, which, from being originally an expansion of the fourth book of the *Principles*, became a standard work of reference in stratigraphical and palæontological geology. This book went through six editions in Lyell's lifetime (some intermediate ones being styled *Manual of Elementary Geology*), and in 1871 a smaller work, the *Student's Elements of Geology*, was based upon it. His third great work, *The Antiquity of Man*, appeared in 1863, and ran through three editions in one year. In this he laid before the world a general survey of the arguments for man's early appearance on the earth, derived from the discoveries of worked flint implements in Post-Pliocene strata in the Somme valley and elsewhere, and in it also he first gave in his adhesion to Darwin's theory of the origin of species. A fourth edition appeared in 1873.

While thus occupied with his writings, Lyell lost no opportunity of carrying out original investigations, and whenever absent from his literary work in London was always to be heard of in the field either in England or on the Continent. In 1831 he held for a short time the post of professor of geology at King's College, London, and delivered while there a highly appreciated course of lectures, which became the foundation of the *Elements of Geology*. In 1832 he married Mary, eldest daughter of Leonard Horner, who became thenceforward associated with him in all his literary and scientific labours, aiding him substantially with her ready intellect, and by her pre-eminent social qualities making his home a centre of attraction to all men of talent. In 1834 he made an excursion to Denmark and Sweden, the result of which was his celebrated paper to the Royal Society, "On the Proofs of the Gradual Rising of Land in Certain Parts of Sweden," and another to the Geological Society, "On the Cretaceous and Tertiary Strata of Seeland and Möen." In 1837 he was again in Norway and Denmark, and in 1841 he spent a year in travelling through the United States, Canada, and Nova Scotia. This last journey, together with a second one to America in 1845, when he visited Boston, Philadelphia, New Orleans, and the alluvial plain of the Mississippi, gave rise, not only to numerous original papers, but also to the publication of two works not exclusively geological, *Travels in North America* (1845) and *A Second Visit to the United States* (1849). In the second work especially he did much to promote good feeling between England and America, by showing a just appreciation of American society and institutions. It was in the course of these journeys that he estimated the rate of recession of the falls of Niagara, and of the annual average accumulation of alluvial matter in the delta of the Mississippi, and studied those vegetable accumulations in the "Great Dismal Swamp" of Virginia, which he afterwards used in illustrating the formation of beds of coal. He also studied with great care the coal-formations in Nova Scotia, and discovered in company with Dr Dawson of Montreal the earliest known land shell, *Pupa vetusta*, in the hollow stem of a *Sigillaria*. But it was chiefly in bringing a thorough knowledge of European geology to bear upon the more widely extended and massive formations of the North American continent that Lyell rendered immense service to geologists on both sides of the Atlântic.

Besides these Transatlantic journeys Lyell undertook geological excursions at different times to all parts of the British Isles, to Belgium, Switzerland, Germany, Spain, Madeira, and Teneriffe, in which latter islands, which he visited in company with G. Hartung, he accumulated much valuable evidence on the age and deposition of lava-beds and the formation of volcanic cones. He also revisited Sicily in 1858, when he made such observations upon the structure of Etna as entirely refuted the theory of "craters of elevation" upheld by Von Buch and Élie de Beaumont (see *Roy. Soc. Proc.*, 1859).

[1] Between 1830 and 1872 eleven editions of this work were published, each so much enriched with new material and the results of riper thought as to form a complete history of the progress of geology during that interval. Only a few days before his death Sir Charles finished revising the 12th edition, which appeared in 1876.

Lyell received the honour of knighthood in 1848, and was created a baronet in 1864, in which year he was president of the British Association, meeting at Bath. His services to the science of geology were now universally recognized both at home and abroad, and he was a member of almost every Continental and American Society. He was elected corresponding member of the French Institute and of the Royal Academy of Sciences at Berlin, and was created a knight of the Prussian Order of Merit.

During the latter years of his life his sight, always weak, failed him altogether, and he became very feeble. He died on February 22, 1875, in his seventy-eighth year, and was buried in Westminster Abbey. His funeral was attended by an immense concourse of public men, all his personal friends; for by young and old the veteran master of geology was deeply loved and revered. His gentle nature, his intense love of truth, his anxiety to help and encourage those who cultivated his favourite science, endeared him to all who approached him; while the extreme freshness of his mind kept him free from that dogmatism which is so often the accompaniment of old age, and enabled him to accept and appreciate heartily the work of younger men.

In order to appreciate justly the influence of Lyell's works upon the geology of the 19th century, it is necessary to bear in mind what was the state of knowledge upon this subject at the time when he entered the field in 1822. The rival schools of Werner and Hutton were then at the height of their famous contest, and, while the vehement discussions between the Neptunists and Vulcanists gave an impetus to the study of rock-masses, the one true principle upon which Hutton himself had so strongly insisted had dropped into oblivion, namely, that "in examining things present we have data from which to reason with regard to what has been," and that therefore we have no need to imagine other causes than those now in action to account for the past. Meanwhile a reaction against the speculative discussions which had so long occupied the world inclined many of the leaders of geological study to confine themselves to the collection of facts, and the science became for a time a mere branch of mineralogy, which, though most valuable in laying a true foundation, was quite inadequate to deal with the earth's history, since it took little or no account of organic remains, and their real significance was not in the least understood. Both in England and France, however, materials were being accumulated which prepared the way for a wider basis. In 1799 William Smith, travelling over England, first grouped the formations according to the fossils contained in them, and in 1815 he published his geological map of England, thus making the first step in stratigraphical geology; and almost simultaneously, in 1812, Cuvier's restorations of the extinct mammalia of the Paris basin, and Lamarck's classification of recent and fossil shells, gave the first impulse to palæontology. But the older schools of geologists, hampered by preconceived theories, were not prepared to make full use of the new facts. Cuvier himself, while insisting on the value of fossils in the chronology of the earth, yet retained all the old notions of sudden and violent convulsions, attributing the destruction of the fauna of the Paris basin to the deluge, or to the bursting of lakes caused by a sudden revolution of the globe; and in like manner Buckland, Sedgwick, and their compeers still explained everything by the diluvial theory, attributing the erratic blocks strewn over the Continent to the universal deluge, and accepting as demonstrated Élie de Beaumont's theory of the sudden elevation of mountain chains. Sedgwick in his address to the Geological Society in 1834 even spoke confidently of the extinct forms in geological strata as "indications of change and of an adjusting power altogether different from what we commonly understand by the laws of nature."

To shake off the influence of preconceived opinions such as these there was needed a fresh impartial mind capable of appreciating the evidence which had been accumulating during the past thirty years, and especially alive to the discoveries of palæontology. These requisites were found in Lyell. His early study of natural history gave him advantages possessed by few of his contemporaries, while the clear insight and calm judgment for which he was thus early remarkable led him alone of the younger school of geologists to grasp the truth enunciated by Hutton of the power of gradual changes to produce great results if only time enough be allowed. This truth he illustrated with such a wealth of facts, derived from his own observation and that of others, that in the first edition of the *Principles* we find sketched in broad outline, and demonstrated by actual examples, nearly all those fundamental truths which, though often vehemently opposed at the time, have now become so much the accepted basis of geology that it is difficult to realize how novel they were in 1830.

Even the opening historical chapters cut boldly at the root of catastrophic geology by showing how the prejudices concerning the short duration of past time on the globe had led men to the mistaken conclusion that "centuries were implied where the characters imported thousands, and thousands where the language of nature signified millions"; and the arguments for the uniform action of nature followed with overwhelming force, as Lyell proceeded to lay under contribution all countries of the world to show how the face of the earth is now being altered by rivers, torrents, springs, currents and tides, volcanoes and earthquakes.

In the second volume the changes in the organic world were used to teach the same lesson. The proofs of extinction of specific forms in historical times were accumulated to explain that the presence of extinct forms in geological formations was the effect of gradual causes and not of sudden and violent catastrophes, while the tranquil imbedding of organic remains now in progress was used to strengthen the previous argument derived from inorganic causes for the slow and gradual accumulation of fossiliferous strata. It was in this volume that Lyell made in 1830 his celebrated attack upon Lamarck's theory of the transmutation of species, and, though this has often been held as a want of appreciation on his part of the arguments of the great naturalist, yet, as we shall see presently, it was really a curious illustration of the impartiality of Lyell's mind (though acting under what he himself would have called the influence of "inherited belief") that this theory, so eminently calculated to harmonize with his own views of the power of minute causes to work appreciable change, was rejected by him because it rested upon an assumption of a law of innate progressive development, which could not be shown to be in accordance with natural facts.

The third volume of the *Principles*, which did not appear till two years later, completed the task which Lyell had set himself, by interpreting the fragmentary record which remains to us of the successive geological formations of the earth's crust with their imbedded remains and the associated volcanic rocks, and thus restoring as far as possible the past history of the earth. Through all its successive editions this volume has remained the standard text-book of geological history, as its two predecessors have of the philosophical principles of the science.

So immediate was the effect of this remarkable work that from the time of its publication the earlier cosmogonies disappeared from the field, and even Cuvier's *Theory of the Earth* never reached another edition. Yet, although geologists began insensibly to follow the lines which Lyell had marked out, they were long in receiving the principles upon which these were founded. Sedgwick, in the address already quoted, while pronouncing a eulogy on the book as a whole, regretted that "from the very title-page of his work Mr Lyell seems to stand forward as the champion of a great leading doctrine of the Huttonian hypothesis," *i.e.*, the explanation of former changes by reference to causes now in operation; and Lyell's oldest friend and fellow-labourer Murchison remained to the last the exponent of the converse truth, that we have no evidence forbidding the possibility of a greater intensity of the forces in action during past periods. This form of catastrophic geology has indeed always prevailed upon the Continent, and still does so in a great degree. There is, however, nothing necessarily antagonistic in the two theories; and, if Lyell in his earlier years accentuated perhaps somewhat too strongly the necessity for making unlimited drafts upon the "bank of time," as he often called it, to the exclusion of intensified volcanic or aqueous action, it was because he had to combat the opposite and deeply rooted error.

Between the year 1853, when the 9th edition of the *Principles* was published, and 1863, when he "read his recantation," as he himself would sometimes express it, in the *Antiquity of Man*, the discovery of the flint implements associated with bones of extinct mammalia at Abbeville, and subsequently in the valley of the Thames and elsewhere, threw an entirely new light upon the data of human existence upon the earth, allowing far more time for the development of the numerous varieties of mankind than had hitherto been supposed possible. In conjunction with these discoveries came also the evidence adduced by Darwin and Wallace of the action of natural causes in producing modifications in living forms,—thus applying the very same principle to organic life which Hutton and Lyell had used to explain the gradual modification of the earth's surface. Then it was that Lyell, who had rejected Lamarck's theory because it rested on a purely imaginary law of innate progressive development, at once accepted "natural selection" as a *vera causa* helping to explain those evidences of the gradual change in organic forms presented in successive geological formations. By recognizing the value of the new principle, and incorporating its results in his *Principles*, Lyell completed in 1872 in a fuller sense than he had contemplated in 1850 the task of "explaining former changes of the earth's surface (including the history of its living inhabitants) by reference to causes now in action"; while at the same time he gave to his original conception that element of expansion and pliability which was alone needed to ensure its continued influence and the permanent celebrity of its author.

Besides his books, Lyell contributed seventy-six geological papers to various societies. The only authorities yet published for his life are *Life and Letters of Sir Charles Lyell*, 1881, edited by Mrs Lyell, and the obituary notices in 1875 at the Royal and other Societies. (A. B. B.)

LYLY, or LILLY, or LYLIE, JOHN (1553–1606), the famous author of *Euphues*, was born in Kent in 1553 or 1554. At the age of sixteen, according to Wood, he became a student of Magdalen College, Oxford, where in due time he proceeded to his bachelor's and master's degrees (1573 and 1575), and from whence we find him in 1574 applying to Lord Burghley "for the queen's letters to Magdalen College to admit him fellow." The fellowship, however, was not granted, and Lyly shortly after left the university. He complains of what seems to have been a sentence of rustication passed upon him at some period in his academical career, in his address to the gentlemen scholars of Oxford affixed to the second edition of the first part of *Euphues*, but in the absence of any further evidence it is impossible to fix either its date or its cause. If we are to believe Wood, he never took kindly to the proper studies of the university. "For so it was that his genius being naturally bent to the pleasant paths of poetry (as if Apollo had given to him a wreath of his own bays without snatching or struggling) did in a manner neglect academical studies, yet not so much but that he took the degrees in arts, that of master being compleated 1575." After he left Oxford, where he had already the reputation of "a noted wit," Lyly seems to have attached himself to Lord Burghley. "This noble man," he writes in the "Glasse for Europe," in the second part of *Euphues* (1580), "I found so ready being but a straunger to do me good, that neyther I ought to forget him, neyther cease to pray for him, that as he hath the wisdom of Nestor, so he may have the age, that having the policies of Ulysses he may have his honor, worthy to lyve long, by whom so many lyve in quiet, and not unworthy to be advaunced by whose care so many have been preferred." Two years later we possess a letter of Lyly to the treasurer, dated July 1582, in which the writer protests against some undefined accusation which had brought him into trouble with his patron, and demands a personal interview for the purpose of clearing his character. What the further relations between them were we have no means of knowing, but it is clear that neither from Burghley nor from the queen did Lyly ever receive any substantial patronage. In 1578 he began his literary career by the composition of *Euphues, or the Anatomy of Wit*, which was licensed to Gabriel Cawood on December 2, 1578, and published in the spring of 1579. In the same year the author was incorporated M.A. at Cambridge, and possibly saw his hopes of court advancement dashed by the appointment in July of Edmund Tylney to the office of master of the revels, a post at which, as he reminds the queen some years later, he had all along been encouraged to "aim his courses." *Euphues and his England* appeared in 1580, and, like the first part of the book, won immediate popularity. For a time Lyly was the most successful and fashionable of English writers. He was hailed as the author of "a new English," as a "raffineur de l'Anglois;" and, as Edmund Blount, the editor of his plays, tells us in 1632, "that beautie in court which could not parley Euphuism was as little regarded as she which nowe there speakes not French." After the publication of *Euphues*, however, Lyly seems to have entirely deserted the novel form himself, which passed into the hands of his imitators, and to have thrown himself almost exclusively into play-writing, probably with a view to the mastership of revels whenever a vacancy should occur. Eight plays by him were probably acted before the queen by the children of the Chapel Royal and the children of St Paul's between the years 1584 and 1589, one or two of them being repeated before a popular audience at the Blackfriars Theatre. Their brisk lively dialogue, classical colour, and frequent allusions to persons and events of the day maintained that popularity with the court which *Euphues* had won. In 1589 Lyly published a tract in the Martin Marprelate controversy, called *Pappe with an hatchet, alias a figge for my Godsonne; Or Crack me this nut; Or a Countrie Cuffe, &c.*[1] About the same time we may probably date his first petition to Queen Elizabeth. The two petitions, transcripts of which are extant among the Harleian MSS., are undated, but in the first of them he speaks of having been ten years hanging about the court in hope of preferment, and in the second he extends the period to thirteen years. It may be conjectured with great probability that the ten years date from 1579, when Edmund Tylney was appointed master of the revels with a tacit understanding that Lyly was to have the next reversion of the post. "I was entertained your Majestie's servaunt by your own gratious favor," he says, "strengthened with condicions that I should ayme all my courses at the Revells (I dare not say with a promise, but with a hopeful Item to the Reversion) for which these ten yeres I have attended with an unwearyed patience." But in 1589 or 1590 the mastership of the revels was as far off as ever,—Tylney in fact held the post for thirty-one years,—and that Lyly's petition brought him no compensation in other directions may be inferred from the second petition of 1593. "Thirteen yeres your highnes servant but yet nothing. Twenty freinds that though they saye they will be sure, I finde them sure to be slowe. A thousand hopes, but all nothing; a hundred promises but yet nothing. Thus casting up the inventory of my friends, hopes, promises, and tymes, the *summa totalis* amounteth to just nothing." What may have been Lyly's subsequent fortunes at court we do not know. Edmund Blount says vaguely that Elizabeth "graced and rewarded" him, but of this there is no other evidence. After 1590 his works steadily declined in influence and reputation; other stars were in possession of the horizon; and so far as we know he died poor and neglected in the early part of James I.'s reign. He was buried in London at St Bartholomew the Less on November 20, 1606. He was married, and we hear of two sons and a daughter.

Comedies.—In 1632 Edmund Blount published "Six Court Comedies," including *Endymion, Sappho and Phao, Alexander and Campaspe, Midas, Mother Bombie*, and *Gallathea*. To these should be added the *Woman in the Moone* (Lyly's earliest play, to judge from a passage in the prologue and therefore earlier than 1584, the date of *Alexander and Campaspe*), and *Love's Metamorphosis*, first printed in 1601. Of these, all but the last are in prose. *A Warning for Faire Women* (1599) and *The Maid's Metamorphosis* (1600) have been attributed to Lyly, but on altogether insufficient grounds. The first editions of all these plays were issued between 1584 and 1601, and the majority of them between 1584 and 1592, in what were Lyly's most successful and popular years. His importance as a dramatist has been very differently estimated. Prof. Minto denies him any appreciable influence upon our literature, while Professor A. Ward, on the other hand, rightly believes his work to have had a great effect upon the development of dramatic dialogue, and the prose drama in general. Lyly's dialogue is still a long way removed from the dialogue of Shakespeare. But at the same time it is a great advance in rapidity and resource upon anything which had gone before it; it represents an important step in English dramatic art. His nimbleness, and the wit which struggles with his pedantry, found their full development in the dialogue of *Twelfth Night* and *Much Ado about Nothing*, just as "Marlowe's mighty line" led up to and was eclipsed by the majesty and music of Shakespearian passion. One or two of the songs introduced into his plays are justly famous, and show a real lyrical gift. Nor in estimating his dramatic position and his effect upon his time must it be forgotten that his classical and mythological plots, flavourless

[1] The evidence for his authorship may be found in Gabriel Harvey's *Pierce's Supererogation* (written November 1589, published 1593), in Nash's *Have with you to Saffron Walden* (1596), and in various allusions in Lyly's own plays. See Fairholt's *Dramatic Works of John Lilly*, vol. i. p. 20.

and dull as they would be to a modern audience, were charged with interest to those courtly hearers who saw in Midas Philip II., Elizabeth in Cynthia, and perhaps Leicester's unwelcome marriage with Lady Sheffield in the love affair between Endymion and Tellus which brings the former under Cynthia's displeasure. As a matter of fact his reputation and popularity as a play-writer were considerable. Gabriel Harvey dreaded lest Lyly should make a play upon their quarrel; Meres, as is well known, places him among "the best for comedy;" and Ben Jonson names him among those foremost rivals who were "outshone" and outsung by Shakespeare.

Euphues.—It was not, however, as a dramatist, but as the author of *Euphues*, that Lyly made most mark upon the Elizabethan world. His plays amused the court circle, but the "new English" of his novel threatened to permanently change the course of English style. The plot of *Euphues* is extremely simple. The hero, whose name may very possibly have been suggested by a passage in Ascham's *Schoolmaster*, is introduced to us as still in bondage to the follies of youth, "preferring fancy before friends, and this present humour before honour to come." His travels bring him to Naples, where he falls in love with Lucilla, the governor's light-minded daughter. Lucilla is already pledged to Euphues's friend Philautus, but Euphues's passion betrays his friendship, and the old lover finds himself thrown over by both friend and mistress. Euphues himself, however, is very soon forsaken for a more attractive suitor. He and Philautus make up their quarrel, and Euphues writes his friend "a cooling card," to be "applied to all lovers," which is so severe upon the fair sex that Lyly feels it necessary to balance it by a sort of apology addressed "to the grave matrons and honest maidens of Italy." Euphues then leaves Naples for his native Athens, where he gives himself up to study, of which the first fruits are two long treatises—the first, "Euphues and his Ephœbus," a disquisition on the art of education addressed to parents, and the second, "Euphues and Atheos," a discussion of the first principles of religion. The remainder of the book is filled up with correspondence between Euphues and his friends. We have letters from Euphues to Philautus on the death of Lucilla, to another friend on the death of his daughter, to one Botonio "to take his exile patiently," and to the youth Alcius, remonstrating with him on his bad behaviour at the university. Finally a pair of letters, the first from Livia "at the emperour's court to Euphues at Athens," answered by "Euphues to Livia," wind up the first part, and announce to us Euphues's intention of visiting England. An address from Lyly to Lord Delawarr is affixed, to which was added in the second edition "An Address to the Gentlemen Scholars of England."

Euphues and his England is rather longer than the first part. Euphues and Philautus travel from Naples to England. They arrive at Dover, halt for the night at Fidus's house at Canterbury, and then proceed to London, where they make acquaintance with Surius, a young English gentleman of great birth and noble blood; Psellus, an Italian nobleman reputed "great in magick"; Martius, an elderly Englishman; Camilla, a beautiful English girl of insignificant family; Lady Flavia and her niece Fraunces. After endless correspondence and conversation on all kinds of topics, Euphues is recalled to Athens, and from there corresponds with his friends. "Euphues' Glasse for Europe" is a flattering description of England sent to Livia at Naples. It is the most interesting portion of the book, and throws light upon one or two points of Lyly's own biography. The author naturally seized the opportunity for paying his inevitable tribute to the queen, and pays it in his most exalted style. "O fortunate England that hath such a queene, ungratefull if thou praye not for hir, wicked if thou do not love hir, miserable if thou lose hir!"—and so on. The book ends with Philautus's announcement of his marriage to Fraunces, upon which Euphues sends characteristic congratulations and retires, "tormented in body and grieved in mind," to the Mount of Silexedra, "where I leave him to his musing or Muses."

Such is a brief outline of the book which for a time set the fashion for English prose. Two editions of each part appeared within the first year after publication, and thirteen editions of both are enumerated by Mr Arber up to 1636, after which, with the exception of a modernized version in 1718, *Euphues* was never reprinted until 1868, when Mr Arber took it in hand. The reasons for its popularity are not far to seek. As far as matter was concerned it fell in with all the prevailing literary fashions. Its long disquisitions on love, religion, exile, women, or education, on court life and country pleasures, handled all the most favourite topics in the secularized speculation of the time; its foreign background and travel talk pleased a society of which Lyly himself said "trafic and travel hath woven the nature of all nations into ours and made this land like arras full of device which was broadcloth full of workmanship;" and, although Lyly steered clear in it of the worst classical pedantries of the day, the book was more than sufficiently steeped in classical learning, and based upon classical material, to attract a literary circle which was nothing if not humanist. A large proportion of its matter indeed was drawn from classical sources. The general tone of sententious moralizing may be traced to Plutarch, from whom the treatise on education, "Euphues and his Ephœbus," and that on exile, "Letter to Botonio to take his exile patiently," are literally translated, as well as a number of other shorter passages either taken direct from the Latin versions or from some of the numerous English translations of Plutarch then current. The innumerable illustrations based upon a kind of pseudo natural history are largely taken from Pliny, while the mythology is that of Virgil and Ovid.

It was not the matter of *Euphues*, however, so much as the style which made it famous. The sources of Lyly's peculiar style have only recently been satisfactorily traced by a German scholar, Dr Landmann, whose interesting and well arranged pamphlet we need do little more than summarize (Landmann, *Der Euphuismus, sein Wesen, seine Quelle, seine Geschichte*, &c., Giessen, 1881). What, asks Dr Landmann, is Euphuism, properly so called? The term till now has been generally used as if it included all the affected modes of speaking and writing in vogue in England during the 16th century. It has even been made to cover all the corruption of English taste from Surrey to Dryden; and the common mode of explaining it has been to say that it was a mere "exaggeration of the Italianating taste which had begun with the revival of our poetical literature" under Henry VIII. In reality, however, *Euphues* has very little to do with the other affectations of the time. Its chief characteristics, to quote Dr Landmann, are "a peculiar combination of antithesis with alliteration, assonance, rhyme, and play upon words, a love for the conformity and correspondence of parallel sentences, and a tendency to accumulate rhetorical figures, such as climax, the rhetorical question, objections and refutations, the repetition of the same thought in other forms, &c." To this may be added constant references to antiquity and a great fondness for comparisons drawn from a sort of fabulous natural history. On the other hand the style is free from what Puttenham calls "mingle mangle," that is to say, from the pedantic and indiscriminate use of foreign or Latinized words, and also from the hyperbolical extravagances of the Petrarchians. Lyly's peculiarities are those of syntax and construction rather than of phraseology. Compared to that of the Surrey school, his diction is simple and direct, and he himself declares that he does not pretend to please those "Englishmen who desire to heare finer speech than the language will allowe," that is to say, the lovers of the Italianate circumlocutions which ruled English poetry from Surrey to Spenser. His work then is not simply to be regarded as the outcome of the classical and Italian influence at work in England since the beginning of the century. It has individual features which have to be accounted for, and which have now been traced with certainty by Dr Landmann to the influence of one foreign author—Don Antonio de GUEVARA (*q.v.*). Guevara's chief work was *El Libro Aureo de Marco Aurelio* (1529),—a sort of historical romance based upon Plutarch and upon Marcus Aurelius's *Meditations*, the object of which was to produce a "mirror for princes," of the kind so popular throughout the Renaissance. Within the year of its publication Guevara issued an enlarged edition of his book, calling it *Libro del Emperador Marco Aurelio con relox de Principes*; and a number of fresh editions and of translations into almost every European language followed. The book became almost immediately popular in England. The first edition, or rather a French version of it, was translated into English by Lord Berners in 1531, and published in 1534. Before 1560 twelve editions of Lord Berners's translation had been printed, and before 1578 six different translators of this and later works of Guevara had appeared. The translation, however, which had most influence upon English literature was that by North, the well-known translator of Plutarch, in 1568, called *The Dial for Princes, Compiled by the Reverend Father in God Don Antony of Guevara, Byshop of Guadix, &c., Englished out of the Frenche by Th. North.* It was from this book, and from certain other translations from Guevara, of which a full account will be found in Dr Landmann's pamphlet, that Lyly borrowed his peculiar style, and even a certain small proportion of his material. The sententious and antithetical style of the *Dial for Princes* is substantially that of *Euphues*, though Guevara on the whole handles it better than his imitator, and has many passages of real force and dignity. The general plan of the two books is also much the same. In both the biography is merely a peg on which to hang moral disquisitions and treatises. The use made of letters is the same in both. Even the names of some of the characters are similar. Thus Guevara's Lucilla is the flighty daughter of Marcus Aurelius. Lyly's Lucilla is the flighty daughter of Ferardo, governor of Naples; Guevara's Livia is a lady at the court of Marcus Aurelius, Lyly's Livia is a lady at the court "of the emperor," of whom no further description is given. The 9th, 10th, 11th, and 12th chapters of the *Dial for Princes* suggested the discussion between Euphues and Atheos. The letter from Euphues to Alcius is substantially the same in subject and treatment as that from Marcus Aurelius to his nephew Epesipo. Both Guevara and Lyly translated Plutarch's work *De Educatione Liberorum*, Lyly, however, keeping closer than the Spanish author to the original. The use made by Lyly of the university of Athens was an anachronism in a novel intended to describe his own time. He borrowed it, however, from Guevara, in whose book a university of Athens was of course entirely in place. The "cooling card for all fond lovers" and the address to the ladies and gentlemen of Italy have their counterparts among the miscellaneous letters by Guevara affixed by North to the *Dial for Princes*; and other instances of Lyly's use of these letters, and of two other treatises by Guevara on court and country life, could be pointed out.

Lyly was not the first to appropriate and develop the Guevaristic style. The earliest book in which it was fully adopted was *A petite Pallace of Pettie his Pleasure*, by George Pettie, which appeared in 1576, a production so closely akin to *Euphues* in tone and style that it is difficult to believe it was not by Lyly. Lyly, however, carried the style to its highest point, and made it the dominant literary fashion. His principal followers in it were Greene, Lodge, and Nash, his principal opponent Sir Philip Sidney; the *Arcadia* in fact supplanted *Euphues*, and the Euphuistic taste proper may be said to have died out about 1590 after a reign of some twelve years. According to Drayton it was Sidney's chief merit that—

> "He did first reduce
> Our tongue from Lillie's writing then in use,
> Talking of Stones, Stars, Plants, of Fishes, Flyes,
> Playing with words and idle similies,
> As th' English Apes and very Zanies be
> Of everything that they doe heare and see,
> So imitating his rediculous tricks
> They spake and writ all like meere lunatiques."

Shakespeare, Dr Landmann maintains, cannot strictly speaking be said to have ridiculed Euphuism. *Love's Labour Lost* is a caricature of the Italianate and pedantic fashions of the day, not of the peculiar style of *Euphues*. The only certain allusion in Shakespeare to the characteristics of Lyly's famous book is to be found in *Henry IV.*, where Falstaff, playing the part of the king, says to Prince Hal, "Harry, I do not only marvel where thou spendest thy time, but also how thou art accompanied; for, though the camomile the more it is trodden on the faster it grows, yet youth the more it is wasted the sooner it wears." Here the pompous antithesis is evidently meant to caricature the peculiar Euphuistic sentence of court parlance. That Shakespeare indeed was well acquainted with what was the court manual of his youth, and at times reproduces both ideas and phrases from it, has been amply proved by Mr Rushton, the German critic Hense, and others, but there is no evidence of antagonism between the two writers. It might have been otherwise had Lyly's Euphuism affected his plays. But these show little or no trace of Guevara's influence; their faults are the common faults of Elizabethan writing, from many of which Shakespeare himself was not free.

See *Euphues*, from early editions, by Edward Arber, 1868; Professor Ad. Ward's *English Dramatic Literature*, i. 151; Collier's *History of Dramatic Poetry*, iii. 172; *John Lilly and Shakespeare*, by C. C. Hense in the *Jahrbuch der deutschen Shakesp. Gesellschaft*, vols. vii. and viii. (1872, 1873); F. W. Fairholt's *Dramatic Works of John Lilly*, 2 vols., 1858; *Shakespeare's Euphuism*, by W. L. Rushton; "Euphuism" in the *Quarterly Review*, 1861. (M. A. W.)

LYMINGTON, a municipal and parliamentary borough and seaport town of Hampshire, England, is situated on the Lym at its entrance to the Solent opposite the Isle of Wight, 94 miles south-west of London and 15 south of Southampton. The parish church, dedicated to St Thomas à Becket, is an irregular structure, dating from the reign of Henry VI., but frequently restored. There are two grammar schools and several charities. The manufacture of salt and of Epsom salts has been declining for some years. A building yard here has turned out some of the most famous racing yachts. In summer the town is much frequented for sea-bathing. Lymington in Domesday is called *Lentune*, changed afterwards to *Limentum*. It was a borough by prescription, and received a grant of incorporation from James I. From the 27th of Elizabeth till 1867 it returned two members to parliament, and it still returns one. The population of the municipal borough (141 acres) was 2431 in 1881, and that of the parliamentary borough (4769 acres) 5462.

LYNCHBURG, a city in Campbell county, Virginia, U.S., is finely situated on the rising ground to the south of the James river 144 miles by rail, west by south of Richmond. Having excellent facilities of communication by the Richmond and Allegheny, the Norfolk and Western, and the Virginia Midland Railways, together with the James River canal, and possessing abundant water-power and immediate access to coal and iron, Lynchburg has become the seat of no small commercial and industrial activity. The tobacco trade, which formerly rendered it the wealthiest city of its size in the United States, except New Bedford, Mass., is still the staple; there are about eighty factories in the town, and the amount of tobacco sold in 1870-71 was 17,425,439 lb, while in 1880-81 it was 26,000,000 lb. Most of the operatives are negroes—men, women, and children all being employed. The local iron-works and flour-mills are of some importance, and large machine-shops are maintained at Lynchburg by the Norfolk and Western Railway. Two reservoirs, constructed in 1828 and 1878, supply the town with water. The population was 8067 in 1850, 6853 in 1860, 6825 (3353 coloured) in 1870, and 15,959 in 1880.

The town dates from 1786, and derives its name from a Mr Lynch who served in the war of independence and is erroneously credited by some with the origination of the term Lynch law. It was incorporated as a city in 1805. During the civil war it was a point of great importance to the Confederates as a base of supplies.

LYNCH LAW, a term used in the United States to characterize the action of private individuals, organized bodies of men, or disorderly mobs, who, without legal authority, proceed to punish by hanging or otherwise real or suspected criminals, without a trial according to the ordinary forms of law. The origin of the term is doubtful. American lexicographers generally refer it to the practice of a Virginia farmer of the 17th century, named Lynch, who, when he caught a wrongdoer, was wont to tie him to a tree and flog him, without waiting to summon the officers of the law. He is also said to have acted, by request of his neighbours, though without any legal authority, as a judge in the summary trial of persons accused of crime. Others trace the origin of the name to the act of James Fitzstephen Lynch, mayor and warden of Galway, Ireland, in 1493, who is said to have "hanged his own son out of the window for defrauding and killing strangers, without martial or common law, to show a good example to posterity." Others trace it still further to the old Anglo-Saxon verb *linch*, meaning to beat with a club, to chastise, &c., which they assert has survived in this cognate meaning in America, as have many other words and expressions long obsolete in Great Britain. While lynch law does not prevail in the old and well-settled States of the Union, and is almost universally deprecated, it is sometimes resorted to even in these States, in times of great popular excitement, or when the legal penalty seems disproportioned to the enormity of the offence. For example, the practice of lynching is said to have increased in Wisconsin since the abolition of the death penalty by law. Lynch law prevailed to a large extent in the early history of California, Oregon, Nevada, Kansas, Colorado, and other western States and Territories, and during the border troubles attending the outbreak of the civil war. Bodies of citizens, organized secretly or openly under the well-known names of "vigilance committees," "vigilantes," "regulators," "law-and-order-men," &c., punished with summary severity, and generally with wise discretion, horse thieves, highway robbers, burglars and swindlers, as well as murderers. Certain rude forms of trial were generally observed, but acquittals were rare, and the punishment was usually death by hanging. The practice, however barbarous under the conditions of well-settled government and society, has its justification in necessity in the newly-settled districts, frontier towns, and mining camps, where a rapid and extraordinary influx of population has preceded the establishment of civil government, or where the assembling of a large number of bold and hardened desperadoes has enabled them to defy the legally constituted authorities, and to commit crime at will, until suppressed by the voluntary and concerted action of the order-loving portion of the community.

LYNDHURST, John Singleton Copley, Baron (1772–1863), four times lord chancellor of England, was born at Boston, New England, in 1772. His father, son of an Englishman, but also a native of Boston, was a painter of very considerable note, who settled in London just before the commencement of the war of American independence. The son studied at Cambridge, where he was second wrangler and fellow of Trinity. Called to the bar in 1804, he gained a considerable practice; but it was not till 1817 that he began to come to the front. In that year he was one of the counsel for Dr Watson, tried for his share in the Spa Fields riot. On this occasion Copley so distinguished himself as to attract the attention of Castlereagh and other Tory leaders, under whose patronage he entered parliament, and was advanced to the highest legal positions, becoming solicitor-general in 1819, attorney-general in 1824, and lord chancellor in 1827, with the title of Lord Lyndhurst. Before being thus taken up by the Tories, Copley was a man of the most advanced views, a republican and Jacobin; and his accession to the Tories naturally excited a good deal of comment, which he bore with the greatest good humour. He gave a brilliant and eloquent but by no means rancorous support to all the reactionary measures of his chief. The same year that he became solicitor-general he married a fashionable wife, and began to take a conspicuous place in society, in which his noble figure, his ready wit, and his never-failing *bonhomie* made him a distinguished favourite.

As solicitor-general he took a prominent part in the trial of Queen Caroline. To the great Liberal measures which marked the end of the reign of George IV. and the beginning of that of William IV. he gave a vigorous opposition. During the Melbourne administration from 1835 to 1841 he figured conspicuously as an obstructionist from his seat in the House of Lords. In these years it was a frequent practice with him, before each prorogation of parliament, to entertain the House with a "review of the session," in which he mercilessly attacked the Whig Government. His former adversary Lord Brougham, now ineffably disgusted at his treatment by the Whig leaders, soon became his most powerful ally in opposition; and the two dominated the House of Lords. Throughout all the Tory Governments from 1827 Lyndhurst held the chancellorship; and in the Peel administration (1841–46) he resumed that office for the fourth and last time. As Peel never had much confidence in Lyndhurst, the latter did not exert so great an influence in the cabinet as his position and experience entitled him to do. But he continued a loyal member of the party. As in regard to Catholic emancipation, so in the agitation against the corn laws, he opposed reform till his chief gave the signal for concession, and then he cheerfully obeyed. After 1846 and the disintegration of the Tory party consequent on Peel's adoption of free trade, Lord Lyndhurst was not so assiduous in his attendance in parliament. Yet he continued to an extreme old age to take a lively interest in public affairs, and occasionally to astonish the country by the power and brilliancy of his speeches. That which he made in 1853, in denunciation of the aggressive policy of the Russian emperor Nicholas, made a sensation in Europe; throughout the Russian war he was a strong advocate of the energetic prosecution of hostilities. In 1859 he denounced with his old energy the restless ambition of Napoleon III. When he was released from the trammels of an official position, he came forward somewhat as the advocate of liberal measures. He strenuously supported the admission of Jews into parliament; his second wife was a Jewess. Under the influence of Mrs Norton he appeared also as the advocate of women's rights in questions of divorce. At the age of eighty-four he passed the autumn at Dieppe, "helping to fly paper kites, and amusing himself by turns with the writings of the Greek and Latin fathers on divorce and the amorous novels of Eugene Sue." His last speech, marked by "his wonted brilliancy and vigour," was delivered in the House of Lords at the age of eighty-nine. He died in 1863, in his ninety-second year. The impression we have of Lyndhurst from Lord Campbell's memoir is that of a man with rather an easy conscience in political life, not too scrupulous in his attention to judicial duties, but possessed of a fine and noble presence, a ready wit, an unfailing sweetness of temper, and a real kindness and charm of manner that won the hearts of men.

See *Lives of the Lord Chancellors of England*, vol. viii. (Lords Lyndhurst and Brougham), by Lord Campbell, 1869. Campbell was a personal friend, but a political opponent.

LYNDSAY, Sir David (*c.* 1490–1555), for about two centuries and a half perhaps the most popular poet of Scotland, was born about 1490, probably either at the family estate of The Mount, in the parish of Monimail, near Cupar in Fife, or at Garleton near Haddington in East Lothian, where the ruins of an old mansion house of the Lyndsays still remain. Little is known of his boyhood, but he is understood to have entered the university of St Andrews about 1505, and he became one of the *incorporati* of St Salvator's College in 1508 or 1509. After leaving college there is reason to think that he went abroad for a year or two, visiting, it is supposed, both France and Italy; but of this there is no certain information. In 1511 he must have been attached in some way to the court of James IV., as in the October of that year an entry appears in the royal treasurer's accounts for the sum of £3, 4s. for "blue and yellow taffities to be a play coat to David Lyndsay for the play playit in the king and queen's presence in the Abbey of Holyrood,"—so that even at that early period Lyndsay would seem to have developed his taste for masques and mummeries, play-acting and tale-telling. After this his name occurs in the treasurer's accounts for a regular salary of £40 a year; and on the birth of James V. in 1512 he was appointed to be the personal attendant of the young prince, in which situation he remained till James had attained his twelfth year in 1524—sometimes under the title of "keeper of the kingis grace," sometimes as the "kingis maister usher," and sometimes as "the kingis maister of houshald," but throughout with the yearly salary of £40. Lyndsay's close connexion with the court led to his being present at the remarkable scene just before Flodden, in the church of Linlithgow, when the so-called apparition came in "calling loudly for the king," and, after warning him against proceeding on his ill-judged expedition against England, vanishing away "as it had been a blink of the sun or ane whiss of the whirlwind." The incident is related both by Pitscottie and by Buchanan, expressly on the authority of Sir David; and Tytler shrewdly remarks that possibly Lyndsay knew more of the affair than he cared to confess, a conjecture which both Lyndsay's well-known prudence and sagacity in political affairs and his skill in arranging masques and stage plays renders exceedingly probable. In 1522 Sir David married Janet Douglas, of whom we know nothing except that she also was attached to the king's court, and was employed as sempstress to "his grace,"—various payments to her being entered in the accounts for her diligence in the humble office of "sewing the kingis sarkis." It is evident from many passages in Lyndsay's poems that his good sense and sweet temper, his varied accomplishments, and his skill in mingling amusement with instruction had greatly endeared him to the young king, and it would have been well for James if he had never listened to other and worse counsels than those of his wise and affectionate "maister usher."

It is to the credit of the king, however, and characteristic of the generous disposition of the earlier Stuarts, that he never forgot or forsook the friend of his infant and boyish years. For when he fell under the power of the Douglases in 1524, and when Lyndsay had to take his dismissal from court, James took care that his salary should continue to be paid him; and no sooner did he escape from their domination than Lyndsay was at once recalled, and the appointment of lyon-king conferred upon him. This was in 1529, and it is a remarkable proof of the reputation which Lyndsay had by this time acquired for prudence and sterling practical ability that he was at various times sent abroad in connexion with embassies from Scotland. In 1531 he went to the Netherlands to renew the commercial treaty with that country. On this occasion the embassy had a personal interview with the emperor Charles V., and the mission was perfectly successful. A few years afterwards (in 1536) he formed one of the envoys sent to France to conclude a treaty of marriage between the Scottish king and Marie de Bourbon, daughter of the Duc de Vendôme. It is evident therefore that Lyndsay's position and employments must have enabled him to gather much experience of life, and to obtain a somewhat varied knowledge both of men and things. His last sad office to his beloved sovereign was to attend at his bedside when the poor king was dying of a broken heart at Falkland, in December 1542. Lyndsay survived the king about thirteen years. At the time of Cardinal Beaton's assassination he held a seat in parliament as commissioner for the burgh of Cupar. In 1548 he was despatched to Denmark to negotiate a free trade, particularly in grain, for the Scottish merchants, which was readily granted. Mr Laing, on the authority of an entry in the Privy Seal Register, states that his death must have taken place early in 1555.

When Lyndsay was driven from the court by the advent of the Douglases to power, he no doubt felt it as a bitter misfortune and a disappointment of all his highest hopes. But we are greatly mistaken if he did not ere long come to regard it in a very different light. Like most men of genius, he had evidently two sides to his character. On the one side he had a taste for pleasure, sociality, pageantry, and frivolous amusements; and a few years more of these might have deadened his nature to everything else, and converted him into a mere dangler after royalty. But he had also elements of a better kind. He was well educated and accomplished; he had read somewhat extensively, and was master of most of the knowledge to be had in books at that time. He had seen not a little of the world, both in Scotland and in foreign countries; he was an acute discerner of character, and had both knowledge of and skill in affairs. Now then was just the time for a man like him, arrived at the full maturity of his intellect, to turn all these varied acquisitions to account. Lyndsay therefore, we may infer, retired to his country seat, either at The Mount, or as we fancy more likely to Garleton (that he might be more within call should a change take place in the political situation at Edinburgh), and there, after the first dull pang of disappointment was over, he doubtless found that there was no lack of subjects to engage his best thoughts. One of the great crises in the history of Europe and in the progress of human thought had just arisen. The trumpet of the Reformation had been sounded in Germany, and its reverberation had already been heard in Scotland, where both political and ecclesiastical disorder had nearly reached their worst, and were becoming the source of deep anxiety and desire for redress to all good men. For Lyndsay, therefore, there was something else to do than to brood moodily over his own private griefs. He had to make up his mind on a variety of great public questions, as well perhaps as to settle the great personal question of his own religious faith; and in his earliest work, *The Dreme*, which seems to have been composed at this time, we have a somewhat vivid picture of the turn his thoughts took.

He represents himself as having spent the long winter night without sleep, "through heavy thought, remembering of divers thingis gone." On getting up and walking out, he finds the dull winter season, with its bitter blasts and sharp sleety showers, but ill-fitted to console him, and only too much in harmony with his own melancholy. He goes down to the sea-shore, but things are no better there; for the "weltering of the waves" at once associates itself in his mind with "this false warld's instability." Thus far, then, his meditations seem to have had a merely personal reference. But by and by, on retiring into a cave near the shore, he falls into a trance, in which his thoughts take a wider range. The miserable state of his country, from misgovernment on the part of its rulers and the vices of both clergy and laity, fills his mind, and, reflecting on the ultimate fate of such men, he finds himself in the twinkling of an eye in hell, where he sees wicked popes, kings, conquerors, princes, and lords temporal, with no end of churchmen, "mansworn merchants," "unleil laboraris," craftsmen "out of number," "hurdaris of gold and common occararis," all "tormentit with pains intolerable." Then, leaving this "dolorous dongeon," he has a passing sight of purgatory, though apparently with some misgiving as to its reality, his significant remark being—

> "Sic things to be great clerkis does conclude,
> Howbeit my hope stands most in Chris'is blood."

Proceeding then to the realms of bliss, he sees something of the rewards of good and just rulers and righteous men; and by and by returning to the earth, and at length looking down upon Scotland, he sees a region both good and fair, its seas abounding in fish, its mountains covered with pasture, the valleys fit for corn, the forests full of game, mines with gold and silver, the people fair, intelligent, strong, and noble-minded,—and yet with all this, the country poor and the inhabitants miserable. What could be the cause? and the answer given is that the realm wants good government, impartial administration of justice, and freedom from war and discord. Viewing the country all over—on the borders

> "Betwixt the Merse and Lochmaben,
> He could not knaw a leil man from a thief.
> To show their reif, theft, murther and mischief,
> And vicious works, it would infest the air."

In the Highlands it was no better:—

> "Unthrift, sweirness, falset, poverty, and strife
> Put policy in danger of her life."

And even in the Lowlands, where better things might be expected, it was impossible for a poor man to live by his industry. If he settled in the towns, "singular profet" (by which we understand him to mean the system of monopolies and of close trade corporations, which everywhere prevailed) "gart him soon dislodge." And if he attempted to get redress to his wrongs there was no help for him anywhere. The spiritual state, plunged in simony, covetousness, pride, ambition, sensuality, and the love of pomp and pleasure, "held him at disdain"; and among the nobility and gentry "liberality and lawté both are lost," knightly courage is "turnit in brag and boast," and disorder and civil war have produced a state of things in which "there is nocht else bot ilk man for himself." The moral of the whole is—"Woe to the land that has ouer young ane king!"—"there sall na Scot have comforting till that I see the country guided by wisdom of ane gude auld prudent king." The poet is then awakened by the sound of cannon from a ship of war approaching the coast,—the suggestion, as we imagine, being that the existing state of things can only end in violence and uproar, in tumult and rebellion, most probably in foreign invasion and revolution.

On the whole *The Dreme* appears the most finished and artistic of Lyndsay's works. It has a tone of greater seriousness, bears the marks of more care and elaboration in the composition; and, though it has a good deal of the crudeness of a first attempt, we think we can discover an effort at least at a finer proportion and harmony of parts than in any of his subsequent poems. In its subject-matter it strikes the keynote of almost all that he afterwards wrote. The evils, the wrongs, the misgovernment of his country evidently filled his whole soul with grief, indignation, and the desire for reform; and we almost doubt if there is to be found anywhere except in the old Hebrew prophets a purer or more earnest breathing of the patriotic spirit. Indeed if we may judge from the motto prefixed to his *Dreme* we should almost fancy that he had made them his model:—*Prophetias nolite spernere. Omnia autem probate: quod bonum est tenete.* Lyndsay accordingly is to be judged of less as a poet than as a great political and ecclesiastical reformer. That his works are written in verse is merely incidental. Though not destitute of poetical genius, this was scarcely the special characteristic of his mind. His greatest work, and the only one to which it is necessary here to make further allusion, was his *Satire of the Three Estates*. It is a drama, and may be said to be in some respects one of the most remarkable that ever was written. The *dramatis personæ* are chiefly allegorical, and under the names of Rex Humanitas, Wantonness, the Vices (Flattery, Falset, and Deceit) in the habit of friars, King Correction, Good Counsel, Temporality, Sensuality, Chastity, Verity, John the Commonweal, &c., the most bitter and unsparing exposure is made of the wickedness and corruption of all classes of the community. King, clergy, lords, merchants, craftsmen —no one escapes the severest censure and the most unmitigated ridicule. And yet this extraordinary production was acted on the borough muir of Edinburgh before the king himself, many of the highest nobility and clergy, and an immense crowd of all classes of the people. How the author escaped being torn in pieces by the mob or burnt at the stake by the ruling powers it is difficult to understand. Perhaps the explanation is that each class saw every other brought under the lash equally with itself, and felt consoled for its own shame by enjoying the infliction visited on its neighbours. Very likely too the grotesque wit and the fun with which the serious matter of the play was so largely spiced charmed the audience into good humour, and left them unable to think of vengeance. It may be somewhat confidently inferred too that the dramatist so exactly expressed the public feeling of the time as to the evils and corruption under which the state was rapidly going to destruction that, even when his stinging reproaches most nearly touched themselves, their consciences were smitten and they were compelled to assent to the perfect truth and justness of his rebukes. But be this as it may, there can hardly be a doubt that this most singular drama formed one of the chief means by which the way was paved for the Reformation afterwards carried out by Knox and his coadjutors.[1] One thing is especially remarkable in Lyndsay's politics both civil and ecclesiastical, that, hopeless and depressing as the condition of the country must have been to a man like him, his opinions never end in mere negations, but are throughout constructive in their character. And yet more thoroughgoing radicalism it would be difficult elsewhere to find. He does not for example scruple to declare that kings who govern ill should be deposed. This, however, was merely a speculative opinion, and it is of more interest to ascertain what his practical suggestions were. Among them we find the following:—that the king should on no account attempt to do anything without the advice of his council and parliament; that John the Commonweal should have a greater voice in parliament, *i.e.*, in our modern phrase, that there should be a considerable extension of the franchise; that (as already mentioned) all close corporations and monopolies should be abolished; that temporal lands should be set in feu to the tenants on condition of their duly rendering the prescribed services to the state, a measure not very dissimilar in principle (if we understand it aright) to that lately introduced into Ireland; that lords should be responsible for thieves who find refuge on their lands, and make restitution to the poor who have been plundered by them; that courts of justice should be established in the remoter parts of the country, such as Elgin and Inverness, in order to avoid the expense attendant on the transference of pleas to the metropolis, and, to provide for their maintenance, the nunneries in that quarter to be abolished and their revenues sequestrated, the reason given being—

> "Thir wanton nuns are na way necessair
> Till common-weill, nor yet to the glorie
> Of Christis kirk, thocht they be fat and fair,
> And als that fragile order feminine
> Will nocht be missit in Christ's religion."

No less stringent and sweeping are his proposals for the reform of the church. The religion of Christ must be purged of all deceit and hypocrisy. The consistorial courts are to have no jurisdiction in matters temporal. No clergyman is to be admitted to office unless duly qualified in learning and piety. Celibacy is to be abolished. Bishops and priests must be compelled to preach regularly and "take better tent to souls under their dominion." Benefices are not to be purchased either from prince or pope, nor is money to be permitted to go to Rome for bulls and pleas. Pluralities and patronage are to be abolished, residence is to be enforced, and the people are to have a voice in the choice of their spiritual guides. In fact many of Lyndsay's proposals of reform have quite a modern look, and this perhaps explains in some degree the long-continued popularity of his works among his countrymen, which otherwise it is rather difficult to account for. They have none of the chivalric spirit-stirring power of many of our ancient songs and ballads, none of the tender love and melancholy which form the charm of Burns's lyrics, none of the joyous abandon of convivial or amorous ditties, and none of the fascination which springs from well-constructed tales or narrative poems, like those of Chaucer or Scott. It is difficult to suppose that even the humour which pervades them, seldom of the most refined kind and often very much the reverse, can have been in any great degree pleasing to readers of a later age than the author's own. The only explanation, we suspect, is that Lyndsay's intense and uncompromising love of liberty, his strong sympathy with the poor, his love of justice, his keen hatred of tyranny, wrong, and oppression, and his shrewd common sense easily found a responsive chord in Scottish bosoms. Nor was the interest which his works so long retained among the Scottish peasantry merely of a sentimental kind. For many of the evils against which he directed his severest invectives continued long afterwards to afflict his country, and even when somewhat changed in their aspect still reappeared in analogous forms or character. Prelatic usurpation and cruelty were as rife as ever in the century which succeeded that in which Lyndsay wrote; aristocratic venality and heartlessness have perhaps even yet hardly ceased out of the land; church patronage, always hateful to religious-minded Scotsmen, was hardly abolished before it was reimposed. And then such incidents as the massacre of Glencoe, the union with England, a measure intensely disliked by the great mass of the Scottish people, the infamous treatment of the Darien colonization scheme, the barbarities which followed the two Jacobite rebellions, the deprivation up to 1832 of any true parliamentary representation, and the continuance of close municipal and trade corporations, all tended to keep up a bitter sense of wrong to which Lyndsay's satires gave point and expression.

The best accessible editions of Lyndsay's works are those of George Chalmers, in 3 vols., London, 1806, and of David Laing, also in 3 vols., Edinburgh, 1879. These, with the Early English Text Society's edition, leave little to be desired for the establishment of a correct text, and for purely antiquarian illustration. In Warton's *History of English Poetry*, and in Irving's *History of Scottish Poetry*, good critical estimates will be found of Lyndsay's place as a poet. It is possible, however, that something yet remains to be done in order to determine his exact position as a great political and religious reformer, and to illustrate the effect which his works have had in directing popular feeling and opinion in Scotland. (J. T. BR.)

[1] See Ellis, *Original Letters*, 3d series, vol. iii. p. 280; and Row, *History of the Kirk of Scotland*, p. 7.

LYNN, a city in Essex county, Massachusetts, U.S., situated near the north end of Massachusetts Bay, on a harbour formed by the peninsula of Nahant, 10 miles north-east of Boston, with which it is connected by different lines of railway. The bulk of Lynn is built on the low grounds near the sea; but in the north-east the elevation is greater, and behind the city proper there is a range of porphyritic hills dotted with villas. Most of the houses are of wood, those of the main thoroughfare—Market Street—of brick. The city hall, a substantial erection of brick and brown stone, is considered one of the finest buildings of its class in New England. It contains the free public library, founded in 1862, and numbering 29,126 volumes in 1880. It was at Lynn that the first smelting-works in this part of the country were established, in 1643; but the place has long been famous rather for the making of boots and shoes, a department, indeed, in which it has hardly a rival in the world. This trade was introduced in 1750 by a Welshman, John Adam Dagyr; in 1767 the output was 80,000 pairs; in 1810, 1,000,000 pairs; in 1865, 5,360,000; in 1868 upwards of 10,000,000; and in 1880, 16,276,380,—the greater proportion being cheap shoes for women and children. About twelve thousand hands are employed, though labour-saving machinery is freely introduced. Another industry of great local importance is the tanning and dressing of sheep and goat skins, and the making of morocco leather. The population was 6138 in 1830, 14,257 in 1850, 28,233 in 1870, and 38,284 in 1880.

The foundation of the town belongs to 1629; and the name was given in memory of Lynn Regis in England, the home of its first pastor. It obtained incorporation as a city in 1850; Swampscott and Nahant, which it then included, were rendered independent in 1852 and 1853 respectively.

LYNN REGIS, KING'S LYNN, or LYNN, a parliamentary and municipal borough and seaport of Norfolk, England, is situated on the Great Ouse, about 2 miles from the Wash, and on several railway lines, 100 miles north of London and 48 west-north-west of Norwich. On the land side the town was formerly defended by a fosse, and there are still considerable remains of the old wall, including a handsome Gothic structure, known as the "South Gates." The streets are generally narrow and winding; some of the dwelling-houses are very ancient. The public walks form a fine promenade, and in the centre of them stands a quaint octagonal chapel called the Red Mount, at one time much frequented by pilgrims. The church of St Margaret's, formerly the priory church, is a fine Gothic building with two towers at the west end, one of which was formerly surmounted by a spire blown down in 1741. St Nicholas chapel, at the north end of the town, is also of mediæval date, and contains many interesting memorials of the past. All Saints church is a beautiful and ancient cruciform structure. At the grammar school, founded in the reign of Henry VIII., Eugene Aram was at one time usher. There are also national schools, a British school, and several charities. Among the other public buildings are the guildhall, with Renaissance porch, the corn exchange, the custom-house, and the athenæum. The shipping trade is steadily progressing, and there is now regular steam communication with Hamburg. The principal exports are corn, wool, and oilcake, and the principal imports, coal, timber, linseed, and manufactured goods. The total value of the exports in 1880 was £1,152,456, the average for the four years 1876–79 being £967,958, and for four years 1872–75 £519,479. The value of the exports in 1880 was £366,649, the average value for 1876-79 being £251,491, and for 1872-75 £140,974. The Alexandra dock, opened in 1869, has a water area of $6\frac{3}{4}$ acres, with an average depth of 31 feet. The fisheries of the town are important, and there are also breweries, corn-mills, iron and brass foundries, agricultural implement manufactories, shipbuilding yards, rope and sail works, and tobacco manufactories. The population of the borough in 1871 was 16,562, and in 1881 it was 18,475.

Lynn is supposed to have been a British town, and was known as a port before the Norman invasion, after which it became the possession of the bishops of Norwich, and was known as Lynn Episcopi. After the suppression of the monasteries it came into the hands of Henry VIII., and its name was changed to Lynn Regis or King's Lynn. The town was taken by the parliamentary forces in 1643. It received its first charter from King John, but its first governing charter from Henry VIII. Since the 23d of Edward I. it has returned two members to parliament.

LYNX, a name now appropriated to several animals forming a small section of the cats or genus *Felis*. It is not quite certain to which of these, if to any of them, the Greek name λύγξ was especially applied, though it was more probably the caracal than any of the northern species. The so-called lynxes of Bacchus were generally represented as resembling panthers rather than any of the species now known by the name. Various fabulous properties were attributed to the animal, whatever it was, by the ancients, that of extraordinary powers of vision, including ability to see through opaque substances, being one; whence the epithet "lynx-eyed," which has survived to the present day, although having no foundation in fact.

There are two forms of cats which are now called lynxes.

1. The caracal or Persian lynx, *Felis caracal*, an animal about the size of a fox, is of slender build, with a moderately long tail, reaching down to the heels. It is of a uniform vinous or bright fulvous brown colour above, and is paler, sometimes almost white, beneath. It is quite or almost entirely unspotted. The tail has a black tip, and the ears are black externally, long and upright, pointed, and surmounted by a pencil of fine black hairs. It inhabits Central and North-West India, Persia, Arabia, Syria, and the greater part of Africa.

2. The name lynx is given to various species or varieties of animals found in the northern and temperate regions of both the Old and New World, all of moderate size, that is, smaller than the lions, tigers, and leopards, and larger than the true cats, with long limbs, short stumpy tail, ears tufted at the tip, and pupil of the eye linear when contracted. Their fur is generally long and soft, varying, however, according to season and locality, and always longish upon the cheeks. Their colour is always light brown or grey, and generally more or less spotted with a darker shade. The naked pads of the feet are more or less covered by the hair that grows between them. The skull and skeleton does not differ markedly from those of the other cats, but the small anterior upper premolar tooth found in many other species is usually wanting. Their habits are exactly those of the other wild cats; they are excelled by none in the untameable savageness of their disposition. They capture their prey in the same manner, either lying in wait, or noiselessly stealing within reach, and then making a sudden rush or spring upon it. Their food consists of any mammals or birds which they can overpower. In inhabited countries they commit extensive ravages upon sheep, lambs, and poultry. They generally frequent rocky places and forests, being active climbers, and passing much of their time among the branches of the trees. Their skins are of considerable commercial value in the fur trade.

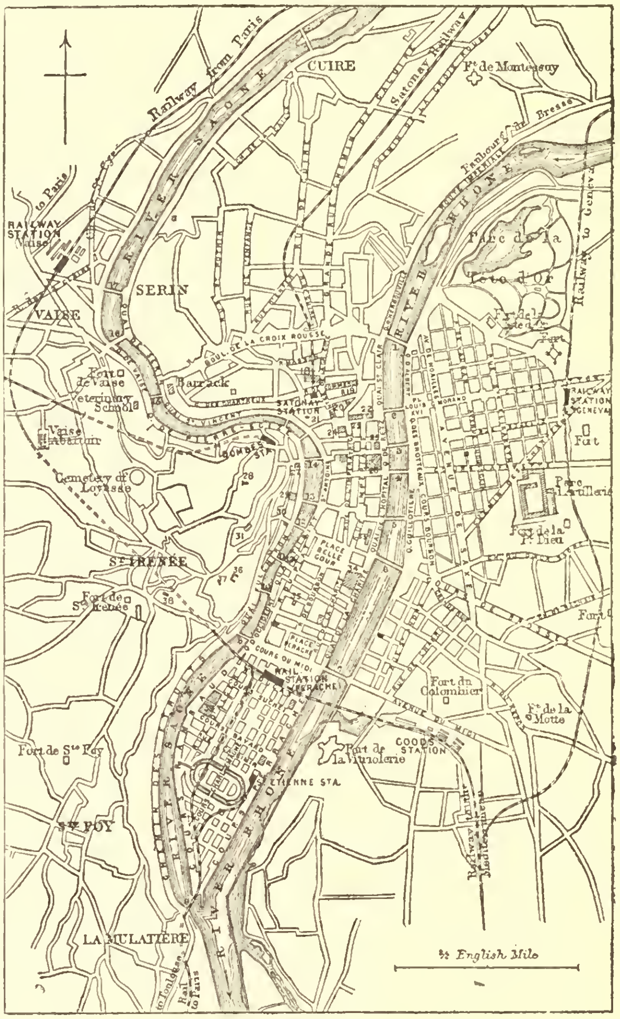
Zoologists are by no means agreed at present as to the specific distinctions, if any really exist, between the various modifications of this group. As many as eight species are sometimes recognized, four belonging to the Old and four to the New World. The former are *Felis lynx*, of Scandinavia, Russia, northern Asia, and till lately the forest regions of central Europe (it has not inhabited Britain during the historic period, but its remains have been found in cave deposits of Pleistocene age); *F. cervaria*, Siberia; *F. pardina*, Turkey, Greece, Sicily, Sardinia, and Spain; and *F. isabellina*, Tibet. The American varieties are *F. canadensis*, the most northern species, and *F. rufa*, the

European Lynx. From a Drawing by Wolf in Elliot's *Monograph of the Felidæ*.

American wild cat or bay lynx, extensively distributed from the Atlantic to the Pacific throughout nearly the whole latitude of the United States, but replaced in Texas and southern California by *F. maculata*, and in northern Oregon and Washington territory by *F. fasciata*.

In both cases, as might be supposed, specimens obtained from the more southern climates are shorter in their fur, more brightly coloured, and more distinctly spotted than those from colder regions. When only a few individuals of each most markedly different form are examined the distinctions are sufficiently evident. The occurrence, however, of transitional or intermediate forms makes it extremely difficult to draw the line between the different varieties or species, or to assign definite characters by which they can be separated. Wherefore it is best at present to accept the so-called species as only provisional, and wait until more abundant materials, with fuller knowledge of the localities from which they are derived, and of the variations due to age, sex, season, and climate, have been more carefully studied. We shall then probably come to the conclusion that all the existing forms of northern lynxes, whether American or Eurasian, belong to what may fairly be called a species, which is becoming by degrees differentiated into several more or less strongly marked local varieties. (W. H. F.)

LYONS (French, *Lyon*), in political, commercial, industrial, and military importance, as well as in point of size, the second city of France, formerly the capital of Lyonnais, and now the chief town of the department of Rhone, seat of a court of appeal and of a military government, and a fortified place, is situated at the confluence of the Rhone and the Saône, in 45° 46′ N. lat. and 4° 49′ 19″ E. long., at an altitude above the sea varying from 540 to rather more than 1000 feet. The population of the city and liberties in 1876 was 342,815. The rivers, both flowing south, are separated by the hill of Croix-Rousse. On the right the Saône is bordered by the scarped heights of Fourvières, St Irénée, and Ste Foy, leaving room only for the quays and one or two narrow streets; this is the oldest part of the city. Where it enters Lyons the Saône has on its right the faubourg of Vaise and on its left that of Serin, whence the ascent is made to the top of the hill of Croix-Rousse. The river next takes a semicircular sweep around the hill of Fourvières (410 feet above it), which is fully occupied by convents, hospitals, and seminaries, and has at its summit the famous church, the resort of 1,500,000 pilgrims annually. From this point the best view of the entire city is obtained. First the busy Saône is seen with its thirteen bridges and animated quays. Next, on the peninsula between the two rivers at the foot of the hill of Croix-Rousse, come the principal quarters of



Plan of Lyons.

1. Pont St Clair.
2. Pont Morand.
3. Pont du Collége.
4. Pont Lafayette.
5. Pont de l'Hôtel Dieu.
6. Pont de la Guillotière.
7., 8. Ponts Napoléon.
9. Pont du Mulatière.
10. Pont d'Ainay.
11. Pont St Georges
12. Pont Tilsitt.
13. Pont du Palais de Justice.
14. Pont Nemours.
15. Pont de Serin.
16. Pont du Port Mouton.
17. Pont de la Gare.
18. Jardin des Plantes.
19. St Polycarpe.
20. Condition des Soies.
21. La Martinière.
22. Opera House.
23. Hôtel de Ville.
24. Palais des Arts.
25. Lycée.
26. Bourse.
27. Protestant Church.
28. Notre Dame de Fourvières.
29. Palais de Justice.
30. St John's Church.
31. Hospice de l'Antiquaille.
32. Jewish Synagogue.
33. Hôtel Dieu.
34. Hospice de la Charité.
35. Église d'Ainay.
36. Great Seminary.
37. St Just.
38. St Irénée.
39. Arsenal.

the town: the Terreaux, containing the hôtel de ville, the prefecture, and the chief commercial establishments; Bellecour with its large open square, one of the finest in Europe; and the aristocratic Quartier de Perrache. The Rhone and Saône formerly met here, till, a hundred years ago, the sculptor Perrache reclaimed from the rivers the quarter which bears his name; on the peninsula thus formed stands the principal railway station. Here too are the docks of the Saône, factories, the arsenal, gas-works, prisons, and the slaughter-house.

The Rhone, less confined than the Saône, flows swiftly in a wide channel, broken when the water is low in spring by pebbly islets. On the right hand it skirts first St Clair, sloping upwards to Croix-Rousse, and then the districts of Terreaux, Bellecour, and Perrache; on the left it has a low-lying plain, subject to disastrous inundations, occupied by the Parc de la Tête d'Or and the quarters of Brotteaux and Guillotière. The park, defended by the Grand Camp embankment, comprises 282 acres, and contains a zoological collection, botanical and pharmaceutical gardens, and the finest greenhouses in France, with unique collections of orchids, palm-trees, and *Cycadaceæ*. Brotteaux is a modern town with boulevards and regular streets, and in this direction Lyons is extending every year. In the old districts there is no room for growth; they are crowded with old buildings of eight or ten stories, or even more, and it has been the task of the last thirty years to open them up by means of thoroughfares. Guillotière, to the south, is a workmen's quarter of wretched houses.

The Rhone is lined with broad quays, and crossed by ten fine bridges, two of them for railway traffic. On the right bank stand the lycée and the public library, the Hôtel Dieu, the military hospital, and the Hospice de la Charité; on the left bank is the long range occupied by the medical faculty. In the east of Guillotière the Geneva railway skirts the artillery barracks.

Northward from Fourvières appear the green slopes of Mont d'Or, descending towards the Saône by pleasant glades sprinkled with villas; to the east, beyond the somewhat monotonous plain, stretch the mountains of Savoy and Dauphiné; to the south, below the confluence of the Rhone and the Saône, the river traverses a rich landscape to pass out of sight at the foot of Mont Pilat; and to the west the horizon is bounded by the Forez hills.

Since 1852 the communes of Croix-Rousse and Guillotière have been united with Lyons. The Rhone and the old fortifications, which, on the right bank of the Saône, stretched in an unbroken line from the rock of Pierre Scize below Vaise to the bridge of Ainay, continued by those now replaced by the Croix-Rousse boulevard, marked the boundaries of the ancient city. The line of Croix-Rousse has now been thrown forward to the north, and further strengthened by Forts Caluire and Montessuy. On the left bank of the Rhone stand Forts Tête d'Or, Charpennes, Brotteaux and Part-Dieu, Villeurbanne, Lamotte, Colombier, and Vitriolerie. On the right bank of the Saône Forts Ste Foy, St Irénée, Loyasse, Vaise, and Duchère completed the defensive system of Lyons previous to 1870; but since that date the dominant points of the neighbourhood have begun to be crowned with batteries and redoubts; but only Forts Brou and Feyzin on the left bank of the Rhone, St Genis on the right bank, Mont Verdun on Mont d'Or, and Vencia are finished.

Of the ancient buildings in Lyons, Fourvières is the one which attracts most visitors. It derives its name from the ancient forum (*Forum vetus*), whose site it occupies. The first chapel, dedicated to the Virgin, was erected in the end of the 9th century. Consecrated afterwards to St Thomas of Canterbury, and then made a collegiate church, Notre Dame de Fourvières was created superior of twenty-five villages by Louis XI., on occasion of his visit in 1476. Laid waste by the Protestants, plundered at the Revolution, it began to be visited again in 1804, and in 1805 Pope Pius VII., returning from the coronation of Napoleon, ascended thither to give his benediction to the city—a ceremony renewed from year to year with great pomp. The church tower, 172 feet high, is surmounted by a statue of the Virgin in gilded bronze, 18 feet high, turned towards the town; on the pedestal are bronze plates with inscriptions assigning to the Virgin the credit of ending the plague of 1643, and of preserving the town during the cholera epidemics of 1832, 1835, and 1850. The first stone of a magnificent new church was laid in 1872. The crypt, 219 feet by 62, is as yet the only portion finished. At the foot of Fourvières, on the right bank of the Saône, lies the metropolitan church of St John (the archbishop of Lyons is primate of all Gaul). The choir belongs to the early years, the transept to the close of the 12th century; the building of the nave, carried on during the next three hundred years, was completed only in 1480. In one of the two towers there is a bell weighing nearly 10 tons. To the right and left of the altar stand two crosses preserved since the council of 1274 as a symbol of the union then agreed upon between the Greek and Latin Churches. St Martin d'Ainay, in the Perrache quarter, is the oldest church in Lyons, dating from the beginning of the 6th century; the chapels of the apse are adorned by paintings by Flandrin. St Nizier, in the heart of the city, was the first cathedral of Lyons; and the crypt in which St Pothinus officiated still exists. The present church is a Gothic edifice of the 15th century, with the exception of the porch, constructed by Philibert Delorme. In the crypt of the church of St Irenæus are the tomb of that saint and a vast quantity of bones, alleged to be those of 19,000 martyrs put to death in the persecution of Severus. The Place Bellecour is adorned west and east by two monumental façades originally erected after plans by Mansard, but destroyed in 1793, and rebuilt under the consulate in a somewhat modified style. In the middle stands an equestrian statue of Louis XIV. by Lemot. The Rue de l'Hôtel de Ville, connecting the Place Bellecour and the Place des Terreaux, and the Rue de la Republique running parallel with it are among the finest streets of the modern city. The east side of the Place des Terreaux (so called from the "terreaux" now occupying the place of the canal which formerly connected the Rhone and the Saône) is formed by the hôtel de ville, which, however, turns a better front in the opposite direction towards the theatre; the south is occupied by the Palais St Pierre (formerly a convent), which gives accommodation to the faculties of science and literature, and to the school of fine arts, the picture gallery, the museums of sculpture, archæology and natural history, and the art library. In the Rue de la Republique, between Place de la Bourse and Place des Cordeliers, each of which contains one of its highly ornamented fronts, stands the building occupied by the exchange and the commercial court. The former has its offices on the ground floor round the central glass-roofed hall; besides the court, the upper stories accommodate the council of prud'hommes, the chamber of commerce, and the industrial museum. The palais de justice, a fine building with a Corinthian colonnade, on the right bank of the Saône, occupies the site of the palace of the counts of Forez. A statue of Jacquart the inventor stands in Place Sathonay, and one of Marshal Suchet in Place Tholozan.

The Academy of Lyons has the five faculties of Catholic theology, science, literature, medicine and pharmacy, and law, with two lyceums, and a number of schools; and the Catholic institute has three faculties—law, science, and theology. The school of fine arts was founded in the 18th century to train competent designers for the textile manufactures, but has also done much for painting and sculpture. The veterinary school of Lyons, instituted in 1761, was the first of its kind in Europe; its laboratory for the study of comparative physiology is admirably equipped. L'École la Martinière (founded by the legacy of Claude Martin) furnishes gratuitous teaching of the sciences and industrial arts. The school of commerce and the Lyons central school complete the list of institutions for industrial education.

Besides the Académie des Sciences, Belles Lettres, et Arts (founded in 1700), Lyons possesses societies of agriculture, natural history, useful arts and sciences, geography, and horticulture.

The Hôtel Dieu, instituted in the beginning of the 6th century by King Childebert, is still one of the chief establishments of its kind in the city, and contains 929 beds. Its façade, fronting the Quai du Rhone for 1060 feet, was commenced according to the designs of Soufflot, architect of the Pantheon at Paris. The Hospice de la Charité and the military hospital are a little larger than the Hôtel Dieu. The Hospice de l'Antiquaille, at Fourvières (2000 beds), occupies the site of the ancient palace of the prætorian prefects, in which Germanicus, Claudius, and Caracalla were born. Lyons has many other benevolent institutions, and is also the centre of the operations of the Propagation de la Foi.

The museum is one of the best provincial collections in France, alike in its ancient, mediæval, and modern departments. Among the Gallo-Roman inscriptions, in which it is particularly rich, are the bronze tables discovered at Lyons in 1528, which contain the speech of the emperor Claudius in regard to the admission of the citizens of Gallia Comata into the Roman senate. The numismatic collection (30,000 pieces) includes a series of the coins struck at Lyons from 43 B.C. to 1857. There is a special gallery of works of Lyonese painters; and the Bernard collection of about 300 pictures is kept entire.

The museum of natural history (for which a new building is to be erected in the Parc de la Tête d'Or) contains a zoological department ranking next to that of Paris, and mineralogical, geological, and anthropological sections—the last enriched with specimens from the classic site of Solutré (Saône and Loire). The museum of art and industries, founded in 1864 by the chamber of commerce, is divided into three sections, the first intended to illustrate the various conceptions of the beautiful formed by different peoples, the second to show the whole method of the textile industry, and the third to give an historical conspectus of woven textures. The Guimet Museum, in a special building in the Tête d'Or, consists of objects brought from the extreme East (mainly by M. Émile Guimet) and designed to facilitate the comparative study of religions, especially those of the Eastern world. Since 1880 the institution has published its *Annales*, consisting of original essays or translations of foreign works.

The library of the school of arts contains 65,000 volumes and 22,000 engravings, and the town library 108,000 volumes and 1300 manuscripts,—about 600 of the printed works being incunabula, and 25 of the MSS. belonging to the Carlovingian period. In the latter institution is the great terrestrial globe made at Lyons in 1701, indicating the great African lakes, the rediscovery of which has been one of the events of the present century.

Under the Romans Lyons was admirably provided with water. Three ancient aqueducts on the Fourvières level, from Montroman, Mont d'Or, and Mont Pilat, can still be traced; and the last was no less than 52 miles long, and capable of supplying 11,000,000 gallons per day. Magnificent remains of this work may be seen at St Irénée and Chaponost. Traces also exist along the Rhone of a subterranean canal conveying the water of the river to a naumachia. At present the water supply of Lyons is obtained from the Rhone by powerful hydraulic engines situated above the town, which raise the water to the Montessuy and the Fourvières plateaus, 456 feet above the low level of the river. The reservoirs are capable of supplying 1,765,829 cubic feet of water per day.

Agrippa made Lyons the starting-point of the principal Roman roads throughout Gaul; and it still remains an important centre in the general system of communication. The Saône above the town and the Rhone below have large barge and steamboat traffic; and the latter river above the town may be used by steamboats during summer as far as Aix in Savoy. Navigation, however, is often interrupted, even below the town, by the lowness of the water, and a canal is projected to remedy this defect. The current of the Saône is less rapid than that of the Rhone, and is controlled by weirs.

The railway from Paris to Marseilles has two stations (Vaise and Perrache) in Lyons; and the line from Lyons to Geneva two (Brotteaux and St Clair). The Montbrison line starts from St Paul, on the right of the Saône. The terminus of Part-Dieu for the newly-opened East of Lyons line is between Perrache and Brotteaux. Within the town there are two rope railways,—the first mounting to Fourvières, and the second, popularly called the *ficelle*, from Rue Terme to Croix-Rousse.

In a city of such importance as Lyons the number of industries is naturally large, but by far the most extensive of them all is the silk manufacture. Derived from Italy, this industry rapidly developed under the patronage of Francis I., Henry II., and Henry IV.; and from time to time new kinds of fabrics were invented—silk stuffs woofed with wool or with gold and silver threads, shawls, watered silks, poplins, velvets, satinades, moires, &c. In the beginning of the present century Jacquart introduced his famous loom by which a single workman was enabled to produce elaborate fabrics as easily as the plainest web, and by changing the "cartoons" to make the most different textures on the same looms. In the 17th century the silk manufacture employed at Lyons 9000 to 12,000 looms. After the revocation of the edict of Nantes the number sank to 3000 or 4000; but after the Reign of Terror was past it rose again about 1801 to 12,000. At present there are about 70,000 in operation when no great commercial crisis comes to diminish production, giving employment to about 140,000 weavers. There are also a large number of persons engaged in the silk-worm hatcheries established in France. The workmen live for the most part in the Croix-Rousse quarter, but many of them inhabit the outskirts. The mean annual value of the silk goods manufactured is estimated at 375,000,000 francs (£15,000,000),—250,000,000 representing the value of the raw material and 125,000,000 the value of the labour. Including the purchase of raw materials and the sale of the manufactured goods, the silk trade gives a total turnover of 1000 million francs (£40,000,000). A special office (known as *La Condition des Soies*) determines the weight and nature of the silk. Extensive dye-works, chemical works, breweries, pork factories, engineering works, printing establishments, and hat factories represent the secondary industries of the place. A large trade is carried on in chestnuts brought from the neighbouring departments, and known as *marrons de Lyon*.

The earliest Gallic occupants of the territory at the confluence of the Rhone and the Saône were the Segusians. In 59 B.C., some Greek refugees from the banks of the Hérault, having obtained permission of the natives to establish themselves beside the Croix Rousse, called their new town by the Gallic name Lugdunum; and in 43 B.C. Munatius Plancus brought a Roman colony to Fourvières from Vienne. This settlement soon acquired importance, and was made by Agrippa the starting point of four great roads. Augustus, besides building aqueducts, temples, and a theatre, gave it a senate and made it the seat of an annual assembly of deputies from the sixty cities of Gallia Comata. Under the emperors the colony of Forum Vetus and the municipium of Lugdunum were united, receiving the *jus senatus*. The town was burnt by Nero in 59 A.D., and afterwards rebuilt by him in a much finer style; it was also adorned by Trajan, Adrian, and Antoninus. The martyrdom of Pothinus and Blandina occurred under Marcus Aurelius (177 A.D.), and in 197 a still more savage persecution of the Christians to k place under Septimius Severus, in which Irenæus, according to some authors, perished. After having been ravaged by the barbarians and abandoned by the empire, Lyons in 478 became capital of the kingdom of the Burgundians. It afterwards fell into the hands of the Franks, and suffered severely from the Saracens, but revived under Charlemagne, and after the death of Charles the Bald was made the capital of the kingdom of Provence. From 1024 it was a fief of the emperor of Germany. Subsequently the superiority over the town was a subject of dispute between the archbishops of Lyons and the counts of Forez; but the royal supremacy was finally established under Louis IX. and Philip the Handsome. The citizens were constituted into a commune ruled by freely elected consuls (1320). In the 13th century two ecclesiastical councils were held at Lyons—one in 1245, presided over by Innocent IV., at which the emperor Frederick II. was deposed; the second, the œcumenical, under the presidency of Gregory X., in 1274, at which five hundred bishops met. Pope Clement V. was crowned here in 1305, and his successor John XXII. elected in 1316. The Protestants obtained possession of the place in 1562; their acts of violence were fiercely avenged in 1572 after the St Bartholomew massacre. Under Henry III. Lyons sided with the League; but it pronounced in favour of Henry IV. In 1793 it rose against the Convention, but was compelled to yield to the army of the republic after enduring a siege of seven weeks (October 10). Terrible chastisement ensued: the name of Lyons was changed to that of Ville-affranchie; the demolition of its buildings was set about on a wholesale scale; and vast numbers of the proscribed, whom the scaffold had spared, were butchered with grape shot. The town resumed its old name after the fall of Robespierre, and the terrorists in their turn were drowned in large numbers in the Rhone. Napoleon rebuilt the Place Bellecour, reopened the churches, and made the bridge of Tilsitt over the Saône between Bellecour and the cathedral. In 1814-15 Lyons was occupied by the Austrians, under the government of Louis Philippe, and in 1870-71 there were several bloody émeutes; in 1856 a disastrous flood laid waste the Brotteaux and rendered 20,000 persons homeless. An international exhibition was held here in 1872. Among the many distinguished natives of Lyons may be mentioned Germanicus and the emperors Claudius, Marcus Aurelius, and Caracalla; Ampère the physicist; Richerand, Récamier, and Bonnet; De Jussieu the naturalist, J. B. Say the economist, Barême the mathematician, Suchet the marshal, Roland the Girondin, and Jacquard the inventor. (G. ME.)

LYONS, EDMUND LYONS, LORD (1790-1858), British admiral, was descended from a family connected with Antigua, and previously with Cork, and was born at Burton near Christchurch, Hampshire, 21st November 1790. He entered the navy at an early age, and served in the Mediterranean, and afterwards in the East Indies, where in 1810 he won promotion by distinguished bravery. He became post-captain in 1814, and in 1828 commanded the "Blonde" frigate at the blockade of Navarino. He took part with the French in the capture of the castle of Morea, receiving for his conduct the orders of St Louis of France and of the Redeemer of Greece. Shortly before his ship was paid off in 1835 he was knighted. From 1840 till the outbreak of hostilities with Russia Lyons was employed on the diplomatic service, being minister plenipotentiary to the court of Greece until 1849, then until 1851 ambassador to the Swiss cantons, whence he was transferred to a similar position at Stockholm. On the outbreak of the war with Russia he was appointed second in command of the British fleet in the Black Sea under Admiral Dundas, whom he succeeded in the chief command in 1854. As admiral of the inshore squadron he had the direction of the landing of the troops in the Crimea, which he conducted with marvellous energy and despatch. According to Kinglake, Lyons shared the "intimate counsels" of Lord Raglan in regard to the most momentous questions of the war, and throughout the Crimean campaign he toiled, with a "painful consuming passion," to guard against disaster, to clear away overpowering difficulties and obstacles, and to win the final purpose of the expedition. His actual achievements in battle were principally two—the support he rendered with his guns to the French at the Alma in attacking the left flank of the Russians, and the bold and brilliant part he took with his ship the "Agamemnon" in the first bombardment of the forts of Sebastopol; but his constant vigilance, his multifarious activity, and his suggestions and counsels were much more advantageous to the allied cause than his specific exploits. In 1855 he was created vice-admiral, and at the conclusion of the war he was, in June 1856, raised to the peerage with the title of Lord Lyons of Christchurch. He died November 23, 1858.

LYRA, NICOLAUS DE (c. 1270-1340), a well-known mediæval commentator, was a native of Lyre, near Evreux, Normandy, and was born most probably about 1270; at least he was still young when in 1291 he entered the Franciscan order at Verneuil. He afterwards studied at Paris, and became doctor of theology and a successful teacher there. In 1325 he became provincial of his order for Burgundy; and on October 23, 1340, he died at Paris.

Lyra (Lyranus) was the author of a controversial treatise against the Jews, entitled *De Messia, ejusque adventu præterito*, and of a *Tractatus de idoneo ministrante et suscipiente sancti altaris sacramentum*, but by far his most important work is the *Postillæ perpetuæ, sive brevia commentaria in universa Biblia*, first printed at Rome (5 vols. fol., 1471-72), and often subsequently. It may be said to mark the first beginnings of a school of natural exegesis; for, though recognizing the old doctrine of a fourfold sense—

"Litera gesta docet, quid credas allegoria,
Moralis quid agas, quo tendas anagogia"—

Lyra explicitly maintained and sought to give effect to the principle that the foundation of every mystical exposition must first be firmly laid by ascertaining the literal meaning. His qualities as an interpreter of Scripture included, besides comparative freedom from dogmatic prepossession, a good knowledge of Hebrew and a fair acquaintance with Greek. Luther was acquainted with his commentaries, and it is through the influence of Rashi upon Lyra that so many traces of the exegesis of that rabbi are found in Luther's writings; hence the oft-quoted saying, "Si Lyra non lyrasset, Lutherus non saltasset." See vol. xi. p. 601.

LYRE. Of all musical instruments the lyre has been the most associated with poetry, the recitations of Greeks having been accompanied by it. Yet the lyre was not of Greek origin; no root in the language has been discovered for λύρα, although the special names bestowed upon varieties of the instrument are Hellenic. We have to seek in Asia the birthplace of the genus, and to infer its introduction into Greece through Thrace or Lydia. The historic heroes and improvers of the lyre were of the Æolian or Ionian colonies, or the adjacent coast bordering on the Lydian empire, while the mythic masters, Orpheus, Musæus, and Thamyris, were Thracians. Notwithstanding the Hermes tradition of the invention of the lyre in Egypt, the Egyptians seem to have adopted it themselves from Assyria or Babylonia.

To define the lyre, it is necessary clearly to separate it from the allied harp and guitar, both, as far as we have record, instruments of as great antiquity. In its primal form the lyre differs from the harp, of which the earliest, simplest notion is found in the bow and bowstring; while the guitar (and lute) can be traced back to the typical "nefer" of the fourth Egyptian dynasty, the fretted finger-board of which, permitting the production of different notes by the shortening of the string, is as different in conception from the lyre and harp as the flute with holes to shorten the column of air is from the syrinx or Pandean pipes. The frame of a lyre consists of a hollow body or sound-chest (ἠχεῖον). From this sound-chest are raised two arms (πήχεις), which are sometimes hollow, and are bent both outward and forward. They are bound near the top by a crossbar or yoke (ζυγόν, ζύγωμα, or, from its having once been a reed, κάλαμος). Another crossbar (μάγας, ὑπολύριον), fixed on the sound-chest, forms the bridge which transmits the vibrations of the strings. The deepest note was the farthest from the player; but, as the strings did not differ much in length, more weight may have been gained for the deeper notes by thicker strings, as in the violin and similar modern instruments, or they were tuned with slacker tension. The strings were never of wire, the drawing of which was unknown to the nations of antiquity, but of gut (χορδή, whence chord). They were stretched between the yoke and bridge, or to a tailpiece below the bridge. There were two ways of tuning: one was to fasten the strings to pegs which might be turned (κόλλαβοι, κόλλοπες); the other was to change the place of the string upon the crossbar; probably both expedients were simultaneously employed. It is doubtful whether ἡ χορδοτόνος meant the tuning key or the part of the instrument where the pegs were inserted. The extensions of the arms above the yoke were known as κέρατα, horns.

The number of strings varied at different epochs, and possibly in different localities,—four, seven, and ten having been favourite numbers. They were, as already said, used without a finger-board, no Greek description or representation having ever been met with that can be construed as referring to one. Nor was a bow possible, the flat sound-board being an insuperable impediment. The plectrum, however (πλῆκτρον), was in constant use at all times. It was held in the right hand to set the upper strings in vibration (κρέκειν, κρούειν τῷ πλήκτρῳ); at other times it hung from the lyre by a ribbon. The fingers of the left hand touched the lower strings (ψάλλειν).

With Greek authors the lyre has several distinct names; but we are unable to connect these with anything like certainty to the varieties of the instrument. Chelys (χέλυς, "tortoise") may mean the smallest lyre, which, borne by one arm or supported by the knees, offered in the sound-chest a decided resemblance to that familiar animal. That there was a difference between lyre and cithara (κιθάρα) is certain, Plato and other writers separating them. Hermes and Apollo had an altar at Olympia in common because the former had invented the lyre and the latter the cithara. Perhaps the lyre and chelys on the one hand, and the cithara and phorminx on the other, were similar or nearly identical. Apollo is said to have carried a golden phorminx. But lyre has always been accepted as the generic name of the family, and understood to include all varieties. The large lyre was supported by a strong ribbon slung over the player's shoulder, passing through holes beneath the yoke in the arms of the instrument, and caught by the player's left hand, the ends hanging in a sash-like fashion. This cithara, or, it may be, phorminx (φόρμιγξ, "portable lyre"), is frequently, by the vase painters, delineated as so held,—the plectrum, attached by another ribbon, being represented, when not in use, as pendent, or as interlaced between the strings.

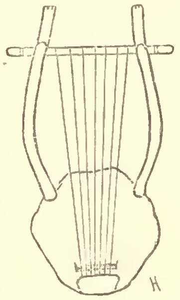


Fig. 1.—Chelys, from a vase in the British Museum, where also are fragments of such an instrument, the back of which is of shell.


Fig. 2.—Cithara or Phorminx, from a vase in the British Museum. Best period of Greek art.

Passing by the story of the discovery of the lyre from a vibrating tortoise-shell by Hermes, we will glance at the real lyres of Egypt and Semitic Asia. The Egyptian lyre is unmistakably Semitic. The oldest representation that has been discovered is in one of the tombs of Beni Hassan, the date of the painting being in the 12th dynasty, that is, shortly before the invasion of the shepherd kings. In this painting, which both Rosellini and Lepsius have reproduced, an undoubted Semite carries a seven or eight stringed lyre of fan-shaped form. The instrument has a four-cornered body and an irregular four-cornered frame above it, and the player carries it horizontally from his breast, just as a modern Nubian would his kissar. He plays as he walks, using both hands, a plectrum being in the right. This ancient lyre, dating 2000 B.C., exists to this day in a remarkable specimen preserved in the Berlin Museum (fig. 3), and is found again in form as well as in manner of holding in the Assyrian lyre of Khorsabad. During the rule of the shepherds the lyre became naturalized in Egypt, and in the 18th dynasty it is frequently depicted, and with finer grace of form. In the 19th and 20th dynasties the lyre is sometimes still more slender, or is quite unsymmetrical and very strong, the horns surmounted by heads of animals as in the Berlin one, which has horses' heads at those extremities. Prokesch copied one in the ruins of Wadi Halfa, splendid in blue and gold, with a serpent wound round it. The Egyptians always strung their lyres fan-shaped, like the modern Nubian kissar. Their paintings shew three to eight or nine strings, but the painters' accuracy may not be unimpeachable; the Berlin instrument had fifteen. The three-stringed lyre typified the three seasons of the Egyptian year—the water, the green, and the harvest; the seven, the planetary system from the moon to Saturn. The Greeks had the same notion of the harmony of the spheres.

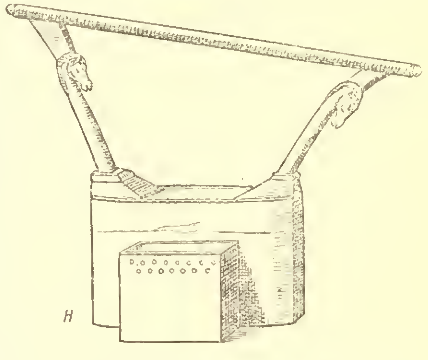
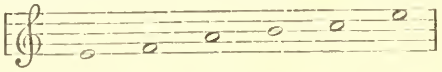


Fig. 3.—Egyptian Lyre now at Berlin. Drawn by permission of Director-General Schöne.

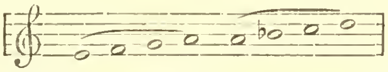
There is no evidence as to what the stringing of the Greek lyre was in the heroic age. Plutarch says that Olympus and Terpander used but three strings to accompany their recitation. As the four strings led to seven and eight by doubling the tetrachord, so the trichord is connected with the hexachord or six-stringed lyre depicted on so many archaic Greek vases. We cannot insist on the accuracy of this representation, the vase painters being so little mindful of the complete expression of details; yet we may suppose their tendency would be rather to imitate than to invent a number. It was their constant practice to represent the strings as being damped by the fingers of the left hand of the player, after having been struck by the plectrum which he held in the right hand. Before the Greek civilization had assumed its historic form, there was likely to be great freedom and independence of different localities in the matter of lyre stringing, which is corroborated by the antique use of the chromatic (half-tone) and enharmonic (quarter-tone) tunings, pointing to an early exuberance, as in language when nations are young and isolated, and perhaps also to an Asiatic bias towards refinements of intonation, from which came the χρόαι, the hues of tuning, old Greek modifications of tetrachords entirely disused in the classic period. The common scale of Olympus



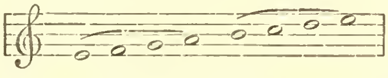
remained, a double trichord which had served as the scaffolding for the enharmonic varieties.

We may regard the Olympus scale, however, as consisting of two tetrachords, eliding one interval in each, for the tetrachord, or series of four notes, was very early adopted as the fundamental principle of Greek music, and its origin in the lyre itself appears sure. The basis of the tetrachord is the employment of the thumb and first three fingers of the left hand to twang as many strings, the little finger not being used on account of natural weakness. As a succession of three whole tones would form the disagreeable and untunable interval of a tritonus, two whole tones and a half-tone were tuned, fixing the tetrachord in the consonant interval of the perfect fourth. This succession of four notes being in the grasp of the hand was called συλλαβή, just as in language a group of letters incapable of further reduction is called syllable. In the combination of two syllables or tetrachords the modern diatonic scales resemble the Greek so-called disjunct scale, but the Greeks knew nothing of our categorical distinctions of major and minor. We might call the octave Greek scale minor, according to our descending minor form, were not the keynote in the middle the thumb note of the deeper tetrachord. The upper tetrachord, whether starting from the keynote (conjunct) or from the note above (disjunct), was of exactly the same form as the lower, the position of the semitones being identical. The semitone was a limma (λεῖμμα), rather less than the semitone of our modern equal temperament, the Greeks tuning both the whole tones in the tetrachord by the same ratio of 8 : 9, which made the major third a dissonance, or rather would have done so had they combined them in what we call harmony. In melodious sequence the Greek tetrachord is decidedly more agreeable to the ear than the corresponding series of our equal temperament. And although our scales are derived from combined tetrachords, in any system of tuning that we employ, be it just, mean-tone, or equal, they are less logical than the conjunct or disjunct systems accepted by the Greeks. But modern harmony is not compatible with them, and could not have arisen on the Greek melodic lines.

The conjunct scale of seven notes



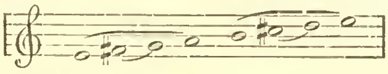
attributed to Terpander, was long the norm for stringing and tuning the lyre. When the disjunct scale



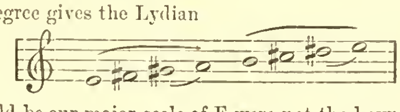
the octave scale attributed to Pythagoras, was admitted, to preserve the time-honoured seven strings one note had to be omitted; it was therefore customary to omit the C, which in Greek practice was a dissonance. The Greek names for the strings of seven and eight stringed lyres, the first note being highest in pitch and nearest the player, were as follows:—*Nete, Paranete, Paramese*; *Mese, Lichanos, Parhypate, Hypate*; or *Nete, Paranete, Trite, Paramese*; *Mese, Lichanos, Parhypate, Hypate*,—the last four from Mese to Hypate being the finger tetrachord, the others touched with the plectrum. The highest string in pitch was called the last, νεάτη; the lowest in pitch was called the highest, ὑπάτη, because it was, in theory at least, the longest string. The keynote and thumb string was μέση, middle; the next lower was λίχανος, the first finger or lick-finger string; τρίτη, the third, being in the plectrum division, was also known as ὀξεῖα, sharp, perhaps from the dissonant quality which we have referred to as the cause of its omission. The plectrum and finger tetrachords together were διαπασῶν, through all; in the disjunct scale, an octave.

In transcribing the Greek notes into our notation, the absolute pitch cannot be represented; the relative positions of the semitones are alone determined. We have already quoted the scale of Pythagoras, the Dorian or true Greek succession:—

Shifting the semitone one degree upwards in each tetrachord, we have the Phrygian



Another degree gives the Lydian



which would be our major scale of E were not the keynote A. The names imply an Asiatic origin. We will not pursue further the much debated question of Greek scales and their derivation; it will suffice here to remark that the outside notes of the tetrachords were fixed in their tuning as perfect fourths,—the inner strings being, as stated, in diatonic sequence, or when chromatic two half-tones were tuned, when enharmonic two quarter-tones, leaving respectively the wide intervals of a minor and major third, and both impure, to complete the tetrachord. (A. J. H.)

LYRE-BIRD, the name by which one of the most remarkable feathered inhabitants of Australia is commonly known, the *Menura superba* or *M. novæ-hollandiæ* of ornithologists. First discovered, January 24, 1798, on the other side of the river Nepean in New South Wales by an exploring party from Paramatta, under the leadership of one Wilson, a single example was brought into the settlement a few days after, and though called by its finders a "Pheasant"—from its long tail—the more learned of the colony seem to have regarded it as a Bird-of-Paradise.[1] A specimen having reached England in the following year, it was described by General Davies as forming a new genus of birds, in a paper read before the Linnean Society of London, November 4, 1800, and subsequently published in that Society's *Transactions* (vi. p. 207, pl. xxii.), no attempt, however, being made to fix its systematic place. Other examples were soon after received, but Latham, who considered it a Gallinaceous bird, in 1801 knew of only five having arrived. The temporary cessation of hostilities in 1802 permitted Vieillot to become acquainted with this form, though not apparently with any published notice of it, and he figured and described it in a supplement to his *Oiseaux Dorés* as a Bird of Paradise (ii. pp. 30 *sq.*, pls. 14–16), from drawings by Sydenham Edwards, sent him by Parkinson, the manager of the Leverian Museum.[2]

It would be needless here to enter at any length on the various positions which have been assigned to this singular form by different systematizers—who had to judge merely from its superficial characters. The first to describe any portion of its anatomy was Eyton, who in 1841 (*Ann. Nat. History*, vii. pp. 49–53) perceived that it was truly a member of the Order then called *Insessores*, and that it presented some points of affinity to the South American genus *Pteroptochus*;[3] but still there were many who could not take advantage of this step in the right direction. In 1867 Professor Huxley stated that he was disposed to divide his very natural assemblage the *Coracomorphæ* (essentially identical with Eyton's *Insessores*) into two groups, "one containing *Menura*, and the other all the other genera which have yet been examined" (*Proc. Zool. Soc.*, 1867, p. 472)—a still further step in advance.[4] In 1875 the present writer put forth the opinion in this work (BIRDS, vol. iii. p. 471) that *Menura* had an ally in another Australian form, *Atrichia* (see SCRUB-BIRD), which he had found to present peculiarities hitherto unsuspected, and accordingly regarded them as standing by themselves, though each constituting a distinct Family. This opinion was partially adopted in the following year by Garrod, who (*Proc. Zool. Society*, 1876, p. 518) formally placed these

[1] Collins, *Account of New South Wales*, ii. pp. 87–92 (London, 1802).

[2] Vieillot called the bird "Le Parkinson"! and hence Bechstein, who seems to have been equally ignorant of what had been published in England concerning it, in 1811 (*Kurze Uebersicht*, &c., p. 134), designated it *Parkinsonius mirabilis*!! Shaw also, prior to 1813, figured it (*Nat. Miscellany*, xiv. p. 577) under the name of *Paradisea parkinsoniana*. The name "*Menura lyra*, Shaw," was quoted by Lesson in 1831 (*Tr. d'Ornithologie*, p. 473), and has been repeated by many copyists of synonymy, but the present writer cannot find that such a name was ever applied by Shaw. Vieillot's principal figure (*ut supra*), which has a common origin with that given by Collins, has been extensively copied, in spite of its inartistic not to say inaccurate drawing. It is decidedly inferior to that of Davies (*ut supra*), the original describer and delineator.

[3] He subsequently (*Osteol. Avium*, pp. 97, 98, pl. 3, F and pl. 14) described and figured the skeleton.

[4] Owing to the imperfection of the specimen at his disposal, Professor Huxley's brief description of the bones of the head in *Menura* is not absolutely correct. A full description of them, with elaborate figures, is given by Professor Parker in the same Society's *Transactions* (ix. pp. 306–309, pl. lvi. figs. 1–5).

two genera together in his group of Abnormal Acromyodian *Oscines* under the name of *Menurinæ*; but the author sees no reason to change his mind, and herein he is corroborated by Mr Sclater, who has recently (*Ibis*, 1880, p. 345) recognized at once the alliance and distinctness of the Families *Menuridæ* and *Atrichiidæ*, forming of them a group which he calls *Pseudoscines.*

Since the appearance in 1865 of Gould's *Handbook to the Birds of Australia*, little if any fresh information has been published concerning the habits of this form, and the account therein given must be drawn upon for what here follows. Of all birds, says that author, the *Menura* is the most shy and hard to procure. He has been among the rocky and thick "brushes"—its usual haunts—hearing its loud and liquid call-notes for days together without getting sight of one. Those who wish to see it must advance only while it is occupied in singing or scratching up the earth and leaves; and to watch its actions they must keep perfectly still—though where roads have been made through the bush it may be more often observed and even approached on horseback. The best way of procuring an example seems to be by hunting it with dogs, when it will spring upon a branch to the height of 10 feet and afford an easy shot ere it has time to ascend further or escape as it does by leaps. Another method of stealing upon it is said to be practised by the natives, and is attained by the hunter fixing on his head the erected tail of a cock-bird, which alone is allowed to be seen above the brushwood. The greater part of its time is said to be passed upon the ground, and seldom are more than a pair to be found in company. One of the habits of the cock is to form small round hillocks, which he constantly visits during the day, mounting upon them and displaying his tail by erecting it over his head, drooping his wings, scratching and pecking at the soil, and uttering various cries—some his own natural notes, others an imitation of those of other animals. The wonderful tail, his most characteristic feature, only attains perfection in the bird's third or fourth year, and then not until the month of June, remaining until October, when the feathers are shed to be renewed the following season. The food consists of insects, especially beetles and myriapods, as well as snails. The nest is always placed near to or on the ground, at the base of a rock or foot of a tree, and is closely woven of fine but strong roots or other fibres, and lined with feathers, around all which is heaped a mass, in shape of an oven, of sticks, grass, moss, and leaves, so as to project over and shelter the interior structure, while an opening in the side affords entrance and exit. Only one egg is laid, and this of rather large size in proportion to the bird, of a purplish-grey colour, suffused and blotched with dark purplish-brown.[1]

Incubation is believed to begin in July or August, and the young is hatched about a month later. It is at first covered with white down, and appears to remain for some weeks in the nest. How much more is needed to be known for a biography of this peculiar and beautiful creature may be inferred by those who are aware of the diligence with which the habits of the much more easily observed birds of the northern hemisphere have been recorded, and of the many interesting points which they present. It is greatly to be hoped that so remarkable a form as the Lyre-bird, the nearly sole survivor apparently of a very ancient race of beings, will not be allowed to become extinct—its almost certain fate so far as can be judged—without many more observations of its manners being made and fuller details of them placed on record. The zoologists of Australia alone can do this, and the zoologists of other countries expect that they will.

Several examples of *Menura* have been brought alive to Europe, but none have long survived in captivity. Indeed a bird of such active habits, and requiring doubtless facilities for taking violent exercise, could not possibly be kept long in confinement until the method of menageries is vastly improved, as doubtless will be the case some day, and, we may hope, before the disappearance from the face of the earth of forms of vertebrate life most instructive to the zoologist.

Three species of *Menura* have been indicated—the old *M. superba*, the Lyre-bird proper, now known for more than eighty years, which inhabits New South Wales, the southern part of Queensland, and perhaps some parts of the colony of Victoria; *M. victoriæ*, separated from the former by Gould (*Proc. Zool. Soc.*, 1862, p. 23), and said to take its place near Melbourne; and *M. alberti*, first described by C. L. Bonaparte (*Consp. Avium*, i. p. 215) on Gould's authority, and, though discovered on the Richmond river in New South Wales, having apparently a more northern range than the other two. All those have the apparent bulk of a hen Pheasant, but are really much smaller, and their general plumage is of a sooty brown, relieved by rufous on the chin, throat, some of the wing-feathers, and the tail-coverts. The wings, consisting of twenty-one remiges, are rather short and rounded; the legs[2] and feet very strong, with long, nearly straight claws. In the immature and female the tail is somewhat long, though affording no very remarkable character, except the possession of sixteen rectrices; but in the fully-plumaged male of *M. superba* and *M. victoriæ* it is developed in the extraordinary fashion that gives the bird its common English name. The two exterior feathers (fig. 1, *a*, *b*) have the outer web very narrow, the inner very broad, and they curve at first outwards, then somewhat inwards, and near the tip outwards again, bending round forwards so as to present a lyre-like form. But this is not all; their broad inner web,

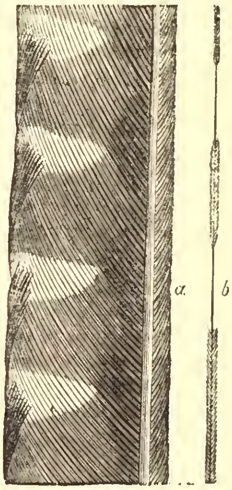


Fig. 1.

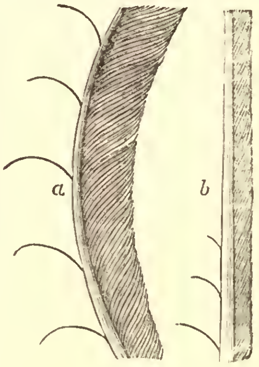


Fig. 2.

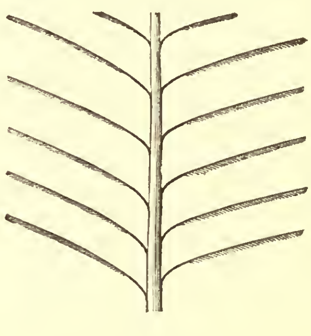


Fig. 3.

which is of a lively chestnut colour, is apparently notched at regular intervals by spaces that, according to the angle at which they are viewed, seem either black or transparent; and this effect is, on examination, found to be due to the barbs

[1] The nest and egg of *Menura alberti*, now in the British Museum, are figured in *Proc. Zool. Society*, 1853, *Aves*, pl. 53. The egg of *M. victoriæ* is represented in *Journ. für Ornithologie*, 1856, pl. ii. fig. 18, under the name of *M. superba*, but the real egg of that species does not seem to have been figured at all.

[2] The metatarsals are very remarkable in form, as already noticed by Eyton (*loc. cit.*), and their tendons strongly ossified.

at those spaces being destitute of barbules. The middle pair of feathers (fig. 2, *a*, *b*) is nearly as abnormal. These have no outer web, and the inner web very narrow; near their base they cross each other, and then diverge, bending round forwards near their tip. The remaining twelve feathers (fig. 3) except near the base are very thinly furnished with barbs, about a quarter of an inch apart, and those they possess, on their greater part, though long and flowing, bear no barbules, and hence have a hair-like appearance. The shafts of all are exceedingly strong. In the male of *M. alberti* the tail is not only not lyriform, but the exterior rectrices are shorter than the rest. (A. N.)

LYSANDER was the leading spirit of Lacedæmonian policy at the end of the Peloponnesian War. He is said by Ælian and Athenæus to have been of servile origin, and by Plutarch to have belonged to a Heraclid family. His father was named Aristoclitus or Aristocritus. He first appears in history when sent to command the fleet on the Ionian coast in 407 B.C. The story of his skilful diplomacy, of his influence with Cyrus the younger, of his naval victory at Notium, of his quarrel with his successor Callicratidas in 406, of his reappointment in 405, of the decisive victory at Ægospotami, and of the capitulation of Athens in 404, belongs to the history of Greece. After his return to Sparta his pride and vanity became boundless; he was celebrated by poets, and even worshipped in some places as a god. The restraint of life in Sparta, and the enemies whom he had there, were irksome to him, and he soon went to Asia Minor. He had established in all the Greek cities associations which maintained an oligarchical government, and his power over them was so great as to increase the jealousy felt for him at home. He was recalled to Sparta, and the machinations of the Persian satrap Pharnabazus brought him into danger. He had soon after the triumph of being sent with an army to support the oligarchy in Athens; but the king (Pausanias) was sent after him with a second army, and made terms with the restored Athenian democracy. When King Agis died in 398, Lysander worked to secure the succession for Agesilaus, but after two years he found that he had helped his most dangerous enemy. He began to concert revolutionary schemes, but had not proceeded to any overt act when he was sent with an army into Bœotia. He did not wait the arrival of Pausanias with an auxiliary army, but attacked Haliartus, and was slain in the battle, 395 B.C. He was buried on the road from Delphi to Chæronea, and a monument was erected on his tomb. It is to his credit that, after the power and opportunities he had enjoyed, he died a poor man.

LYSIAS, whose name follows those of Antiphon and Andocides on the list of the ten Attic orators, marks an important stage in the development of Greek literary prose, and is, in his own province, one of its most perfect masters. He never acquired the Athenian citizenship, but most of his years were passed at Athens; and his life has the interest of close personal association with the most critical period in the history of the Athenian democracy.

Date of birth.

His extant work belongs to the space from 403 to 380 B.C., but the date of his birth is uncertain. Dionysius of Halicarnassus, and the author of the life ascribed to Plutarch, give 459 B.C. This date was evidently obtained by reckoning back from the foundation of Thurii (444 B.C.), since there was a tradition that Lysias had gone thither at the age of fifteen. Modern critics would place his birth later,—between 444 and 436 B.C.,—because, in Plato's *Republic*, of which the scene is laid about 430 B.C., Cephalus, the father of Lysias, is among the *dramatis personæ*, and the emigration of Lysias to Thurii was said to have followed his father's death. The latter statement, however, rests only on the Plutarchic life; nor can Plato's dialogue be safely urged as a minutely accurate authority for a biographical detail. We must be content to say that, while the modern view avoids some difficulties, the higher date assigned by the ancient writers is not inconsistent with any ascertained fact, while it agrees better with the tradition that Lysias reached, or passed, the age of eighty. On the other view, all traces of his industry, previously unremitting, would cease abruptly at the age of sixty-six.

Life to 413 B.C.

Cephalus, the father of Lysias, was a native of Syracuse. On the invitation of Pericles he had settled at Athens as a "resident alien" (μέτοικος). The opening scene of Plato's *Republic* is laid at the house of his eldest son, Polemarchus, in the Peiræus. Cephalus complains that the visits of Socrates have been rare of late, and expresses the hope that he will come oftener, and without ceremony, as to intimate friends. The tone of the picture warrants the inference that the Sicilian family were well known to Plato, and that their houses must often have been hospitable to such gatherings as the *Republic* supposes. Thus we have an indirect, but very interesting, confirmation of the phrase used by Dionysius in regard to Lysias—"he grew up in the society of the most distinguished Athenians."

At the age of fifteen—when Cephalus, according to the Plutarchic life, was now dead—Lysias removed from Athens to Thurii, the Athenian colony newly planted on the Tarentine Gulf, near the site of the ancient Sybaris. There the boy may have seen the historian Herodotus,—another of Thurii's early residents,—now a man in middle life; and it pleases the imagination to think that, in their new Italian home, a friendship may have grown up between these two, neither of them an Athenian by birth, yet alike in a simple grace which Athens loved, and alike also in the love which they bore to Athens. At Thurii Lysias is said to have commenced his studies in rhetoric,—doubtless under a master of the Sicilian school,—possibly, as tradition said, under Tisias, the pupil of Corax, whose name is associated with the first attempt to formulate rhetoric as an art. In 413 B.C. the Athenian armament in Sicily suffered that crushing disaster which at the moment seemed to imperil the existence of Athens itself. The desire to link famous names is curiously illustrated by the ancient ascription to Lysias of a rhetorical exercise purporting to be a speech in which the captive general Nicias appealed for mercy to the Sicilians. The terrible blow to Athens quickened the energies of an anti-Athenian faction at Thurii. Lysias and his elder brother Polemarchus, with three hundred other persons, were "accused of Atticizing" (Ἀττικισμὸν ἐγκληθεῖσι),—a charge which, under the circumstances, implies an honourable loyalty. They were driven from Thurii.

412-404.

Lysias and Polemarchus now settled at Athens (412 B.C.). They were rich men, having inherited property from their father, Cephalus; and Lysias claims that, though merely resident aliens, they discharged public services with a liberality which shamed many of those who enjoyed the franchise (οὐχ ὁμοίως μετοικοῦντας ὥσπερ αὐτοὶ ἐπολιτεύοντο, *In Eratosth.*, § 20). The fact that they owned house property shows that they were classed as ἰσοτελεῖς, *i.e.*, foreigners who paid only the same tax as citizens, being exempt from the special tax (μετοίκιον) on resident aliens. Polemarchus occupied a house in Athens itself, Lysias another in the Peiræus, near which was their shield manufactory, employing a hundred and twenty skilled slaves. This life of comparative peace and prosperity was broken up by the defeat of Athens at Ægospotami (405 B.C.). In the next spring Athens surrendered to Lysander. The Thirty Tyrants were established at Athens under the protection of a Spartan garrison. One of their earliest measures was an attack upon the resident aliens, who were represented as disaffected to the new government. As foreign residents successful in commerce, the Attic *metoikoi* were exposed at such a time to perils like those of the Jews in a mediæval city, or in modern Russia. Lysias and Polemarchus were on a list of ten singled out to be the first victims. Polemarchus was arrested, and received "the usual message" (τὸ εἰθισμένον παράγγελμα, *In Eratosth.*, § 17) "to drink the hemlock." Lysias had a narrow escape, with the help of a large bribe and a lucky accident. He slipped by a back-door out of the house in which he was a prisoner, and took boat to Megara.

403-380. After the expulsion of the Thirty Tyrants, the democracy was formally restored in the autumn of 403 B.C. Lysias appears to have rendered valuable services to the exiles during the reign of the tyrants, both by his own liberality and by procuring aid from other quarters. Thrasybulus now proposed that these services should be recognized by the bestowal of the citizenship. The proposal happened to be informal in one particular. The senate of five hundred had not yet been reconstituted, and hence the measure could not be introduced to the ecclesia by the requisite "preliminary resolution" (προβούλευμα) of the senate. On this ground it was successfully opposed; and Lysias missed the reward which he had so well earned. That passage of his Ὀλυμπιακός (§ 3) in which he claims to give advice as a good citizen seems to breathe the feeling that, if he was still but an alien at Athens, he was at least a true πολίτης of Greece.

The last chapter of his life now opens. He is no longer the wealthy merchant, superintending his shield manufactory in the Peiræus. The pillage by the tyrants, and his own generosity to the Athenian exiles, had probably left him poor. He now appears as a hard-working member of a new profession,—that of writing speeches to be delivered in the law-courts. The thirty-four compositions extant under his name are but a small fraction of those which the ancient world possessed. From 403 to about 380 B.C. his industry must have been great and incessant. The notices of his personal life in these years are scanty. In 403 he came forward as the accuser of Eratosthenes, one of the Thirty Tyrants, and delivered the splendid oration which we possess. This was his only direct contact with Athenian politics. The story that Lysias wrote a defence for Socrates, which the latter declined to use, probably arose from a confusion. Several years after the death of Socrates the sophist Polycrates composed a declamation against him; and to this Lysias replied with a defence of the philosopher. A more authentic tradition represents Lysias as having spoken his own "Olympiacus" at the Olympic festival of 388 B.C. The occasion was one of peculiar interest. Dionysius I., tyrant of Syracuse, had sent to the festival a magnificent embassy. Tents embroidered with gold were pitched within the sacred enclosure; and the wealth of Dionysius was vividly brought before the minds of the Panhellenic concourse by the number of chariots which he had entered for the most costly and brilliant of the Olympic contests. This was the moment at which Lysias lifted up his voice to denounce Dionysius as, next to Artaxerxes, the worst enemy of Hellas, and to impress upon the assembled Greeks that one of their foremost duties was to deliver Sicily from a hateful oppression. The latest work of Lysias which we can date (a fragment of a speech "For Pherenicus") belongs to 381 or 380 B.C. He probably died in or soon after 380 B.C.

[Char]ar-[act]er of man [and] of [his] work. The qualities of the man are expressed in his work; indeed, it is through this, rather than through the recorded facts of his biography, that he becomes a living person to us. It is a kindly and genial nature which we see reflected there,—warm in friendship, loyal to country,—with a keen perception of character, and a fine, though strictly controlled, sense of humour. The literary tact which is so remarkable in the extant speeches is that of a singularly flexible intelligence, always obedient to an instinct of gracefulness. Among the earlier artists of Greek prose Lysias owes his distinctive place to the power of concealing his art. The clients of the professional "speech-writer," like those of the modern advocate, might be of all sorts and conditions. The modern advocate, however, speaks in his own person. The Athenian "logographer" merely wrote the speech which his client delivered. It was obviously desirable that such a speech should be suitable to the age, station, and circumstances of the person into whose mouth it was put. Lysias was the first disciple of Greek rhetoric who succeeded in making this adaptation really artistic. He aimed, not merely at impressive effect in eloquence, pathos, or argument, but at dramatic propriety. Hence it was absolutely essential for him to abandon the stiff and monotonous splendour of the earlier and cruder rhetoric. He could not achieve his purpose unless he brought his art into harmony with the ordinary idiom of everyday life. His client must appear to be speaking as the citizen, who was not a professed rhetorician, might conceivably speak. Lysias achieved this reconciliation with a skill which can be best appreciated if we turn from the easy flow of his graceful language to the majestic emphasis of his predecessor Antiphon, or to the self-revealing art of his successor Isæus. Translated into terms of ancient criticism, the achievement of Lysias is described by saying that he became the model of the "plain style" (ἰσχνὸς χαρακτήρ, ἰσχνή, λιτή, ἀφελὴς λέξις; *genus tenue* or *subtile*). From the latter part of the 4th century B.C. onwards, Greek, and then Roman, critics distinguished three styles of rhetorical composition—the "grand" (or "elaborate"), the "plain," and the "middle." These epithets were relative to the language of daily life,—the "plain" being nearest to this, and the "grand" furthest from it. Greek rhetoric began in the "grand" style; then Lysias set an exquisite pattern of the "plain"; and Demosthenes might be considered as having effected an almost ideal compromise. We moderns perhaps cannot fully seize that nameless and undefinable grace (χάρις) of Lysias which the Greek critic of the Augustan age indicates in such striking words:—

"When I am puzzled about one of the speeches ascribed to him," says Dionysius, "and when it is hard for me to find the truth by other marks, I have recourse to this excellence, as to the last piece on the board. Then, if the graces of speech seem to me to make the writing fair, I count it to be of the soul of Lysias; and I care not to probe the question further. But if the stamp of the language has no winningness, no loveliness, I am chagrined, and suspect that, after all, the speech is not by Lysias; and I do no more violence to my instinct (οὐκέτι βιάζομαι τὴν ἄλογον αἴσθησιν), even though in all else the speech seems to me clever and well finished,—believing that to write well, in special styles other than this, is given to many men, but that to write winningly, gracefully, with loveliness, is the gift of Lysias" (Dionys., *De Lys.*, ii.).

The more salient traits of the Lysian style can be Style. recognized by all. The vocabulary is pure and simple. Most of the rhetorical "figures" are sparingly used,—except such as consist in the parallelism or opposition of clauses. The taste of the day,—not yet emancipated from the influence of the Sicilian rhetoric,—probably demanded a large use of antithesis as an essential condition of impressive speaking. Lysias excels in vivid description; he has also a happy knack of marking the speaker's character by light touches. The structure of his sentences varies a good deal according to the dignity of the subject. He has equal command over the "periodic" style (κατεστραμμένη λέξις) and the non-periodic or "continuous" (εἰρομένη, διαλελυμένη)—using now one now the other, or blending them, according to circumstances. His disposition of his subject-matter is always simple. The speech has usually four parts,—introduction (προοίμιον), narrative of facts (διήγησις), proofs (πίστεις), which may be either external, as from witnesses, or internal, derived from argument on the facts, and, lastly, conclusion (ἐπίλογος). It is in the introduction and the narrative that Lysias is seen at his best. In his greatest extant speech—that "Against Eratosthenes"—and also in the fragmentary "Olympiacus," he has pathos and fire; but these were not characteristic qualities of his work. In Cicero's judgment, Demosthenes was peculiarly distinguished by force (*vis*), Æschines by resonance (*sonitus*), Hyperides by acuteness (*acumen*), Isocrates by sweetness (*suavitas*); the distinction which he assigns to Lysias is *subtilitas*, an Attic refinement,—which, as he elsewhere says, is often joined to an admirable vigour (*lacerti*), (Cic., *De Or.*, iii. 7, § 28; *Brutus*, § 64). The judgment is interesting as showing how a Roman critic of unquestionable competence recognized the peculiar place of Lysias in the development of Greek oratory. Nor was it oratory alone to which Lysias rendered service; his work had an important effect on all subsequent Greek prose, by showing how perfect elegance could be joined to plainness. Here, in his artistic use of familiar idiom, he might fairly be called the Euripides of Attic prose. And his style has an additional charm for modern readers, because it is employed in describing scenes from the everyday life of Athens.[1]

orks. Thirty-four speeches (of which three are fragmentary) have come down under the name of Lysias; no fewer than one hundred and twenty-seven more, now lost, are known from smaller fragments or from titles. In the Augustan age four hundred and twenty-five works bore his name, of which more than two hundred were allowed as genuine by the critics. The enormous number of ascriptions indicates that Lysias was reputed to have been a fertile writer. Our thirty-four works may be classified as follows:—

A. Epideictic.—1. Olympiacus, xxxiii., 388 B.C.; 2. Epitaphius, ii. (purporting to have been spoken during the Corinthian War; certainly spurious), perhaps composed about 380–340 B.C.

B. Deliberative.—Plea for the Constitution, xxxiv., 403 B.C.

C. Forensic, in Public Causes.—I. *Relating to Offences directly against the State* (γραφαὶ δημοσίων ἀδικημάτων); *such as treason, malversation in office, embezzlement of public moneys.* 1. For Polystratus, xx., 407 B.C.; 2. Defence on a Charge of Taking Bribes, xxi., 402 B.C.; 3. Against Ergocles, xxviii., 389 B.C.; 4. Against Epicrates, xxvii., 389 B.C.; 5. Against Nicomachus, xxx., 399 B.C.; 6. Against the Corndealers, xxii., 386 B.C. (?) II. *Cause relating to Unconstitutional Procedure* (γραφὴ παρανόμων). On the Property of the Brother of Nicias, xviii., 395 B.C. III. *Causes relating to Claims for Money withheld from the State* (ἀπογραφαί). 1. For the Soldier, ix. (probably not by Lysias, but by an imitator, writing for a real cause), 394 B.C. (?); 2. On the Property of Aristophanes, xix., 387 B.C.; 3. Against Philocrates, xxix., 389 B.C. IV. *Causes relating to a Scrutiny* (δοκιμασία); *especially the Scrutiny, by the Senate, of Officials Designate.* 1. Against Evandrus, xxvi., 382 B.C.; 2. For Mantitheus, xvi., 392 B.C.; 3. Against Philon, xxxi., between 404 and 395 B.C.; 4. Defence on a Charge of Seeking to Abolish the Democracy, xxv., 401 B.C.; 5. For the Invalid, xxiv., 402 B.C. (?) V. *Causes relating to Military Offences* (γραφαὶ λιποταξίου, ἀστρατείας). 1. Against Alcibiades, I. and II. (xiv., xv.), 395 B.C. VI. *Causes relating to Murder or Intent to Murder* (γραφαὶ φόνου, τραύματος ἐκ προνοίας). 1. Against Eratosthenes, xii., 403 B.C.; 2. Against Agoratus, xiii., 399 B.C.; 3. On the Murder of Eratosthenes, i. (date uncertain); 4. Against Simon, iii., 393 B.C.; 5. On Wounding with Intent, iv. (date uncertain). VI. *Causes relating to Impiety* (γραφαὶ ἀσεβείας). 1. Against Andocides, vi. (certainly spurious, but perhaps contemporary); 2. For Callias, v. (date uncertain); 3. On the Sacred Olive, vii., not before 395 B.C.

D. Forensic, in Private Causes.—I. *Action for Libel* (δίκη κακηγορίας). Against Theomnestus, x., 384–3 B.C. (the so-called second speech, xi., is merely an epitome of the first). II. *Action by a Ward against a Guardian* (δίκη ἐπιτροπῆς). Against Diogeiton, xxxii., 400 B.C. III. *Trial of a Claim to Property* (διαδικασία). On the Property of Eraton, xvii., 397 B.C. IV. *Answer to a Special Plea* (πρὸς παραγραφήν). Against Pancleon, xxiii. (date uncertain).

E. Miscellaneous.—1. To his Companions, a Complaint of Slanders, viii. (certainly spurious); 2. The ἐρωτικός in Plato's *Phædrus*, pp. 230 E–234. This has generally been regarded as Plato's own work; but the certainty of this conclusion will be doubted by those who observe (1) the elaborate preparations made in the dialogue for a recital of the ἐρωτικός which shall be *verbally exact*, and (2) the closeness of the criticism made upon it. If the satirist were merely analysing his own composition, such criticism would have little point. Lysias is the earliest writer who is known to have composed ἐρωτικοί; it is as representing both rhetoric and a false ἔρως that he is the object of attack in the *Phædrus*.

F. Fragments.—Three hundred and fifty-five of these are collected by Sauppe, *Oratores Attici*, ii. 170–216. Two hundred and fifty-two of them represent one hundred and twenty-seven speeches of known title; and of six the fragments are comparatively large. Of these, the fragmentary speech "For Pherenicus" belongs to 381 or 380 B.C., and is thus the latest known work of Lysias.

In literary and historical interest, the first place among the extant speeches of Lysias belongs to that "Against Eratosthenes" (403 B.C.), one of the Thirty Tyrants, whom Lysias arraigns as the murderer of his brother Polemarchus. The speech is an eloquent and vivid picture of the reign of terror which the thirty established at Athens; the concluding appeal, to both parties among the citizens, is especially powerful. Next in importance is the speech "Against Agoratus" (399 B.C.), one of our chief authorities for the internal history of Athens during the months which immediately followed the defeat at Ægospotami. The "Olympiacus" (388 B.C.) is a brilliant fragment, expressing the spirit of the festival at Olympia, and exhorting Greeks to unite against their common foes. The "Plea for the Constitution" (403 B.C.) is interesting for the manner in which it argues that the wellbeing of Athens—now stripped of empire—is bound up with the maintenance of democratic principles. The speech "For Mantitheus" (392 B.C.) is a graceful and animated portrait of a young Athenian ἱππεύς, making a spirited defence of his honour against the charge of disloyalty. The defence "For the Invalid" is a humorous character-sketch. The speech "Against Pancleon" illustrates the intimate relations between Athens and Platæa, while it gives us some picturesque glimpses of Athenian town life. The defence of the person who had been charged with destroying a *moria*, or sacred olive, places us amidst the country life of Attica. And the speech "Against Theomnestus" deserves attention for its curious evidence of the way in which the ordinary vocabulary of Athens had changed between 600 and 400 B.C.

All MSS. of Lysias yet collated have been derived, as H. Sauppe first showed, from the Codex Palatinus X (Heidelberg). The next most valuable MS. is the Laurentianus C (15th century), which I. Bekker chiefly followed. Speaking generally, we may say that these two MSS. are the only two which carry much weight where the text is seriously corrupt. In *Oratt.* i.–ix. Bekker occasionally consulted eleven other MSS., most of which contain only these nine speeches: viz., Marciani F, G, I, K (Venice); Laurentiani D, E (Florence); Vaticani M, N; Parisini U, V; Urbinas O. Bibliography.

Lysias in *Oratores Attici*, ed. I. Bekker, 1828; ed. G. S. Dobson, with variorum notes, 1828; ed. J. G. Baiter and Hermann Sauppe, 1850. In Teubner's series, ed. Carl Scheibe, 1st ed. 1852, 2d ed. (based on C. L. Kayser's collation of X), 1876. Text, ed. Cobet, 1863. Selections from Lysias and Æschines, ed. Bremi, 1826. Selections from Lysias, ed. Rauchenstein, 1864; ed. Frohberger, 1868; ed. Jebb, in *Selections from the Attic Orators*, 1880. German translation, with notes, by Baur (1869); and of selections, by Westermann (1869). (R. C. J.)

LYSIMACHUS, son of Agathocles, a Thessalian in the service of Philip of Macedon, was born about 361 B.C. During Alexander's campaigns he was one of his immediate bodyguard; he distinguished himself in India, and was appointed a trierarch when Alexander constructed his fleet on the Hydaspes. After the death of Alexander, Lysimachus was appointed to the government of Thrace and the district about the Chersonese. For a long time the Odrysians under their king Seuthes caused him so much trouble that he could take very little part in the struggles of the rival satraps; but in 316 he joined the alliance which Cassander, Ptolemy, and Seleucus made against Antigonus. In 309 he founded Lysimachia in a commanding situation on the neck connecting the Chersonese with the mainland. He followed the example of Antigonus in taking the title of king. When in 302 the second alliance between Cassander, Ptolemy, and Seleucus was made, Lysimachus, reinforced by troops from Cassander, entered Asia Minor, where he met with little resistance. On the approach of Antigonus he retired into winter quarters near Heraclea, marrying its widowed queen Amastris, a Persian princess. Seleucus joined him in 301, and the decisive battle was fought in the plain of Ipsus; Antigonus was slain, and his dominions divided among the victors, Lysimachus receiving the greater part of Asia Minor. Feeling that Seleucus was becoming dangerously great, he now allied himself with Ptolemy, marrying his

[1] For a detailed account of the life, the style, and the works of Lysias, the reader is referred to Jebb, *The Attic Orators from Antiphon to Isæus*, vol. i. pp. 142–316.

daughter Arsinoe. Amastris returned to Heraclea. During the absence of Antigonus's son Demetrius in Greece, Lysimachus seized his towns in Asia Minor and rebuilt Ephesus, calling it Arsinoe. He tried to carry his power beyond the Danube, but was defeated and taken prisoner by the Getæ, who, however, set him free on amicable terms. After Demetrius had entered Macedon to help Alexander against his brother Antipater, and by murdering the former had gained possession of the whole country, he invaded Thrace, but had to retire in consequence of a rising in Bœotia, and an attack from Pyrrhus of Epirus. In 287 Lysimachus and Pyrrhus invaded Macedon. Demetrius marched against Pyrrhus, thinking the Macedonians would not fight against Lysimachus, one of Alexander's companions in arms; but his army went over to Pyrrhus, and he was obliged to fly. Lysimachus claimed a share of the kingdom and received it. Demetrius, crossing into Asia Minor, seized Caria and Lydia, but Agathocles, the son of Lysimachus by an Odrysian princess, was sent against him, and forced him to retreat into the territory of Seleucus, who obliged him to surrender. Lysimachus attacked Pyrrhus and Demetrius's son Antigonus, now his ally, and forced Pyrrhus to give up part of Thessaly and the whole of Macedon. Amastris had been murdered by her two sons, and Lysimachus resolved to avenge her; he got them into his hands on pretence of friendship and put them to death. On his return Arsinoe asked the gift of Heraclea, and he granted her request, though he had promised to free the city. In 284 Arsinoe, desirous of gaining the succession for her sons in preference to Agathocles, intrigued against him with the help of her brother Ptolemy Ceraunus; they accused him of conspiring with Seleucus to seize the throne, and he was put to death. To remove the disquietude of the Egyptian court, Agathocles being the husband of Ptolemy's daughter Lysandra, Lysimachus married his daughter Arsinoe to the young Ptolemy Philadelphus. The widow of Agathocles fled to Seleucus, and war between the latter and Lysimachus soon followed. In 281 the decisive battle took place at the plain of Corus, the exact situation of which is doubtful; Lysimachus was killed; after some days his body was found on the field watched by a faithful dog.

Lysimachus was a man of distinguished bravery and great personal strength; on one occasion he had killed a lion single-handed, though at the cost of fearful wounds. He did not rise to political importance till after the battle of Ipsus. Tenacious and insatiate, he framed schemes of aggrandisement till his death, and in pursuit of the schemes his craft suggested he was ready to sacrifice even his own family.

LYSIPPUS, a Greek sculptor whose professional activity falls between the years 372 and 316 B.C. In addition to the sketch with accompanying illustrations of his style given under ARCHÆOLOGY (vol. ii. p. 361, figs. 9 and 11), it may here be stated that the head of Alexander the Great (fig. 11 just referred to) is now admitted to be the best existing representation of the style of Lysippus in portrait sculpture. When we read of successful portraits by him of Socrates and Æsop, as well as of Alexander, we are driven to believe that one of the forces of which he was conscious within himself was that of seizing the spiritual expression and making it illumine faces and forms which under other conditions would be more or less repulsive. This in fact is confirmed by the head of Alexander in the British Museum (fig. 11 *supra*). But with the possession of this force it is difficult to reconcile the tradition of his having taken as his model the Doryphorus of Polycletus, the style of which may be seen in the bronze statuette fig. 6 in the article ARCHÆOLOGY, and, to a less extent, in fig. 7 of the same article. There everything turns on the refinements of physical form. It is admitted that Lysippus introduced great changes in the accepted rules for the proportions of the human figure, and from a number of sculptures traceable to his time, or shortly after his time, it is not only obvious but strikingly in contrast with earlier works that the legs are made long and massive while the body is proportionately shortened, though still retaining a very powerful rendering of the forms. Among the best examples of this are two bronze statuettes of Neptune and Jupiter in the British Museum found at Paramythia in Epirus, or, less satisfactory, the larger bronze of Hercules from Byblus, also in the British Museum. In these cases the limbs and various parts of the figure are studied with extreme skill worthy of the best time. Yet the combined effect is such as to do away with the impassive beauty which is ascribed to Polycletus, and to replace it with a beauty of expression so far as was consistent with powerful physical form. One of his works famed in antiquity was a bronze statuette of Hercules, called Epitrapezius, because, as the story goes, Alexander the Great carried it with him to be placed always on his table. A copy of this, in stone, enlarged somewhat from the original, was obtained by the British Museum from Babylonia in 1881. It is signed with the name of an artist, Diogenes, apparently otherwise unknown, and it bears clearly the evidence of having been copied from a work in bronze. But except in the face, which is carefully executed ("argutiæ operum custoditæ in minimis quoque rebus" is said of Lysippus by Pliny, *Nat. Hist.*, xxxiv. 65), the sculpture is poor and could not be quoted as illustrating any particular style of art, though not inconsistent with the characteristics of Lysippus. With reference to the marble statue of Alexander the Great in Munich, standing with one foot raised on a helmet, it is clear that this affected attitude, which occurs in several other existing statues, such as the so-called Jason in Lansdowne House, cannot fairly be traced to the invention of Lysippus, since it is to be found twice on the frieze of the Parthenon. At the same time the merit may belong to him, as has recently been claimed, of having first applied this attitude in producing a new type of the god Neptune for his temple on the isthmus of Corinth. It was a bolder step to apply this attitude to a draped female figure as in the existing statues of the Muse Melpomene standing with one foot raised on a rock, and if this was really introduced into art by Lysippus it would confirm to some extent his reputation for novelties of representation. But at present we cannot do more than say that he is known to have made a group of the Muses for the town of Megara, and that several statues still exist representing a Muse in an attitude corresponding with that of the Alexander in Munich, which is reasonably inferred to be a copy from a work of Lysippus. If it could be proved that in these cases Lysippus had worked upon Athenian types, we should then understand how it happens that in some respects he was in ancient times classed with the Athenian Praxiteles (Quintilian, xii. 10, 9, "ad veritatem Lysippum ac Praxitelem accessisse optime affirmant"), and is still compared with him so far as the remaining works of both, or copies therefrom, enable a comparison to be made.

See Kekulé, *Ueber den Kopf des Praxitelischen Hermes*, Stuttgart, 1881; Lange, *Das Motiv des aufgestützten Fusses*, Leipsic, 1879.

LYTE, HENRY FRANCIS (1793–1847), a well-known hymn-writer, was born at Kelso, June 1, 1793, received his early education in Ireland, and entered Trinity College, Dublin, in 1812, becoming a scholar of that college in the following year. Having entered deacon's orders in 1815, he for some time held a curacy near Wexford. He did not long remain in Ireland, however, chiefly because of infirm health; and, coming to England, after several changes he finally, in 1823, settled in the parish of Brixham, where he laboured until fatal illness interrupted his work. In 1844 his health, never robust, gave way; and he died at Nice on the 20th November, 1847.

Lyte's first work was *Tales in Verse illustrative of several of the Petitions in the Lord's Prayer*, which was completed during a period of rest at Lymington, but was not published till the year 1826; it drew a word of warm commendation from a competent critic in the *Noctes Ambrosianæ*. He next published a volume of *Poems, chiefly Religious*, in 1833, and in the following year a little collection of psalms and hymns entitled *The Spirit of the Psalms*. These productions were drawn from various sources, but many were his own; and the idea of the book was to express, in language specially accordant with Christian experience, the leading thoughts contained in the Psalter. Probably one of the best productions of Lyte's pen was a finely appreciative memoir of Henry Vaughan, the "Silurist," which he prefixed to an edition of his works. After his death, a volume of *Remains* with a memoir was published, and the poems contained in this, with those in *Poems, chiefly Religious*, were afterwards issued in one volume. In the region of pure poetry Lyte cannot be said to have taken any special rank; refinement and pathos, rather than great imaginative power, were the chief marks of his work. As a divine he was evangelical in doctrine, but his ecclesiastical sympathies were with the Oxford school; as a preacher he was simple, earnest, and graceful in style; but his chief claim to remembrance lies in the beauty and spiritual elevation of his hymns, some of which may be said to have become classical. The best known are "Abide with me! fast falls the eventide"; "Jesus, I my cross have taken"; "Praise, my soul, the King of Heaven"; and "Pleasant are thy courts above."

LYTTELTON, George, Lord (1709–1773), statesman and man of letters, born at Hagley, Worcestershire, in 1709, was a descendant of the great Thomas de Littleton (*q.v.*), and the eldest son of Sir Thomas Lyttelton, Bart., who at the Revolution of 1688 and during the following reign was one of the ablest Whig debaters of the House of Commons. Lyttelton was educated at Eton and Oxford, and in 1728 set out on the grand tour, spending considerable periods at Paris and Rome. On his return to England he sat for Okehampton, Devonshire, beginning public life in the same year with Pitt; and from 1744 to 1754 he held the office of a lord commissioner of the treasury. In 1755 he succeeded Legge as chancellor of the exchequer, but in the following year he quitted office, on which occasion he was raised to the peerage as Lord Lyttelton, baron of Frankley, in the county of Worcester. In the political crisis of 1765, before the formation of the Rockingham administration, it was at one time suggested that he might be placed at the head of the treasury, but he firmly declined to take part in any such scheme. The closing years of his life were devoted chiefly to literary pursuits. He died on August 22, 1773.

Lyttelton's earliest publication (1735), *Letters from a Persian in England to his Friend at Ispahan*, appeared anonymously. Much greater celebrity was achieved by his *Observations on the Conversion and Apostleship of St Paul*, also anonymous, published in 1747. It takes the form of a letter to Gilbert West, and is designed to show that St Paul's conversion is of itself a sufficient demonstration of the divine character of Christianity. The drift of the argument is that it is equally inconceivable that the apostle could have been the victim or the originator of a cheat, and that therefore he must have been divinely inspired. It is interesting to know that Dr Johnson regarded the work as one "to which infidelity has never been able to fabricate a specious answer." Lord Lyttelton's *Dialogues of the Dead*, a creditable performance, though hardly rivalling either Lucian or Landor, appeared in 1760. His *History of Henry II.* (1764–67), the fruit of twenty years' labour, is not now cited as an authority, but is painstaking and fair. Lyttelton was also a writer of verse; his *Monody* on his wife's death has been praised by Gray for its elegiac tenderness, and his *Prologue* to the *Coriolanus* of his friend Thomson shows genuine feeling. He was also the author of the well-known stanza in the *Castle of Indolence*, in which the poet himself is described. A complete collection of the *Works* of Lord Lyttelton was published after his death by his nephew, G. E. Ayscough. See *Memoirs and Correspondence of Lord Lyttelton*, 1734–1773 (2 vols., 1845).

LYTTON, Edward George Earle Lytton Bulwer Lytton, Baron (1805–1873), novelist, dramatist, poet, politician, miscellaneous essayist, the most versatile writer and one of the most active and widely discursive theorizers of his generation, was born in May 1805, the youngest of the three sons of General Bulwer, of Heydon Hall and Wood Dalling, Norfolk. He was a few months younger than Benjamin Disraeli; the two lives acted not a little one on the other, and offer many curious points of likeness and contrast. Bulwer's father died when he was two years old; the care of the boy devolved on his mother, one of the Lyttons of Knebworth, Hertfordshire, whose name he afterwards assumed. To this devoted and accomplished mother he always expressed the warmest gratitude for his early training. He was not sent to a public school; he was educated privately.

In his novels and essays he often discusses the advantages and disadvantages of public schools. One thing is tolerably certain—that if he had been sent to a public school he would not have published at the age of fifteen a volume of poems (*Ismael, an Oriental Tale, with other Poems*, 1820). Generous sentiment and eager love of fame are more conspicuous in these juvenile productions than metrical faculty. One of the poems dwells warmly on the ancient glories of the house of Lytton; the volume as a whole is dedicated to "the British public—that generous public who have always been the fosterers of industry or genius, who have always looked forward from the imperfections of youth to the fruits of maturity." The youthful poet criticizes Byron from the point of view of a respectable household; but, though he seems to have been taught to make Pope, Gray, and Collins his models, the Byronic influence is very apparent both in phrase and in sentiment. In the local colouring of the "Oriental Tale" he gives promise, afterwards amply fulfilled, of painstaking study of his materials; and "Geraldine, or the Fatal Boon," gives a good foretaste of his fertility in the invention of romantic incident.

At Cambridge, in 1825, Bulwer won the chancellor's medal with a poem on "Sculpture." In 1826 he printed for private circulation *Weeds and Wild Flowers*. In 1827 he published *O'Neill, or the Rebel*, a romance, in heroic couplets, of patriotic struggle in Ireland, dedicated to Lady Blessington. These juvenilia, and also a metrical satire, *The Siamese Twins*, issued in 1831, he afterwards ignored, describing *The New Timon* as his first publication in verse, with the exception of his dramas and translations from Schiller.

Bulwer's first romance, *Falkland*, published anonymously in 1827, was in the vein of fantastic German romance popular at the beginning of the century, and did not bring him the fame that he coveted so ardently. It was otherwise with *Pelham*, published in the following year. In this he went with the native stream of fiction, and at once made himself felt as a power. For two or three years before he wrote *Pelham*, the books of the season had been novels of remarkable freshness and brilliancy dealing with fashionable life—Plumer Ward's now forgotten but then much-talked-of *Tremaine*, Theodore Hook's *Sayings and Doings*, Lister's *Granby*, Disraeli's *Vivian Grey*. With these brilliant celebrities Bulwer, always a chivalrous emulator of whatever was famous, entered into direct competition, and at once became at least their equal in popular favour. If we compare this his first novel with any of his last productions, he strikes us as having attained at a bound to the full measure of his powers. That he wrote *Pelham* at twenty-two is a much more remarkable fact than that he wrote ballads at five. The plot is not perhaps so closely woven together as in *The Parisians*, but the variety of character introduced from high life, low life, and middle life is quite as great. He had evidently been fascinated by *Wilhelm Meister*, and the central purpose of his story is to run the hero through an apprenticeship like Wilhelm's. All kinds of human beings and all their works are interesting to Pelham, the man of fashion, the bustling statesman, the selfish epicure, the retiring scholar, the reckless rogue and vagabond, the melodramatic Byronic man of mystery; and his adventures are so contrived as to bring him in contact with many different types. The novel might have been called *The Londoners*; most of the criticisms of life and books in *England and the English*, published in 1833, may be found in *Pelham*, delivered through the mouths of various characters. These characters are great talkers; no subject, from a rare dish or a nicety of costume to a painting or a philosophical treatise, is strange to them. And, curiously enough, the judgments of the youth of twenty-two are as mature, as large, catholic, generous, widely sympathetic, as those of the sage of sixty-six, and his knowledge of men and books hardly less extensive. *Pelham* displayed—in the literal sense of the word—extraordinary vivacity of intellect and range of interest. The author was yet to prove that with his wonderful powers of reading, observing, and reflecting was combined a faculty rarely found in union with such gifts, untiring rapidity of production. In the preface to his juvenile "Ismael," he speaks of a habit of his never to leave anything unfinished, and during his long life he began and finished many works in many different veins. *Pelham* was followed in quick succession by *The Disowned* (1828), *Devereux* (1829), *Paul Clifford* (1830), *Eugene Aram* and *Godolphin* (1833). Bulwer was deeply impressed with German theories of art; all these novels were novels with a purpose, moral purpose, psychological purpose, historical purpose. To embody the leading features of a period, of a phase of civilization, to trace the influence of circumstance on character, to show how the criminal may be reformed by the development of his better nature, and how men of fine nature may be led stage by stage into crime, to explain the secrets of success and failure in life—these, apart from the purely dramatic object of exhibiting inward struggles between the first conceptions of desires and their fulfilment, and between triumph and retribution, were his avowed aims as a novelist. He did not leave his purposes to the interpreter; he was a critic as well as a creator, and he criticized his own works frankly, and laboured to admit other critics to a fair point of view. It was perhaps a tribute to the intrinsic interest of his plots, characters, and descriptions that he was under the necessity of begging attention to these higher aims. In *The Pilgrims of the Rhine* (1834), a work of graceful fantasy, in which some of his most acute observations on human life are incorporated with the sayings and doings of elves and fairies, an ambitious author is made to complain that "the subtle aims that had inspired him were not perceived," and that he was often approved for what he condemned himself. The *Pilgrims*, charmingly written in many passages, was too German in its combination of serious thought and mundane personages with fairies to be heartily welcomed by the English public. Bulwer was more successful in another attempt to break new ground in *The Last Days of Pompeii* (1834) and *Rienzi* (1835). No historical romances dealing with times and scenes so remote were ever more widely popular in England, and in aiming at popularity the author laboured hard to secure historical accuracy. In *Athens, its Rise and Fall* (1836), we received in the form of historical essays what had probably been acquired industriously as materials for romance. Two romances from Spanish history, *Leila* and *Calderon*, published in 1838, aimed at a less realistic treatment, and, with all their purely literary excellences, were not so popular. In *Ernest Maltravers* (1837) and its sequel *Alice, or The Mysteries* (1838), the novelist returned to English ground and psychological and social problems—"the affliction of the good, the triumph of the unprincipled." Critics to whom he failed to make the full purpose of these works apparent in the execution complained of the low tone of their morality, a fair complaint concerning most exhibitions of vice as a warning.

To his other literary labours Bulwer superadded for some time the editorship of a magazine. He succeeded Campbell as editor of *The New Monthly* in 1833. In 1838 he projected a magazine called *The Monthly Chronicle*, and contributed to it as a serial story the fantastic romance "Zicci." The magazine expired before the story was completed, and it was afterwards developed into *Zanoni*, a romance of which he was himself especially proud, and which suffered in public estimation from being tried by realistic standards.

During the most productive period of his literary life Bulwer was an eminent member of parliament. He was returned for St Ives in 1831, and sat for Lincoln from 1832 to 1841. He spoke in favour of the Reform Bill, and took the leading part in obtaining the reduction, after vainly trying to procure the repeal, of the newspaper stamp duties. His support of the Whigs in parliament, and by a pamphlet on "the crisis" when they were dismissed from office in 1834, was considered so valuable that Lord Melbourne offered him a place in the administration. His intimacy with Radical leaders at this period exposed him to an undeserved charge of tergiversation when later in life he was a member of a Conservative Government. Charles Buller and Charles Villiers were among his friends at Cambridge; he was an admiring student of Bentham; Mill's *Essay on Government* was the text-book on which was founded "Pelham's" instruction by his uncle in the principles of politics; J. S. Mill contributed the substance of the appendices to *England and the English*, on Bentham and Mill; Godwin suggested to him the subject and some part of the plot of *Eugene Aram*; he even succeeded in winning the good opinion of Miss Martineau; but we have only to read his speech in favour of the Reform Bill to see that it was the situation that had changed and not the man when he assailed the repeal of the corn laws, and took office under Lord Derby. Bulwer's leading political aim, like his leading artistic aims, was early formulated, and the formula governed all his political reasoning: it was to "aristocratize the community," "to elevate the masses in character and feeling to the standard which conservatism works in aristocracy," a standard not of wealth or pedigree but of "superior education, courteous manners, and high honour." Hence it was "social reforms" from first to last that enlisted his interest, and he sought the motive power for these reforms in the public spirit of the classes enfranchised by the Reform Act of 1832.

There was a slight break in Bulwer's career as a novelist between 1838 and 1847. During this interval he applied himself enthusiastically to play writing,—Macready's management of Covent Garden having inspired men of letters with the hope of reconciling poetry with the stage. In 1836 he had produced *The Duchess of La Vallière*. It was a failure. But in 1838 and the two following years he produced three plays which have kept the stage ever since—*The Lady of Lyons*, *Richelieu*, and *Money*. In his plays as in his novels definite theory preceded execution. The principles on which he wrote his plays were laid down in his chapter on the drama in *England and the English*. For many of the details of stagecraft, all-important to success under any principles, he is said to have been indebted to Macready. No Englishman not himself an actor has written so many permanently successful plays as Bulwer Lytton, and this is another instance of his extraordinary plasticity of mind and practical insight. Thirty years afterwards, in 1869, he turned his thoughts again to writing for the stage, recast an old failure with a new title *The Rightful Heir*, and produced a new comedy, *Walpole*. Neither was a success.

From 1841 to 1852 Bulwer (he assumed his mother's name of Lytton on succeeding to her estates in 1843) had no seat in parliament. But the issue of novels and romances was not so rapid as it had been in the full energy of his youth. Before 1849, when he opened a new vein with *The Caxtons*, he produced five works in his familiar vein:—*Night and Morning* (1841, in which the influence of Dickens is traceable), *Zanoni* (1842), *The Last of the Barons* (1843, the most historically solid, and perhaps the most effective of his romances), *Lucretia, or the Children of the Night* (1847; moral purpose—to exhibit the horrors caused by the worship of money; popular effect—disgust at these horrors, and indignation at the author's sentiment as morbid), *Harold, The Last of the Saxon Kings* (1848).

The cause of the comparative infertility of this period in prose fiction probably was that Lytton was now making a determined effort to win high rank as a poet. He published a volume of poems in 1842, a volume of translations from Schiller in 1844, *The New Timon*, a satire, in 1845.[1] Then came the work on which mainly Lytton rested his pretensions, *King Arthur*, a romantic epic. "I am unalterably convinced," he said, "that on this foundation I rest the least perishable monument of those thoughts and those labours which have made the life of my life." But *King Arthur* fell flat. The verse, the six-lined stave of elegiac quatrain and couplet, lacks charm and variety; the incidents are monotonous, the personages uninteresting, the plot unexciting, and the allegory obscure. *St Stephen's*, a gallery of parliamentary portraits from the time of Queen Anne, was a kind of metrical composition that lay more within his powers. In this the satire is keen-edged, the admiration just and generous. It was published in 1860. The *Lost Tales of Miletus* (1866) and a translation of Horace's *Odes* (1869) were Lytton's last essays in verse.

In the skill with which he sustained a new style in *The Caxtons* (1848) Lytton gave a more convincing proof of his versatility. This imitation of Sterne (by no means a servile imitation, rather an adaptation of Sterne's style and characters to the circumstances of the 19th century) appeared anonymously in *Blackwood's Magazine*, and made a reputation before the authorship was suspected. *My Novel* (1853) and *What will He Do with It?* (1858) continued in the same strain. The sub-title of *My Novel*, "Varieties of English life," shows still operative the same purpose that we find in *Pelham*, but the criticism of the "Varieties" is more polemical in spirit. There is more than a shade of defiance in his praise of the virtues of a territorial aristocracy, and a strong spice of hostility to the vulgarities of the manufacturers who threatened to push them from their stools. There is a blindness to defects in the one case and to merits in the other quite foreign to the broad sympathies of the dandy Pelham; Caxton paints the ideal best of the one class and the ideal worst of the other. In these, as in all Lytton's novels, the characters are placed on the stage and described; they are not left to reveal themselves gradually in action.

Lytton returned to parliament in 1852 as member for Hertfordshire, and sat on the Conservative side. Early in life he had decided in his mind against the reduction of the corn duties, and, unchanged in 1851, he addressed a "Letter to John Bull," enlarging on the dangers of their repeal. Incapable of failure in any intellectual exercise that he set his mind to, he was an effective speaker; but the effort was against nature: he could speak only under extreme excitement or after laborious preparation, and he never took a high place among parliamentary orators. He was colonial secretary in Lord Derby's Government from 1858 to 1859, and threw himself industriously into the duties of his office. He was raised to the peerage as Baron Lytton in 1866.

That he had not forgotten his power of moving the sense of melodramatic and romantic mystery when he adopted the more subdued style of *The Caxtons*, Lytton proved by *A Strange Story*, contributed to *All the Year Round* in 1862. A serial story of the kind made a new call on his resources, but he was equal to it, and fairly rivalled the school of Dickens in the art of sustaining thrilling interest to the close.

When he died, in January 1873, after a short painful illness, two works of high repute, *The Coming Race* and *The Parisians*, were not acknowledged, and were only vaguely suspected to be his. They had freshness enough to be the work of youth, and power enough to shame no veteran. These two books, the fable and the novel, are classed by Lytton's son and successor in the the title with the romance of *Kenelm Chillingly*, left completed at his death, as forming a trilogy, animated by a common purpose, to exhibit the influence of "modern ideas" upon character and conduct. The moulding force whose operation is traced in *The Parisians* is the society of imperial and democratic France, in *Chillingly* the society of England in relation to its representative institutions. The leading purpose is kept well in view throughout both works, and the tendencies to corruption analysed and presented with admirable skill; but the theorist has omitted from his problem certain important regenerating and safeguarding factors in the large world outside the pale of society. Problems and theories apart, these last works show no falling off of power; he is as vivid as ever in description, as fertile as ever in the invention of humorous and melodramatic situation. If he had been content to abandon his purpose in *Chillingly*, and end with the first volume by some such commonplace contrivance as giving "motive power" to his hero in the love of Cecilia Travers, it would have been the most perfect of his works in unity of humorous sentiment. The veteran author died in harness,—two novels all but completed; another, an historical romance, *Pausanias the Spartan*, outlined and partly written.

The fact that in the fiftieth year of his authorship, after publishing at least fifty separate works, most of them popular, Lord Lytton had still vigour and freshness enough to make a new anonymous reputation with *The Coming Race* would seem to indicate that critics had not fairly gauged his versatility, and also that an erroneous fixed idea had been formed of his style. The explanation probably is that even after the publication of *The Caxtons* he was thought of in connexion with that school of melodramatic romance of which he was indisputably the leader, if not the founder, and that heavily loaded rhetorical style which was made ridiculous by his imitators. "Every great genius," one of his characters is made to say, "must deem himself alone in his conceptions. It is not enough for him that these conceptions should be approved as good, unless they are admitted as inventive." Invention and originality are matters of degree, and, though no one can deny that Lytton possessed great inventive powers, he did not put that individual stamp on his work without which no writer is entitled to a place in the foremost rank. He was not self-centred enough; he was too generally emulous to win the highest individual distinction. But his freshness of thought, brilliancy of invention, breadth and variety of portraiture, gave him a just title to his popularity, and, with all allowance for superficial affectations, his generous nobility of sentiment made his influence as wholesome as it was widespread. (W. M.)

[1] A feeble attack in the last on Mr Tennyson's poetry provoked a brusque but powerful reply from the enraged laureate, aimed at his assailant's person.

M

M. THE letter M denotes a nasal sound, which varies little, if at all, in different languages.

Nasal sounds are produced as follows. The breath—turned into voice at its passage through the glottis—does not pass out wholly through the mouth. Part of it is diverted behind the soft palate, and so through the nostrils; the remainder passes through the mouth-cavity, and is there completely checked at some point of its course. When that check is taken away, we hear, not the sonant which would have been produced if all the breath had passed through the mouth, but a nasal varying in nature according to the part of the cavity where the check of the tongue or the lips has been applied. There may be as many definite nasal sounds in any language as there are recognized classes of consonants, as guttural, palatal, dental, labial. In Sanskrit there were even five nasal sounds so clearly differentiated that each had a special symbol to denote it; the cerebral class of sounds (produced by turning the tip of the tongue slightly back against the middle of the palate) had its nasal as well as each of the other four classes above mentioned. In English we have three sounds, but only two simple symbols, *m* and *n*; for the guttural nasal heard in *sing*, &c., we employ the digraph *ng*. Spanish has a palatal nasal.

The nasal sound denoted by M is the labial nasal. It corresponds to the sonant *b*-sound; for each of them the lips are completely closed, and if no voice were diverted through the nostrils a *b*-sound only would be heard when the lips are opened; all the organs of the mouth are in exactly the same position for one sound as for the other, but, the soft palate being lowered, the voice is divided in its egress. Hence we see why a man who has a cold pronounces *m* as *b*; the voice cannot get through the nostrils, which are blocked up; it must therefore escape mainly or entirely through the lips, and so produce a *b*-sound. Therefore, instead of "talking through his nose," as the phrase goes, such a person tries to talk through his nose, but cannot.

The symbol M stands in numeration for 1000. See Alphabet.

MAAS. See Meuse.

MABILLON, Jean (1632–1707), the learned and discriminating historian of the Benedictine order, was born at the village of Saint Pierremont, Champagne (now in the department of Ardennes), on November 23, 1632. He received his early education from an uncle who held the post of village curé in the neighbourhood, and afterwards he went to Rheims, where, in 1653, he entered upon his noviciate in the Benedictine Abbey of Saint Remy, taking the vows in the following year. The following four years were spent at various houses of the order, to which he was sent on account of his health, impaired by excessive study. From 1658 to 1663 he was at Corbie, and in 1664 he assisted Chantelon at Saint Denis in the preparation of a new edition of the works of St Bernard. Shortly afterwards he was removed to Saint-Germain-des-Prés, and charged with the task of editing materials which had already been amassed for a general history of the Benedictine order. While engaged on this work (*Acta Sanctorum ordinis S. Benedicti in sæculorum classes distributa*), the publication of which, in 9 vols. folio, extended from 1668 to 1701, he made several journeys, for literary research, into Germany and Italy, as well as into the provinces of France; amongst the more important of the numerous monographs to which his investigations gave rise, the work *De Re Diplomatica*, which appeared in 1681, deserves special mention (see Diplomatics). Mabillon died at Saint-Germain-des-Prés, on December 27, 1707.

For a complete list of his works reference may be made to Bayle's *Dictionnaire*, or to the *Biographie Générale*. They include, besides those mentioned above, *Vetera Analecta*, 1675–85 (a work similar in character to the *Miscellanea* of Baluze); *Animadversiones in Vindicias Kempenses*, 1677 (in which he claims the *Imitatio* for Gersen); *De Liturgia Gallicana*, 1685; *Museum Italicum*, 1687–89; and *Annales Ordinis S. Benedicti*, 6 vols. fol., 1703–39.

MABINOGION. See Celtic Literature, vol. v. p. 321.

MABUSE. See Gossart.

MACAO (A-Ma-ngao, "Harbour of the goddess A-Ma"; Portuguese, *Macau*), a Portuguese settlement on the coast of China, in 22° N. lat. and 132° E. long., consists of a tongue of land 1½ square miles in extent, running south-south-west from the island of Hiang Shang (Portuguese, Ançam) on the western side of the estuary of the Canton river. Bold and rocky hills about 300 feet in height occupy both extremities of the peninsula, the picturesque-looking city, with its flat-roofed houses painted blue, green, and red, lying in the far from level stretch of ground between. The forts are effective additions to the general view, but do not add much to the real strength of the place. Along the east side of the peninsula runs the Praya Grande, or Great Quay, the chief promenade in Macao, on which stand the governor's palace, the administrative offices, the consulates, and the leading commercial establishments. The church of St Paul, erected between 1594 and 1602, the seat of the Jesuit college in the 17th century, was destroyed by fire in 1835. The Hospital da Misericordia (1569) was rebuilt in 1640. The Camoens grotto—where the exiled poet found leisure to celebrate the achievements of his ungrateful country—lies in a secluded spot to the north of the town, which has been partly left in its native wildness strewn with huge granite boulders and partly transformed into a fine botanical garden. In 1871 there were in Macao 5375 persons of European birth or extraction, 53,761 Chinese living on land and 10,268 in boats. Half-castes are very numerous. Though most of the land is under garden cultivation, the mass of the people is dependent more or less directly on mercantile pursuits; for, while the exclusive policy both of Chinese and Portuguese which prevented Macao becoming a free port till 1845–46 allowed what was once the great emporium of European commerce in eastern Asia to be outstripped by its younger and more liberal rivals, the trade of the place is still of very considerable extent. Since the middle of the century indeed much of it has run in the most questionable channels: the nefarious coolie traffic gradually increased in extent and in cruelty from about 1848 till it was prohibited in 1874, and much of the actual trade is more or less of the nature of smuggling. The total value of exports and imports was in 1876–77 upwards of £1,536,000. Commercial intercourse is most intimate with Hong-Kong, Canton, Batavia, and Goa. The preparation and packing of tea is the principal industry in the town. The colonial revenue, which is largely recruited by a tax on the notorious gambling tables, increased from 104,643 dollars in 1856–57 to 380,012 in 1872–73, while the expenditure rose from 69,757 to 266,344.

In 1557 the Portuguese were permitted to erect factories on the peninsula, and in 1573 the Chinese built the wall across the isthmus which still cuts off the barbarian from the rest of the island. Jesuit missionaries established themselves on the spot, and in 1580 Gregory XIII. constituted a bishopric of Macao. A senate was organized in 1583, and in 1628 Jeronimo de Silveira became first royal governor of Macao. Still the Portuguese remained largely under the control of the Chinese, who had never surrendered their territorial rights and maintained their authority by means of mandarins,—these insisting that even European criminals should be placed in their hands. Ferreira do Amaral, the Portuguese governor, put an end to this state of things in 1849, and left the Chinese officials no more authority in the peninsula than the representatives of other foreign nations; and, though his antagonists procured his assassination (August 22d), his successors have succeeded in carrying out his policy. The Chinese Government has hitherto refused (notably in 1862) to recognize the territorial claims of the Portuguese; but the European powers treat Macao as *de facto* a colonial possession, and not only the governor, the president of the courts, and other Portuguese officials, but even the Chinese magistrates, are directly appointed by the king of Portugal. For a short time in 1802, and again in 1808, Macao was occupied by the English as a precaution against seizure by the French.

See De Beauvoir, *Voyage Round the World*, 1870; Wiselius, "Macausche toestanden," in *Tijds. van het Aardr. Gen.*, 1877; *Relatorio e documentos sobre a abolição da emigração de Chinas contratados em Macau*, Lisbon, 1874; English parliamentary papers on the coolie trade, 1874; Biker, *Mem. sobre o estabelecimento de Macau*, Lisbon, 1879.

MACARONI (from dialectic Italian *maccare*, "to bruise or crush") is a preparation of wheat originally peculiar to Italy, in which country it is an article of food of national importance. The same substance in different forms is also known as vermicelli, pasta or Italian pastes, taglioni, fanti, &c. These substances are prepared from the hard semi-translucent varieties of wheat which are largely cultivated in the south of Europe, Algeria, and other warm regions, and which are distinguished by the Italians as *grano duro* or *grano da semolino*. Hard wheats are much richer in gluten and other nitrogenous compounds than the soft or tender wheats, and their preparations are more easily preserved, to which conditions their suitability for the manufacture of Italian pastes are mainly due. The various preparations are met with in the form of fine thin threads which constitute vermicelli, so called from its thread-worm like appearance, thin sticks and pipes (macaroni), small lozenges, stars, disks, ellipses, &c. (pastes), and ribbons, tubes, and other fanciful forms. These various forms are prepared in a uniform manner from a granular meal of hard wheat which itself, under the name of semolina or semola, is a commercial article. The semolina is thoroughly mixed and incorporated into a stiff paste or dough with boiling water, and in the hot condition it is placed in a strong metallic cylinder, the end of which is closed with a thick disk pierced with openings which correspond with the diameter or section of the article to be made. Into this cylinder an accurately fitting plunger or piston is introduced, and by very powerful pressure it causes the stiff dough to squeeze out through the openings in the disk in continuous threads, sticks, or pipes, as the case may be. When pipe or tube macaroni is being made, the openings in the disk are widened internally, and mandrels, the gauge of the tubes to be made, are centred in them. In making pastes the cylinder is laid horizontally, the end is closed with a disk pierced with holes having the sectional form of the pastes, and a set of knives revolves close against the external surface of the disk, cutting off the paste in thin sections as it exudes from each opening. Macaroni is dried rapidly by hanging it in long sticks or tubes over wooden rods in stoves or heated apartments through which currents of air are driven. It is only genuine macaroni, rich in gluten, which can be dried in this manner; spurious fabrications made with common flour and coloured to imitate the true material will not bear their own weight. Imitations must therefore be laid out flat and dried slowly, during which they very readily split and break up, while in other cases they become mouldy on the inside of the tubes. True macaroni can be distinguished by observing the flattened mark of the rod over which it has been dried within the bend of the tubes; it has a soft yellowish colour, is rough in texture, elastic, and hard, and breaks with a smooth glassy fracture. In boiling it swells up to double its original size without becoming pasty or adhesive, maintaining always its original tubular form without either rupture or collapse. It can be kept any length of time without alteration or deterioration, and it is on that account, in many circumstances, a most convenient as well as a highly nutritious and healthful article of food. In its various forms it is principally used as an ingredient in soups, and for the preparation of puddings, with cheese, &c. Many of the good qualities of genuine macaroni may be obtained by enriching the flour of common soft wheat with gluten obtained in the preparation of wheaten starch, and proceeding as in the case of semolina. Such imitations, and others of inferior quality, are extensively made both in France and Germany.

MACARTNEY, George Macartney, Earl of (1737–1806), was descended from an old Scotch family, the Macartneys of Auchinleck, who had settled in 1649 at Lissanoure, Antrim, Ireland, where he was born May 13, 1737. After graduating at Trinity College, Dublin, in 1759, he became a student of the Inner Temple, London. Appointed envoy-extraordinary to Russia in 1764, he succeeded in negotiating an alliance between England and that country. After for some time occupying a seat in the English parliament, he was in 1769 returned for Armagh in the Irish parliament, in order to discharge the duties of chief secretary for Ireland. On resigning this office he received the honour of knighthood. In 1775 he became governor of Granada, in 1780 governor of Madras, and in 1785 he was appointed governor-general of Bengal, but, his health demanding his return to England, he declined to accept office. After being created earl of Macartney in the Irish peerage, he was appointed in 1792 the first envoy of Britain to China. On his return from a confidential mission to Italy he was raised to the English peerage in 1796, and in the end of the same year was appointed governor of the newly acquired territory of the Cape of Good Hope, where he remained till ill health compelled him to resign in November 1798. He died at Chiswick, Surrey, 31st March 1806.

An account of Macartney's embassy to China, by Sir George Staunton, was published in 1797, and has been frequently reprinted. See also *Life and Writings of Lord Macartney*, by Barrow, 2 vols., London, 1807.

MACASSAR. See Celebes, vol. v. p. 288.

MACAULAY, Thomas Babington Macaulay, Lord (1800–1859), was born at Rothley Temple, Leicestershire, on the 25th of October 1800. His father, Zachary Macaulay, had been governor of Sierra Leone, and was in 1800 secretary to the chartered company who had founded that colony. Happy in his home, the boy at a very early age gave proof of a determined bent towards literature. Before he was eight years of age he had written a *Compendium of Universal History*, which gave a tolerably connected view of the leading events from the creation to 1800, and a romance in the style of Scott, in three cantos, called the *Battle of Cheviot*. At a little later time the child composed a long poem on the history of Olaus Magnus, and a vast pile of blank verse entitled *Fingal, a Poem in Twelve Books*.

The question between a private and a public school was anxiously debated by his parents, and decided in favour of the former. The choice of school, though dictated by theological considerations, was a fortunate one. Mr Preston of Little Shelford enjoyed the confidence of Mr Simeon, but was himself a judicious tutor; and at his table, where master and pupil dined in common, not only the latest Cambridge topics were mooted, but university ambitions and ways of thought were brought home to the boys.

In October 1818 young Macaulay went into residence at Trinity College, Cambridge. Here he revelled in the possession of leisure and liberty, which he could not forego for the sake of those university honours which at that day were only to be obtained by a severely exclusive course of mathematical study. But he succeeded in obtaining the prize which in his eyes was the most desirable that Cambridge had to give, viz., a fellowship at Trinity. A trifling college prize for an essay on the character of William III. was awarded to an essay by young Macaulay, which may be regarded as the first suggestion and the earnest of his future *History*.

In 1826 Macaulay was called to the bar and joined the northern circuit. But after the first year or two, during which he got no business worth mention, he gave up even the pretence of reading law, and spent many more hours under the gallery of the House of Commons than in the court. His first attempt at a public speech, made at an anti-slavery meeting in 1824, was described by the *Edinburgh Review* as "a display of eloquence of rare and matured excellence." His first considerable appearance in print was in No. 1 of Knight's *Quarterly Magazine*, a periodical which enjoyed a short but brilliant existence, and which was largely supported by Eton and Cambridge. In August 1825 began Macaulay's connexion with the periodical which was to prove the field of his literary reputation. The *Edinburgh Review* was at this time at its height of power, not only as an organ of the growing opinion which leant towards reform, but as a literary tribunal from which there was no appeal. The essay on Milton, though so crude that the author said of it that "it contained scarcely a paragraph such as his matured judgment approved," created for him at once a literary reputation which suffered no diminution to the last, a reputation which he established and confirmed, but which it would have been hardly possible to make more conspicuous. Murray declared that it would be worth the copyright of *Childe Harold* to have Macaulay on the staff of the *Quarterly Review*. Robert Hall, writhing with pain, and well-nigh worn out with disease, was discovered lying on the floor employed in learning by aid of grammar and dictionary enough Italian to enable him to verify the parallel between Milton and Dante. The family breakfast table was covered with cards of invitation to dinner from every quarter of London.

The sudden blaze of popularity kindled by a single essay, such as are now produced every month without attracting any notice, is partly to be explained by the dearth of literary criticism in England at that epoch. For, though a higher note had already been sounded by Hazlitt and Coleridge, it had not yet taken hold of the public mind, which was still satisfied with the feeble appreciations of the *Retrospective*, or the dashing and damnatory improvisation of Wilson in *Blackwood* or Jeffrey in the *Edinburgh*. Still, after allowance made for the barbarous partisanship of the established critical tribunals of the period, it seems surprising that a social success so signal should have been the consequence of a single article. The explanation is to be found in the fact that it had been discovered at the same time that the writer of the article on Milton was, unlike most authors, also a brilliant converser. There has never been a period when an amusing talker has not been in great demand at London tables; but at the date at which Macaulay made his début witty conversation was studied and cultivated as it has ceased to be in the more busy age which has succeeded. At the university Macaulay had been recognized as pre-eminent for talk and companionship among a circle of young men of talents so brilliant as were Charles Austin, Romilly, Praed, Villiers, and others. He now displayed these gifts on a wider theatre. Crabb Robinson's diary, under date 1826, records the judgment of one who had been in the constant habit of hearing the best talk of the London of his day. Such as he was in 1826 Macaulay continued to be to the end. In Lord Carlisle's journal, under date 27th June 1843, we read—"Breakfasted with Hallam, John Russell, Macaulay, Everett, Van de Weyer, Hamilton, Mahon. Never were such torrents of good talk as burst and sputtered over from Macaulay and Hallam." Again, 11th October 1849, "the evening went off very pleasantly, as must almost always happen with Macaulay. He was rather paradoxical, as is apt to be his manner, and almost his only social fault. The greatest marvel about him is the quantity of trash he remembers." In March 1850 Lord Carlisle records—"Macaulay's flow never ceased once during the four hours, but it is never overbearing."

Thus launched (1825) on the best that London had to give in the way of society, Macaulay accepted and enjoyed with all the zest of youth and a vigorous nature the opportunities opened for him. He was courted and admired by the most distinguished personages of the day. He was admitted at Holland House, where Lady Holland listened to him with deference, and scolded him with a circumspection which was in itself a compliment. Rogers spoke of him with friendliness, and to him with affection, and ended by asking him to name the morning for a breakfast party. He was treated with almost fatherly kindness by "Conversation" Sharp.

Thus distinguished, and justifiably conscious of his great powers, it was not unnatural that Macaulay's thoughts should take the direction of politics, and his ambition aspire to a political career. But the shadow of pecuniary trouble early began to fall upon his path. When he went to college his father believed himself to be worth £100,000, and declared his intention of making him, in a modest way, an eldest son. But commercial disaster overtook the house of Babington and Macaulay, and the son now saw himself compelled to work for his livelihood. His Trinity fellowship of £300 a year became of great consequence to him, but it expired in 1831; he could make at most £200 a year by writing; and a commissionership of bankruptcy, which was given him by Lord Lyndhurst in 1828, and which brought him in about £400 a year, was swept away, without compensation, by the ministry which came into power in 1830. Macaulay now found himself a poor man, and was reduced to such straits that he had to sell his Cambridge gold medal.

In February 1830 the doors of the House of Commons were opened to him in the only way in which a man without fortune could enter them, through what was then called a "pocket borough." Lord Lansdowne, who had been struck by two articles on Mill (James) and the Utilitarians, which appeared in the *Edinburgh Review* in 1829, offered the author the seat at Calne. The offer was accompanied by the express assurance that the noble patron had no wish to interfere with his freedom of voting. He thus entered parliament at one of the most exciting moments of English domestic history, when the compact phalanx of reactionary administration which for nearly fifty years had commanded a crushing majority in the Commons was on the point of being broken by the growing strength of the party of reform. Macaulay made his maiden speech on 5th April 1830, on the second reading of the bill for the removal of Jewish disabilities. In July the king died and parliament was dissolved; the revolution took place in Paris. Macaulay, who was again returned for Calne, visited Paris, eagerly enjoying a first taste of Continental travel. On 1st March 1831 the Reform Bill was introduced, and on the second night of the debate Macaulay made the first of his reform speeches. It was a signal success. Sir Robert Peel said of it that "portions were as beautiful as anything I have ever heard or read."

Encouraged by this first success, Macaulay now threw himself with ardour into the life of the House of Commons, while at the same time he continued to enjoy to the full the social opportunities which his literary and political celebrity had placed within his reach. For these reasons he dined out almost nightly, and spent many of his Sundays at the suburban villas of the Whig leaders, while he continued to supply the *Edinburgh Review* with a steady series of his most elaborate articles. On the triumph of Earl Grey's cabinet, and the passing of the Reform Act in June 1832, Macaulay, whose eloquence had signalized every stage of the conflict, became one of the commissioners of the Board of Control, and applied himself to the study of Indian affairs. His industry was untiring, and the amount of intellectual product which he threw off very great. Giving his days to India and his nights to the House of Commons, he could only devote a few hours to literary composition by rising at five when the business of the House had allowed of his getting to bed in time on the previous evening. Between September 1831 and December 1833 he furnished the *Review* with the following articles:—"Boswell's Life of Johnson": "Lord Nugent's Hampden"; "Burleigh and his Times"; "Mirabeau"; "Horace Walpole"; "Lord Chatham"; besides writing his ballad on the Armada for one of the Albums, annual publications of miscellanies then in fashion.

In the first reform parliament, January 1833, Macaulay took his seat as one of the two first members for Leeds, which up to that date had been unrepresented in the House of Commons. He replied to O'Connell in the debate on the address, meeting the great agitator face to face, with high, but not intemperate, defiance. In July he defended the Government India Bill in a speech of great power, and to his aid was greatly due the getting the bill through committee without unnecessary friction. When the abolition of slavery came before the House as a practical question, Macaulay had the prospect of being placed in the dilemma of having to surrender office or to vote for a modified abolition, viz., twelve years' apprenticeship, which was proposed by the ministry, but condemned by the abolitionists. He was prepared to make the sacrifice of place rather than be unfaithful to the cause to which his father had devoted his life. He placed his resignation in Lord Althorp's hands, and spoke against the ministerial proposal. But the sense of the House was so strongly expressed as unfavourable that, finding they would be beaten if they persisted, the ministry gave way, and reduced apprenticeship to seven years, a compromise which the abolition party accepted; and Macaulay remained at the Board of Control.

While he was thus growing in reputation, and advancing his public credit, the fortunes of the family were sinking, and it became evident that his sisters would have no provision except such as their brother might be enabled to make for them. Macaulay had but two sources of income, both of them precarious—office and his pen. As to office, the Whigs could not have expected at that time to retain power for a whole generation; and, even while they did so, Macaulay's resolution that he would always give an independent vote made it possible that he might at any moment find himself in disagreement with his colleagues, and have to quit his place. As to literature, he wrote himself to Lord Lansdowne (1833), "it has been hitherto merely my relaxation; I have never considered it as the means of support. I have chosen my own topics, taken my own time, and dictated my own terms. The thought of becoming a bookseller's hack, of spurring a jaded fancy to reluctant exertion, of filling sheets with trash merely that sheets may be filled, of bearing from publishers and editors what Dryden bore from Tonson and what Mackintosh bore from Lardner, is horrible to me." Though pennyless, Macaulay could never be accused of playing the game of politics from selfish considerations. But it was impossible that, circumstanced as he was, he should not look with anxiety upon his own future and that of his sisters,—sisters who had been, and who had deserved to be, the intimate confidants of all his thoughts and doings, and to whom he was attached by the tenderest affection. He was therefore prepared to accept the offer which was made him of a seat in the supreme council of India, a body which had been created by the India Act he had himself been instrumental in passing. The salary of the office was fixed at £10,000, an income out of which he calculated to be able to save in five years a capital of £30,000. His sister Hannah accepted his proposal to accompany him, and in February 1834 the brother and sister sailed for Calcutta.

Macaulay's appointment to India occurred at the critical moment when the government of the company was being superseded by government by the crown. His knowledge of India was, when he landed, but superficial. But at this juncture there was more need of statesmanship directed by general liberal principles than of a practical knowledge of the details of Indian administration. Macaulay's presence in the council was of great value; his minutes are models of good judgment and practical sagacity. The part he took in India has been described as "the application of sound liberal principles to a government which had till then been jealous, close, and repressive." He vindicated the liberty of the press; he maintained the equality of Europeans and natives before the law; and as president of the committee of public instruction he inaugurated that system of national education which has since spread over the whole of the Indian peninsula.

A clause in the Indian Act of 1833 occasioned the appointment of a commission to inquire into the jurisprudence of our Eastern empire. Macaulay was appointed president of that commission. The draft of a penal code which he submitted became, after a revision of many years, and by the labour of many experienced lawyers, that criminal code under which law is now administered throughout the empire. Of this code Sir James Stephen says that "it reproduces in a concise and even beautiful form the spirit of the law of England, in a compass which by comparison with the original may be regarded as almost absurdly small. The Indian penal code is to the English criminal law what a manufactured article ready for use is to the materials out of which it is made. It is to the French Code Pénal, and to the German code of 1871, what a finished picture is to a sketch. It is simpler and better expressed than Livingston's code for Louisiana; and its practical success has been complete."

As might be expected, Macaulay's enlightened views and measures drew down on him the abuse and ill-will of Anglo-Indian society in Calcutta and the Mofussil. Fortunately for himself he was enabled to maintain a tranquil indifference to political detraction by withdrawing his thoughts into a sphere remote from the opposition and enmity by which he was surrounded. Even amid the excitement of his early parliamentary successes literature had balanced politics in his thoughts and interests. Now in his exile, for such he felt it to be, he began to feel more strongly each year the attraction of European letters and European history. He writes to his friend Ellis, "I have gone back to Greek literature with a passion astonishing to myself. I have never felt anything like it. I was enraptured with Italian during the six months which I gave up to it; and I was little less pleased with Spanish. But when I went back to the Greek I felt as if I had never known before what intellectual enjoyment was." In thirteen months he read through, some of them twice, a large part of the Greek and Latin classics. The attention with which he read is proved by the pencil marks and corrections of press errors which he left on the margin of the volumes he used.

The fascination of these studies produced their inevitable effect upon his view of political life. He began to wonder what strange infatuation leads men who can do something better to squander their intellect, their health, and energy on such subjects as those which most statesmen are engaged in pursuing. He was already, he says, "more than half determined to abandon politics and give myself wholly to letters, to undertake some great historical work, which may be at once the business and the amusement of my life, and to leave the pleasures of pestiferous rooms, sleepless nights, and diseased stomachs to Roebuck and to Praed."

In 1838 Macaulay and his sister Hannah, who had now become Lady Trevelyan, returned to England. He at once entered parliament as member for Edinburgh. In 1839 he became secretary at war, with a seat in the cabinet in Lord Melbourne's ministry. His acceptance of office diverted him for a time from prosecuting the plan he had already formed of a great historical work. But only for a time. In less than two years the Melbourne ministry fell, and Macaulay was liberated from having to support a Government wretchedly weak, and maintaining its struggle for bare existence.

He returned to office in 1846, in Lord John Russell's administration. But it was in an office which gave him leisure and quiet rather than salary and power—that of paymaster-general. His duties were very light, and the contact with official life and the obligations of parliamentary attendance were even of benefit to him while he was engaged upon his *History*. In the sessions of 1846–47 he spoke only five times, and at the general election of July 1847 he lost his seat for Edinburgh upon issues which did not reflect credit upon that constituency. Over and above any political disagreement with the constituency, there was the fact that the balance of Macaulay's faculties had now passed to the side of literature. Lord Cockburn wrote in 1846, "the truth is, Macaulay, with all his knowledge, talent, eloquence, and worth, is not popular. He cares more for his *History* than for the jobs of constituents, and answers letters irregularly and with a brevity deemed contemptuous." At an earlier date he had relished crowds and the excitement of ever new faces; as years went forward and absorption in the work of composition took off the edge of his spirits, he recoiled from publicity. He began to regard the prospect of business as worry, and had no longer the nerve to brace himself to the social efforts required of one who represents a large constituency.

Macaulay retired into private life, not only without regret, but with a sense of relief. He gradually withdrew from general society, feeling the bore of big dinners, and country-house visits, but he still enjoyed close and constant intercourse with a circle of the most eminent men that London then contained. At that time social breakfasts were in vogue. Macaulay himself preferred this to any other form of entertainment. Of these brilliant reunions nothing has been preserved beyond the names of the men who formed them,—Rogers, Hallam, Sydney Smith, Lord Carlisle, Lord Stanhope, Nassau Senior, Charles Greville, Milman, Panizzi, Lewis, Van de Weyer. His biographer thus describes Macaulay's appearance and bearing in conversation: "Sitting bolt upright, his hands resting on the arms of his chair, or folded over the handle of his walking-stick, knitting his eyebrows if the subject was one which had to be thought out as he went along, or brightening from the forehead downwards when a burst of humour was coming, his massive features and honest glance suited well with the manly sagacious sentiments which he set forth in his sonorous voice and in his racy and intelligible language. To get at his meaning people had never the need to think twice, and they certainly had seldom the time."

But, great as was his enjoyment of literary society and books, they only formed his recreation. In these years he was working with unflagging industry at the composition of his *History*. His composition was slow, his corrections both of matter and style endless; he spared no research to ascertain the facts. He sacrificed to the prosecution of his task a political career, House of Commons fame, the allurements of society. The first two volumes of the *History of England* appeared in December 1848. The success was in every way complete beyond expectation. The sale of edition after edition, both in England and the United States, was enormous.

In 1852, when his party returned to office, he refused a seat in the cabinet, but he could not bring himself to decline accepting the compliment of a voluntary amende which the city of Edinburgh paid him in returning him at the head of the poll at the general election in July of that year. He had hardly accepted the summons to return to parliamentary life before he was struck down by the malady which in the end proved fatal. This first betrayed itself in deranged action of the heart; from this time forward till his death his strength continued steadily to sink. The process carried with it dejection of spirits as its inevitable attendant. The thought oppressed him that the great work to which he had devoted himself would remain a fragment. Once again, in June 1853, he spoke in parliament, and with effect, against the exclusion of the Master of the Rolls from the House of Commons, and at a later date in defence of competition for the Indian civil service. But he was aware that it was a grievous waste of his small stock of force, and that he made these efforts at the cost of more valuable work.

In November 1855 vols. iii. and iv. of the *History* appeared. No work, not being one of amusement, has in our day reached a circulation so vast. During the nine years ending with the 25th June 1857 the publishers (Longmans) sent out more than 30,000 copies of vol. i.; in the next nine years more than 50,000 copies of the same volume; and in the nine years ending with June 1875 more than 52,000 copies. Within a generation of its first appearance upwards of 140,000 copies of the *History* will have been printed and sold in the United Kingdom alone. In the United States no book except the Bible ever had such a sale. On the Continent of Europe, the sale of Tauchnitz editions was very large, a sale which did not prevent six rival translations in German. The *History* has been published in the Polish, Danish, Swedish, Hungarian, Russian, Bohemian, Italian, French, Dutch, Spanish languages. Flattering marks of respect were heaped upon the author by the foreign Academies. His pecuniary profits were on a scale commensurate with the reputation of the book: the cheque for £20,000 has become a landmark in literary history.

In May 1856 he quitted the Albany, in which he had passed fifteen happy years, and went to live at Holly Lodge, then, before it was enlarged, a tiny bachelor's dwelling, but with a lawn whose unbroken slope of verdure gave it the air of a considerable country house. In the following year (1857) he was raised to the peerage by the title of Baron Macaulay of Rothley. "It was," says Lady Trevelyan, "one of the few things that everybody approved; he enjoyed it himself, as he did everything, simply and cordially." It was a novelty in English life to see eminence which was neither that of territorial opulence nor of political or military services recognized and rewarded by elevation to the peerage.

The distinction came just not too late. Macaulay's health, which had begun to give way in 1852, was every year visibly failing; in May 1858 he went to Cambridge for the purpose of being sworn in as high steward of the borough, to which office he had been elected on the death of Earl Fitzwilliam. When his health was given at a public breakfast in the town-hall, he was obliged to excuse himself from speaking on the ground of inability. His nephew, who was in attendance upon him on the occasion, records that "it was already apparent that a journey across Clare Bridge and along the edge of the great lawn at King's, performed at the rate of ½ mile in the hour, was an exertion too severe for his feeble frame." In the Upper House he never spoke. Absorbed in the prosecution of his historical work, he had grown indifferent to the party politics of his own day. Gradually he had to acquiesce in the conviction that, though his intellectual powers remained to him unimpaired, his physical energies would not carry him through the reign of Anne; and, though he brought down the narrative to the death of William III., the last half volume wants the finish and completeness of the earlier portions.

The winter of 1859 was very severe, and hastened the end. He died on 28th December, and on 9th January 1860 was buried in Westminster Abbey, in Poet's Corner, near the statue of Addison.

Lord Macaulay was never married. A man of warm domestic affections, he found their satisfaction in the attachment and close sympathy of his sister Hannah, the wife of Sir Charles Trevelyan. Her children were to him as his own. Macaulay was a steadfast friend, and a generous enemy. No act inconsistent with the strictest honour and integrity has ever been imputed to him. When a poor man, and when salary was of consequence to him, he twice resigned office rather than make compliances for making which he would not have been severely blamed. In 1847, when his seat in parliament was at stake, he would not be persuaded to humour, to temporize, even to conciliate. He took a lofty tone, and haughtily rebuked the Edinburgh constituency for their bigotry. He had a keen relish for the good things of life, and desired fortune as the means of obtaining them; but there was nothing mercenary or selfish in his nature. When he had raised himself to opulence, he gave away with an open hand, not seldom rashly. His very last act was to write a letter to a poor curate, enclosing a cheque for £25. The purity of his morals was not associated, as it not unfrequently is, with a tendency to cant, or parade of religious phrases.

The lives of men of letters are often records of sorrow or suffering. The life of Macaulay was eminently happy. Till the closing years 1857–59, when his malady had begun to tell upon his strength, he enjoyed life with the full zest of healthy faculty, happy in social intercourse, happy in the solitude of his study, and equally divided between the two. For the last fifteen years of his life he lived for literature, as none of our eminent men since Gibbon have done. His writings were remunerative to him far beyond the ordinary measure, yet he never wrote as the professional author writes. He lived in his historical researches; his whole heart and interest were unreservedly given to the men and the times of whom he read and wrote. His command of literature was imperial. Beginning with a good classical foundation, he made himself familiar with the imaginative, and then with the historical, remains of Greece and Rome. He went on to add the literature of his own country, of France, of Italy, of Spain. He learnt Dutch enough for the purposes of his history. He read German, but for the literature of the northern nations he had no taste, and of the erudite labours of the Germans he had little knowledge and formed an inadequate estimate. The range of his survey of human things had other limitations more considerable still. All philosophical speculation was alien to his mind; nor does he seem aware of the degree in which such speculation has influenced the progress of humanity. A large —the largest—part of ecclesiastical history lay outside his historical view. Of art he confessed himself ignorant, and even refused a request which had been made him to furnish a critique on Swift's poetry to the *Edinburgh Review*. Lessing's *Laocoon*, or Goethe's criticism on Hamlet, "filled" him "with wonder and despair."

Of the marvellous discoveries of science which were succeeding each other day by day he took no note; his pages contain no reference to them. It has been told already how he recoiled from the mathematical studies of his university. These deductions made, the circuit of his knowledge still remains very wide,—as extensive perhaps as any human brain is competent to embrace. His literary outfit was as complete as has ever been possessed by any English writer; and, if it wants the illumination of philosophy, it has an equivalent resource in a practical acquaintance with affairs, with administration, with the interior of cabinets, and the humour of popular assemblies. Nor was the knowledge merely stored in his memory; it was always at his command. Whatever his subject, he pours over it his stream of illustration, drawn from the records of all ages and countries. "Figures from history, ancient and modern, sacred and secular; characters from plays and novels, from Plautus down to Walter Scott and Jane Austen; images and similes from poets of every age and every nation; shrewd thrusts from satirists, wise saws from sages, pleasantries caustic or pathetic from humorists,—all these fill Macaulay's pages with the bustle and variety of some glittering masque and cosmoramic revel of great books and heroical men. His style is before all else the style of great literary knowledge." His *Essays* are not merely instructive as history; they are, like Milton's blank verse, freighted with the spoils of all the ages. They are literature as well as history. In their diversified contents the *Essays* are a library by themselves; for those who, having little time for study, want one book which may be a substitute for many, we should recommend the *Essays* in preference to anything else.

As an historian Macaulay has not escaped the charge of partisanship. He was a Whig; and in writing the history of the rise and triumph of Whig principles in the latter half of the 17th century he identified himself with the cause. But the charge of partiality, as urged against Macaulay, means more than that he wrote the history of the Whig revolution from the point of view of those who made it. When he is describing the merits of friends and the faults of enemies, his pen knows no moderation. He has a constant tendency to glaring colours, to strong effects, and will always be striking violent blows. He is not merely exuberant, but excessive. There is an overweening confidence about his tone; he expresses himself in trenchant phrases, which are like challenges to an opponent to stand up and deny them. His propositions have no qualifications. Uninstructed readers like this assurance, as they like a physician who has no doubt about their case. But a sense of distrust grows upon the more circumspect reader as he follows page after page of Macaulay's categorical affirmations about matters which our own experience of life teaches us to be of a contingent nature. We inevitably think of a saying attributed to Lord Melbourne, "I wish I were as cock-sure of any one thing as Macaulay is of everything." Macaulay's was the mind of the advocate, not of the philosopher; it was the mind of Bossuet, which admits no doubts or reserves itself and tolerates none in others, and as such was disqualified from that equitable balancing of evidence which is the primary function of the historian. It was a fortunate circumstance that rhetoric so powerful was enlisted in the constitutional cause,—that Macaulay was, as he himself has said of Bishop Burnet, "a strong party man on the right side."

Macaulay, the historian no less than the politician, is always on the side of justice, fairness for the weak against the strong, the oppressed against the oppressor. But though a Liberal in practical politics, he had not the reformer's temperament. The world as it is was good enough for him. The glories of wealth, rank, honours, literary fame, the elements of a vulgar happiness, made up his ideal of life. A successful man himself, every personage and every cause is judged by its success. "The brilliant Macaulay," says Emerson, "who expresses the tone of the English governing classes of the day, explicitly teaches that 'good' means good to eat, good to wear, material commodity." Macaulay is in accord with the average sentiment of orthodox and stereotyped humanity on the relative values of the objects and motives of human endeavour. And this commonplace materialism is one of the secrets of his popularity, and one of the qualities which guarantee that that popularity will be enduring.

Macaulay's whole works have been collected by his sister, Lady Charles Trevelyan, in eight volumes. The first four volumes are occupied by the *History*; the next three contain the *Essays*, and the *Lives* which he contributed to the *Encyclopædia Britannica*. In vol. viii. are collected his *Speeches*, the *Lays of Ancient Rome*, and some miscellaneous pieces. His life has been written by his nephew, George Otto Trevelyan (2 vols., London, 1878), and is one of the best biographies in the language. His diary remains in MS. in the hands of his family. It is to be hoped that measures will be taken to secure this valuable record from the fate that has overtaken so many private diaries, and thus impoverished the sources of English history. (M. P.)

MACAW, or, as formerly spelt, MACCAW,[1] the name given to some fifteen or more species of large, long-tailed birds of the Parrot Family, natives of the Neotropical Region, and forming a very well-known and easily-recognized group to which the generic designation *Ara* is usually applied by ornithologists, though some prefer for it *Macrocercus* or *Sittace*. Most of the Macaws are remarkable for their gaudy plumage, which exhibits the brightest scarlet, yellow, blue, and green in varying proportion and often in violent contrast, while a white visage often adds a very peculiar and expressive character.[2] With one exception the known species of *Ara* inhabit the mainland of America from Paraguay to Mexico, being especially abundant in Bolivia, where no fewer than seven of them (or nearly one half) have been found (*Proc. Zool. Soc.*, 1879, p. 634). The single extra-continental species, *A. tricolor*, is one of the most brilliantly coloured, and is peculiar to Cuba, where, according to Dr Gundlach (*Ornitologia Cubana*, p. 126), its numbers are rapidly decreasing, so that there is every chance of its becoming extinct.[3]

It will perhaps be enough here to dwell on the best known species of the group, and first the Blue-and-yellow Macaw, *A. ararauna*, which has an extensive range in South America from Guiana in the east to Colombia in the west, and southwards to Paraguay. Of large size, it is a bird to be seen in almost every zoological garden, and is very frequently kept alive in private houses, for its temper is pretty good, and it will become strongly attached to those who tend it. Its richly-coloured plumage, sufficiently indicated by its common English name, has the additional recommendation of supplying feathers which are eagerly sought by salmon-fishers for the making of artificial flies. Next may be mentioned the Red-and-blue Macaw, *A. macao*, which is even larger and more gorgeously clothed, for, besides the colours expressed in its ordinary appellation, yellow and green enter into its adornment. It inhabits Central as well as South America as far as Bolivia, and is also a common bird in captivity, though perhaps less often seen than the foregoing. The Red-and-yellow species, *A. chloroptera*, ranging from Panama to Brazil, is smaller, or at least has a shorter tail, and is not quite so usually met with in menageries. The Red-and-green, *A. militaris*, smaller again than the last, is not unfrequent in confinement, and presents the colours of the name it bears. This has the most northerly extension of habitat, occurring in Mexico and thence southwards to Bolivia. All the other species are comparatively rare in a reclaimed condition. Four of them, *A. hyacinthina*, *A. leari*, *A. glauca*, and *A. spixi*, are almost entirely blue, while in *A. manilata* and *A. nobilis* the prevailing colour is green, and *A. severa* is green and blue.

As is the case with most Neotropical birds, very little is known of the life history of Macaws in a state of nature. They are said to possess considerable power of flight, rising high in the air and travelling long distances in search of their food, which consists of various kinds of fruits; but of any special differences of habit we are wholly ignorant. The sexes appear in all cases to be alike in colouring, and the birds, though constantly paired, are said to live in companies. As with others of the Order *Psittaci*, the nest is made in a hollow tree, and the eggs, asserted to be two in number, are white without any lustre. Of the habits of these birds in confinement it is needless to speak, as they are so extremely well known. If caged, their long tail-feathers are sure to suffer, but chained by the leg to a perch, Macaws seem to enjoy themselves as well as any captive can, and will live for many years.

In our present state of ignorance as to the best mode of classifying Parrots, it would be premature to hazard any guess as to the place occupied in the Order by the genus *Ara*. (A. N.)

[1] Thus Willughby, *Ornithologia*, p. 73 (1676); but an earlier form of the word is found in the "great blew and yellow Parrat called the *Machao*, or *Cockatoon*" of Charleton, *Onomasticon*, p. 66 (1668). Its derivation is shown by De Laet, who, in his description of certain Brazilian birds (*Novus Orbis*, ed. 1633, p. 556), has "inter alios [*sc.* Psittacos] excellunt magnitudine & pulchritudine, quos barbari *Araras* & *Macaos* vocant," and again (*loc. cit.*) "Tertium locum meretur *Araruna* vel *Machao*." Webster, in his dictionary, says that Macaw, "written also Macao," is "the native name in the Antilles," but gives no authority for his statement, which, considering that one West Indian island only is known to possess a Macaw (and that in that island the bird is known as *Guacamayo*), is very unlikely. Some of the older writers, Buffon (*Oiseaux*, vi. p. 278) for instance, say that *Makavouanne* was the name given by natives of Guiana to one species of Macaw found in that country; but the Antillean origin of the name cannot at present be accepted.

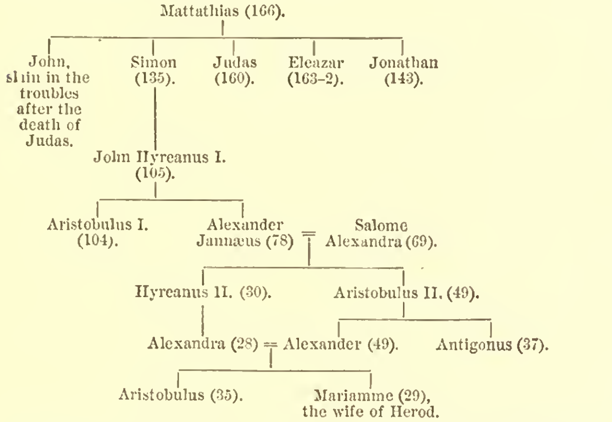
[2] This serves to separate the Macaws from the long-tailed Parrakeets of the New World (*Conurus*), to which they are very nearly allied.

[3] There is some reason to think that Jamaica may have formerly possessed a Macaw (though no example is known to exist), and if so it was most likely a peculiar species. Sloane (*Voyage*, ii. p. 297), after describing what he calls the "Great Maccaw" (*A. ararauna*, to be spoken of above), which he had seen in captivity in that island, mentions the "Small Maccaw" as being very common in the woods there, and Mr Gosse (*Birds of Jamaica*, p. 260) gives, on the authority of Robinson, a local naturalist of the last century, the description of a bird which cannot be reconciled with any species now known, though it must have evidently been allied to the Cuban *A. tricolor*.

MACBETH, MACBETHAD, or MACBEDA, son of Finnlaech, was king of Scotland from 1040 to 1057. He had previously been "mormaer" of Moravia or Moray; and his predecessor on the throne was Duncan, son of Crinan, and grandson of Malcolm, whom he slew (according to some accounts at "Bothgowan," said to have been near Elgin). Macbeth's wife was Gruoch, a descendant of the royal house. Of the events of his reign almost nothing is known. The ecclesiastical records of St Andrews bear that he and his wife, "rex et regina Scotorum," made over certain lands to the Culdees of Lochleven; and in 1050 he appears to have visited Rome, perhaps to obtain absolution for the murder of Duncan. The sons of Duncan, who had taken refuge with their uncle Siward, earl of Northumberland, brought about an invasion of Scotland in 1054; a battle was fought at Dunsinnane with indecisive results, but three years afterwards Macbeth fell at Lumphanan in Aberdeenshire (August 15, 1057). The war was continued for some time in the interests of a certain Lulach, the son of Queen Gruoch by a former marriage; but he too was slain in Strathbogie in March 1058, and Malcolm, the son of Duncan, ascended the throne.

See Skene, *Celtic Scotland*, vol. i. chap. 8; and compare Burton (*History of Scotland*, vol. i. chap. 10 *ad fin.*), who gives special prominence to the circumstance that when the genealogy of the Scottish kings is traced upwards the first break in the hereditary succession occurs when Macbeth is reached; the break of continuity at this point becomes all the more prominent when it is found that the father of Macbeth's successor had occupied the throne. "This had to be accounted for, and the easiest way was by treating the intruder as a 'usurper.' The loyal monks of the 15th century looked on a usurper with horror. Being so placed in the seat of political infamy, we have perhaps the reason why so many events, natural and supernatural, came to cluster round the career of Macbeth." It is most probable that Shakespeare's only source for the tragedy of *Macbeth* was the *Chronicles* of Holinshed (derived from John of Fordun and Hector Boece).

MACCABEES. The name Maccabee (Μακκαβαῖος) is properly and originally the distinguishing surname of Judas, son of Mattathias, the first great hero of the Jewish revolt against Antiochus Epiphanes. The source of the name is uncertain, but it is most natural to connect it with מַקָּב, "hammer," and so the Syriac writes the name with ק not כ. Ewald (*Gesch.*, iv. 403) is doubtless right in arguing from 1 Mac. vi. 43, &c., that the surnames of the sons of Mattathias were simply distinguishing epithets which they bore in ordinary life, and in this light "hammerman" appears as a natural surname enough, the occasion of which it would be vain to inquire into.[1] From Judas the name was in later times extended to the whole family, or to the party it represented, or even, as in the title of 3 Maccabees, to other contenders or sufferers for the faith of Israel in the Greek period. The more correct name of the family was Hasmoneans, Ἀσ[σ]αμωναῖοι, בית חשמונאי (Tgm. Jon. on 1 Sam. ii. 4). According to Josephus, *Ant.*, xii. 6, § 1, this name is taken from Asamonæus, the grandfather of Mattathias. Modern writers have suggested a connexion with the town Heshmon (Josh. xv. 27) or with חַשְׁמַנִּים, *magnates*, in Psalm lxviii. 31 [32]. The history of the Hasmoneans is given in Israel (vol. xiii. p. 421 *sq.*); in the appended genealogical tables (after Schürer) the dates are those of the death of each individual in years B.C.



The chief authorities are 1 and 2 Maccabees (see next article) and Josephus. For details as to other sources see Schürer's *Neutestamentliche Zeitgeschichte*, which gives also a good summary of the history. Of other works subsequent to Ewald's *Geschichte*, vol. iv., it is enough to name Derenbourg, *Histoire de la Palestine* (1867), and Wellhausen's *Pharisäer and Sadducäer* (1874). For the coins of the Hasmoneans see Madden, *Coins of the Jews*, 1881.

MACCABEES, Books of. Two books of this name are included among the Apocrypha of the English Bible, as they had formerly been in the Vulgate, and were accepted as canonical by the council of Trent. A third book is usually included in editions of the Septuagint, and is found in common with books iv. and v. in the Syriac, but never took a place in Latin Bibles; a fourth is found in some MSS. of the Septuagint (including the Sinaitic and Alexandrian—the Vatican does not contain the Maccabee books) and also in MSS. of Josephus, and has been printed in both connexions.

1 *Maccabees* was originally written in Hebrew, as appears, not only from the testimony of Jerome (*Prol. Gal.*), who had seen the Hebrew text, but from internal evidence. Josephus, however, already used the Greek,[2] and no trace of the Semitic original survives except the problematical title recorded by Origen (*ap.* Eus., *H. E.*, vi. 25).[3] The book gives the history of the national movement in Judæa from the accession of Antiochus Epiphanes (175 B.C.) to the murder of Simon (135 B.C.), in a plain and honest style, and evidently from good information. When the book was written there already existed a history of the reign or high priesthood of John Hyrcanus, to which the author refers for the continuation of his narrative. On the other hand, the friendly tone in which he always speaks of the Romans seems to justify the inference that he wrote before 63 B.C.[4]

2 *Maccabees*, covering the history from 176 B.C. to the victory over Nicanor (160 B.C.), is much inferior in value. It begins with two epistles which are certainly forgeries, and then proceeds to the task of summarizing in one book the five books of a certain Jason of Cyrene on the war of liberation against Antiochus Epiphanes. The narrative is a useful supplement to that in the first book, but is not nearly so trustworthy, and can never claim the preference where the two are in conflict. Geiger has shown that in 2 Maccabees the history is coloured and distorted by sympathy with the Pharisees, who became the bitter enemies of the Hasmoneans (*Urschrift und Uebers.*, book i. § 4).

3 *Maccabees* records a persecution of the Alexandrian Jews by Ptolemy IV. Philopator, with the ultimate repentance of the tyrant. It is quite unhistorical, and the local feast of the Alexandrian Jews, of which it professes to explain the origin (vi. 36), is connected by Josephus (*Cont. Ap.*, ii. 5) with an event that took place under Ptolemy Physcon. Ewald's conjecture that the story contains a hidden reference to the emperor Caius (*Gesch.*, iv. 611 *sq.*) has found considerable favour. It seems strange that this book should ever have found entrance in Christian circles. It had, however, considerable acceptance in the Eastern Church.

4 *Maccabees*, also known by the title περὶ αὐτοκράτορος λογίσμου, "on the sovereignty of reason," was ascribed to Josephus by Eusebius and Jerome. This opinion is now given up, and nothing certain can be said of its origin. It is a not uninteresting specimen of a Jewish philosophical theme composed under Stoic influence. The author illustrates the sovereignty of pious reason over the passions by historical examples, and is thus led to give anecdotes from the time of the Maccabees.

Fritzsche's edition of the Apocrypha (1871) is the best, and contains the four books of Maccabees. Grimm's commentary on 1 Mac. appeared in 1853, on the other three books in 1857. There is also a commentary on 1 Mac. by Keil, 1875. On 4 Mac. there is an elaborate study by Freudenthal, *Die Fl. Josephus beigelegte Schrift Ueber die Herrschaft der Vernunft*, Breslau, 1869. For further literature see Schürer, *NTliche Zeitgeschichte* (1874), pp. 19, 650 *sq.*, and his excellent article "Apokryphen" in Herzog-Plitt, *R.E.*, vol. i. An Arabic "Book of Maccabees," giving a compend of Jewish history from the affair of Heliodorus to the last part of Herod's reign, is printed in the Paris and London Polyglotts. A so-called "Fifth Book of Maccabees" is also contained in the great Ambrosian Peshito. It is in fact the sixth book of Josephus *De Bello Judaico*.

MACCLESFIELD, a municipal and parliamentary borough and market-town of Cheshire, England, is situated on a declivity near the borders of what is still known as the Macclesfield Forest, 17 miles south-south-east of Manchester, and 37 east-north-east of Chester. It consists

[1] One theory which has had much acceptance is that the name is made up of the initials of the first words of Exod. xv. 11. This is a pure guess, and requires the spelling מכבי or מכבאי found in the late work of Jos. ben Gorion. Equally unproved is the guess of S. J. Curtiss, resting on the Latin spelling Machabæus, that the word is properly from כבה, Isa. xliii. 17, the "quencher" or "queller" (*The Name Machabee*, Leipsic, 1876).

[2] Such at least is the current view (see Grimm, p. XXVIII *sq.*). J. D. Michaelis in his German translation of 1 Mac. argued that Josephus used the original; and a modified form of this view, viz., that he used an anonymous source resting on the original, has been put forth by Destinon (*Quellen des Fl. Josephus*, Kiel, 1882).

[3] This title is usually given σαρβὴθ σαρβανὲ ἔλ, and the attempts at decipherment, none of which are satisfactory (see Grimm's *Com.*, p. XVII; Derenbourg, *La Palestine*, p. 450 *sq.*), proceed from it. Heinichen, however, reads σαρβὴθ σαβαναιέλ, on overwhelming MS. authority, and in the Nitrian MS. used by Lagarde for his edition of the Syriac Apocrypha (*cf.* Wright's *Cat.*, i. 98), the title runs ספרא קדמיא דמקביא דמתקרין לות עבריא סרבסת סבעא איל. This seems to confirm Heinichen's reading (ע and נ being easily interchanged in Syrian MSS.). The sense may be "the prince of the house which God hath built up."

[4] Ewald (*Gesch.* iv. 436) and before him Whiston conjectured that Josephus did not possess the last part of the book. Destinon (*ut supra*, p. 80 *sq.*) develops this conjecture, and believes that the book originally ended with the liberation of Judæa under Simon, and that the interval between this book and the annals of Hyrcanus was filled up later.

of four principal streets, which meet in the market-place, and within the last twenty years has undergone great improvements. The old church of St Michael, on the brow of the hill, was founded by Eleanor, queen of Edward I., in 1278, and in 1740 was partly rebuilt and greatly enlarged. The lofty steeple by which its massive tower was formerly surmounted was battered down by the parliamentary forces during the civil war. Connected with the church there are two chapels, one of which, Rivers Chapel, belonged to a college of secular priests founded in 1501 by Thomas Savage, afterwards archbishop of York. Both the church and chapels contain several ancient monuments. For the free grammar school, originally founded in 1502 by Sir John Percival, and refounded in 1552 by Edward VI., a new building was erected in 1856 at a cost of £3000. A commercial school was erected in 1840 out of the funds of the grammar school. Among the other public buildings are the town-hall in the Grecian style (1823–24), with a new frontage (1869–70), the union workhouse (1843–44), the county lunatic asylum (1868–71), and the infirmary (1872). The neighbouring castle of the duke of Buckingham was the residence of Duke Humphrey in the 15th century. Originally the trade of Macclesfield was principally in twist and silk buttons, but this has been completely superseded by the manufacture of all kinds of silk. The first mill for silk-throwing was opened in 1756, and the manufacture of broad silks was introduced in 1790. Besides this staple trade, there are various textile manufactures and extensive breweries. The population of the municipal borough (3235 acres) in 1871 was 35,540, and of the parliamentary borough (3272 acres) 35,570. In 1881 the numbers were 37,514 and 37,620.

Previous to the Conquest, Macclesfield constituted a portion of the royal demesne of the earls of Mercia. At Domesday it was included in the earldom of Chester, and after the abolition of that jurisdiction it relapsed to the crown. In 1261 it was made a borough, and in 1678 it obtained incorporation from Charles II. It has returned two members to parliament since the first Reform Act, and its boundary was enlarged in 1868.

M'CLURE, Sir Robert John Le Mesurier, the discoverer of the North-West Passage, was born at Wexford, January 28, 1807, and died in London, October 17, 1873. He was the posthumous son of one of Abercrombie's captains, and spent his childhood under the care of his godfather, General Le Mesurier, hereditary governor of Alderney. Schooled in Arctic exploration by his service under Captain Back on board the "Terror," he was first lieutenant of the "Enterprise" during the Franklin search expedition (1848–49), and in 1850 was placed in command of the expedition which, battling with the frozen sea for four years, succeeded in passing from ocean to ocean to the north of the American continent. M'Clure was knighted on his return, and received gold medals from the English and the French geographical societies. During the Canadian insurrections of 1836–38 he had performed some gallant exploits on the lakes,—on one occasion, in the eagerness of pursuit, infringing the territory of the United States; and between 1856 and 1861 he rendered good service in the Chinese war at the storming of Canton, &c. His latter years were spent in a quiet country life. He was appointed Commander of the Bath in 1859, and had attained the rank of vice-admiral on the retired list. See Admiral Sherard Osborn, *The Discovery of a North-West Passage.*

M'CRIE, Thomas (1772–1835), was born at Dunse or Duns in Berwickshire, Scotland, November 1772. He studied in Edinburgh University, and thereafter in the divinity hall at Whitburn. In 1796 he was ordained minister of the Second Associate Congregation, Edinburgh, the place of worship being in the Potterrow.

At an early period in its history the Secession Church in Scotland had been divided by a controversy about the burgess oath into Burghers and Antiburghers; but towards the close of the century the Antiburgher Synod, to which M'Crie belonged, showed symptoms of a disposition to qualify adherence to the subordinate standards of the Church of Scotland on such points as the magistrate's power *circa sacra* and national covenanting, and a new historical manifesto was prepared called *The Narrative and Testimony*, which was adopted as a term of communion by the general synod in 1804. M'Crie was one of those who protested against this departure, as they deemed it, from Secession principles, and, declining to acknowledge the jurisdiction of the synod, constituted themselves into a presbytery under the name of "The Constitutional Associate Presbytery." M'Crie was in consequence deposed by the Associate Synod, and his congregation withdrew with him to a place of worship in the south side of the town, in which he officiated to the close of his life.

From the time of his settlement in Edinburgh, M'Crie devoted himself to historical investigations into the history, constitution, and polity of the churches of the Reformation; and the first ripe fruits of his study were given to the public in November 1811 in the form of *The Life of John Knox, containing illustrations of the History of the Reformation in Scotland*, which procured for the author the degree of D.D. from his alma mater, an honour conferred then for the first time upon a Scottish dissenting minister. At the solicitation of his friend Andrew Thomson, M'Crie became a contributor to *The Edinburgh Christian Instructor*, and in three successive numbers for 1817 he subjected Sir W. Scott's *Tales of my Landlord* to a criticism which took the form of a *Vindication of the Covenanters.* Preserving the continuity of his historical studies, he followed up his first work with *The Life of Andrew Melville*, 1819. Negotiations for union between the Burghers and Antiburghers resulted, in 1820, in the formation of the United Secession Synod, and called forth from Dr M'Crie *Two Discourses on the Unity of the Church, her Divisions, and their Removal*, in which what he considered to be the fallacious and unscriptural character of the plan for union adopted by the United Synod is pointed out. Several of his former brethren among the Antiburghers, dissatisfied with the union of 1820, had formed themselves into a separate synod, and between these and the Constitutional Presbytery a union was formed in 1827, the uniting bodies assuming the name of the Associate Synod of Original Seceders, of which branch of the Secession in Scotland M'Crie continued through the rest of his life the best known representative. In 1827 he published a *History of the Progress and Suppression of the Reformation in Italy in the 16th century*, and in 1829 a similar *History of the Reformation in Spain.*

Great as was his absorption in historical research, it did not prevent his taking a lively interest in the leading questions of the day; in pamphlets and on the platform he maintained his convictions, not always popular, on such matters as Greek independence, Catholic emancipation, the "Marrow" and "Voluntary" controversies, Irish education, and church patronage. His evidence on the last-named matter before a committee of the House of Commons is contained in the parliamentary publications of 1834.

The latest literary undertaking of M'Crie was a life of John Calvin. Although he had been gathering material for this project for several years, it was not till a late period of his life that, stimulated by the assistance of his son John, then in Geneva, he seriously addressed himself to the task. Only three chapters of the work were completed when the writer was struck down by apoplexy. He died on the 5th of August 1835.

In addition to the works the titles of which have been already given, Dr M'Crie published the following:—(1) *The Duty of Christian Societies towards each other, a Sermon*, 1797 (afterwards suppressed by the author, now extremely scarce); (2) *Statement of the Difference between the Profession of the Reformed Church of Scotland and the Profession contained in the New Testimony adopted by the General Associate Synod*, 1807; (3) *Free Thoughts on the late Religious Celebration of the Funeral of the Princess Charlotte*, 1817; (4) *Memoirs of Veitch and Brysson*, 1825; (5) *What Ought the General Assembly to do at the Present Crisis?* 1833. The posthumous publications are—(1) *Sermons*, 1836; (2) *Lectures on the Book of Esther*, 1838; (3) *Miscellaneous Writings*, 1841; (4) *The Early Years of John Calvin, a Fragment*, 1880.

An estimate of the services and a graphic description of the personal appearance of Dr M'Crie are to be found in *The Headship of Christ* (pp. 77–129), and in *My Schools and Schoolmasters* (chap. xvi.), both by Hugh Miller.

MACCULLAGH, James (1809–1846), one of the most elegant geometers of modern times, was born in 1809, near Strabane, Ireland. After an exceptionally brilliant undergraduate career in Trinity College, Dublin, he was elected fellow in 1832. From 1832 to 1843 he held the chair of mathematics; and during his tenure of this post, for which he was specially fitted, he improved in a most marked manner the position of his university as a mathematical centre. In 1843 he was transferred to the chair of natural philosophy, for which he was not nearly so well qualified. Overwork, mainly on subjects beyond the natural range of his powers, induced mental disease; and he died by his own hand in 1846. His *Works* have been published in a collected form (Dublin University Press Series, 1880). Their distinguishing feature is the geometry,—which has rarely been applied either to pure space problems or to known physical questions such as the rotation of a rigid solid or the properties of Fresnel's wave-surface with such singular elegance. In this respect his work takes rank with that of Poinsot. No higher praise could be given. One specially remarkable geometrical discovery of Maccullagh's is that of the "modular generation of surfaces of the second degree"; and a noteworthy contribution to physical optics is his "theorem of the polar plane." But his methods, which, in less known subjects, were almost entirely tentative, were altogether inadequate to the solution of the more profound physical problems to which his attention was mainly devoted, such as the theories of double refraction, of crystalline reflexion, &c. Here not only are the utmost powers of analysis required, but also the highest physical knowledge; and in consequence Maccullagh's work was entirely overshadowed by that of contemporaries, such as Cauchy and Green. See, on this point, Stokes's "Report on Double Refraction" (*B. A. Report*, 1862). The story of his later days painfully suggests the comparison of a high-bred but slight racer tearing itself to pieces in the vain endeavour to move a huge load, which a traction-engine could draw with ease and promptitude. He wasted, on problems altogether beyond his strength, powers of no common order, which, had they only been suitably directed, might have immensely extended our knowledge. Such, at least, is the estimate which we cannot avoid forming from a perusal of his published works. He had "conical refraction" in his hand for years without knowing its value. The reader who wishes to see the other side of the question (Maccullagh represented as standing to Fresnel in the same relative position as Newton to Kepler) is referred to the *Proceedings of the Royal Society*, vol. v. p. 712 (1847).

MACCULLOCH, Horatio (1805–1867), Scotch landscape painter, was born in Glasgow in 1805. An early friendship with Sir Daniel Macnee, and William Leitch, the water-colourist, was the means of turning the lad's attention to art, which he studied for a year under John Knox, a Glasgow landscapist of some repute, with whom Macnee was apprenticed at the time. After leaving the studio of Knox, we find him engaged at Cumnock, painting the ornamental lids of snuff-boxes in the manufactory of the Messrs Smith, and afterwards he was employed in Edinburgh by Lizars, the engraver, to colour the illustrations in Selby's *British Birds* and similar works. Meanwhile he was diligently prosecuting his studies in higher walks of art, and working unweariedly from nature, greatly influenced in his early practice by the water-colours of H. W. Williams,—"Grecian Williams" as he was called,—whose works had a charm for the young painter after the drier and more elaborate method of his first master. Returning to Glasgow in some four or five years, he was employed by Mr Lumsden, the lord provost, on several large pictures for the decoration of a public hall which he had erected in St George's Place, and he did a little as a theatrical scene-painter in Kilmarnock and other provincial towns. About this time he was greatly impressed with a picture by Thomson of Duddingston, and upon the works of this artist, the greatest Scottish landscapist that had yet appeared, the art of Macculloch may be said to have been founded. Gradually he asserted his individuality, and formed his own style on a closer study of nature than had been possible to his predecessor, and his works form an interesting link of connexion between the old world of Scottish landscape and the new. By its love of elaborate and balanced compositions, by its choice of noble and exceptional scenes, his art connects itself with that of sixty years ago; by its brilliant and varied colouring, by its care for detail, it differentiates itself from the quietude and the stately abstraction of the older landscape. In 1829 Macculloch first figured in the Royal Scottish Academy's exhibition, with a View of the Clyde, and, year by year, till his death on the 24th of June 1867, he was a liberal contributor to its displays. In 1838 he was elected a member of the Scottish Academy, and came to reside in Edinburgh, where his genial manners gathered round him a large and appreciative circle of the artists and litterateurs of the city.

Among the more important of the long series of landscapes which he produced, subjects almost exclusively from Scottish scenery, may be mentioned—Moonlight Deer Startled, 1840; Moor Scene, Sunset, 1841; A Dream of the Highlands, 1844; Inversnaid Ferry, Loch Lomond, 1847; A Highland Deer Forest, 1856; Ben Venue from Silver Strand, 1862; and Bothwell Castle, 1863. Several works by Macculloch were engraved by William Miller and William Forrest, and a volume of photographs from his landscapes, with an excellent biographical notice of the artist by Alexander Fraser, R.S.A., was published in Edinburgh in 1872.

MACCULLOCH, John (1773–1835), one of the most eminent geologists of his time, descended from the Maccullochs of Nether Ardwell in Galloway, was born in Guernsey, 6th October 1773, his mother being a native of that island. Having displayed remarkable powers as a boy, he was sent to study medicine in the university of Edinburgh, took his diploma there, and entered the army as assistant surgeon. Attaching himself to the artillery, he became chemist to the Board of Ordnance (1803), and thus began relations with the Government which materially affected his future career. He still continued, however, to practise for a time as a physician, and then resided at Blackheath. In the year 1811 he communicated his first papers to the Geological Society. They were devoted to an elucidation of the geological structure of Guernsey, of the Channel Islands, and of Heligoland. The evidence they afforded of his capacity, and the fact that he already had received a scientific appointment, probably led to his being selected by Government to make some geological and mineralogical investigations in Scotland. He was asked to report upon stones adapted for use in powder-mills, upon the suitability of the chief Scottish mountains for a repetition of the pendulum experiments previously conducted by Maskelyne and Playfair at Schiehallion, and on the deviations of the plumb-line along the meridian of the Trigonometrical Survey. In the course of the explorations necessary for the purposes of these reports he made extensive observations on the geology and mineralogy of Scotland. He formed also a collection of the mineral productions and rocks of that country, which he presented to the Geological Society in 1814. At that time comparatively little had been done in the investigation of Scottish geology. Finding the field so entirely his own, and so full of promise, he devoted himself to its cultivation with great ardour. One of his earliest and most important labours was the examination of the whole range of islands along the west of Scotland, at that time not easily visited, and presenting many obstacles to a scientific explorer. The results of this survey appeared (1819) in the form of his *Description of the Western Islands of Scotland, including the Isle of Man* (2 vols. 8vo, with an atlas of plates in 4to), which forms one of the classical treatises on British geology. He continued to write papers, chiefly on the rocks and minerals of Scotland, and had at last gathered so large an amount of information that the Government was prevailed upon in the year 1826 to employ him in the preparation of a geological map of Scotland. From that date up to the time of his death he returned each summer to Scotland and traversed every district of the kingdom, inserting the geological features upon Arrowsmith's map, which was the only one then available for his purpose. He lived to complete this great labour, and to prepare also a small volume explanatory of the map, but he died before these were published in 1836. Among his other works the following may be mentioned :—*A Geological Classification of Rocks, with Descriptive Synopses, comprising the Elements of Geology*, 1 vol. 8vo, 1821 ; *The Highlands and Western Islands of Scotland*, in a series of letters to Sir Walter Scott, 4 vols. 8vo, 1824 ; *A System of Geology, with a Theory of the Earth and an examination of its Connexion with the Sacred Records*, 2 vols. 8vo, 1831. His versatility of acquirement was shown by the publication also of works on malaria, remittent and intermittent diseases, the art of making wines, natural and revealed religion, besides numerous memoirs in various departments of natural history and antiquities. During a visit to Cornwall he was killed by being dragged along in the wheel of his carriage, 21st August 1835.

Dr Macculloch's name will ever be regarded with honour as one of the pioneers of geology in Britain. Essentially a mineralogist and petrographer, he was the first to trace out with some approach to truth the general distribution of the various rock-formations of Scotland. His temperament unhappily led him to look with jealousy and mistrust upon the labours of some of his more illustrious contemporaries, and even to ignore them in his published writings. In particular he appears to have been irritated by the rapid advances made by palæontological geology, and the increasingly large place given to that department of the science, while his own favourite domain of minerals and rocks was proportionately neglected. His feelings of dissent were strongly expressed in the posthumous memoir to accompany his map of Scotland ; but their bitterness may in part be attributed to the influence of failing health. Much hostile criticism was expended on his description of the manners and customs of the Highlanders, which were certainly amusing and picturesque, though sometimes his love of an effective period seems to have led him to exaggeration. The way in which he was appointed to conduct a geological survey of Scotland, unknown to the public bodies of that country, also led to considerable opposition. But the solid services rendered by Macculloch to the progress of geology must be regarded as far outweighing any objections that have been made to his literary work or peculiarities of character.

M'CULLOCH, John Ramsay (1779–1864), a distinguished writer on political economy and statistics, was born on 1st March 1779, at Whithorn in Wigtownshire. His family belonged to the class of "statesmen," or small landed proprietors. Having received his early education from his maternal grandfather, a Scotch clergyman, he came to Edinburgh, and was for some time employed there as a clerk in the office of a writer to the signet. But, the *Scotsman* newspaper having been established at the beginning of 1817, M'Culloch sent a contribution to the fourth number, the merit of which was at once recognized ; he soon became connected with the management of the paper, and during 1818 and 1819 acted as editor. Most of his articles in the *Scotsman* related to questions of political economy, and he delivered lectures in Edinburgh on that science. He now also began to write on subjects of the same class in the *Edinburgh Review*, his first contribution to that periodical being an article on Ricardo's *Principles of Political Economy* in 1818. Within the next few years he gave both public lectures and private instruction in London on political economy, and had amongst his hearers or pupils many persons of high social position, and some who were important in the political world. In 1823 he was chosen to fill the lectureship established by subscription in honour of the memory of Ricardo. A movement was set on foot in 1825 by Jeffrey and others to induce the Government to found in the university of Edinburgh a chair of political economy, separate from that of moral philosophy, the intention being to obtain the appointment for M'Culloch. This project fell to the ground ; but in 1828 he was made professor of political economy in the London University. He then fixed his residence permanently in London, where he continued his literary work, being now one of the regular writers in the *Edinburgh Review.* Indeed it appears from a letter of his to Macvey Napier in 1830 that he regarded himself, though Napier did not admit the justice of the claim, as entitled to be the sole contributor of economical articles to the *Review.* In 1838 he was appointed comptroller of Her Majesty's Stationery Office ; the duties of this position, which he held till his death, he discharged with conscientious fidelity, and introduced important reforms in the management of the department. Sir Robert Peel, in recognition of the services he had rendered to political science, conferred on him a literary pension of £200 per annum. He was elected a foreign associate of the Institute of France (Academy of Moral and Political Sciences). He died, after a short illness, on 11th November 1864, in the seventy-sixth year of his age. To his personal character and social qualities very favourable testimony is borne by those who knew him best. In general politics he always remained a Whig pure and simple ; though he was in intimate relations with James Mill and his circle, he never shared the Radical opinions of that group.

M'Culloch cannot be regarded as an original thinker on political economy. He did not contribute any new ideas to that science, or introduce any noteworthy correction of the views, either as to method or doctrine, generally accepted by the dominant school of his day. But the work he did must be pronounced, in relation to the wants of his time, a very valuable one. It was at an important crisis that he appeared in the field of economical discussion. The principles of free trade had been powerfully asserted before the public in the celebrated petition of the merchants of London, drawn up by Mr Tooke and presented to parliament by Mr Alexander Baring in 1820. Political economy, to which the bullion controversy had previously attracted much attention, was more and more engaging the minds of political writers and of statesmen. But the new views had to encounter fierce and sometimes unscrupulous opposition. The *Edinburgh Review* was the principal organ of the reformers, and was maintaining, when M'Culloch became a writer in it, an energetic warfare against the policy founded on the mercantile theory of wealth. Naturally endowed with strong sense and sagacity, and possessing a rare capacity for arduous and prolonged mental exertion, he threw himself, with the ardour of conviction, into the great struggle. There can be no doubt that his labours on the whole contributed largely to the diffusion of just ideas on the economic questions then under debate, and to the right direction of the national legislation with respect to them. It must at the same time be admitted that his treatment of the subjects with which he dealt is not marked by any special breadth or elevation. He adopted too hastily the theoretic exaggerations of some of Smith's successors, and exhibited in full measure their habitual deadness, in the study of social questions, to all but material considerations. In his evidence before the parliamentary committee on the state of Ireland in 1825 he stated opinions, afterwards more fully asserted in the *Edinburgh Review*, on the subject of Irish absenteeism, which tended to disgust persons of intelligence and right feeling with a science which, as interpreted by him, seemed to lead to practical absurdities, and in other quarters had, it is to be feared, the effect of supplying a plausible excuse for carelessness on the part of the rich and great with respect to the inferior classes of society. These opinions could not be justified even on strictly economic grounds, as has since been shown by Longfield and Senior. M'Culloch had in him an element of intellectual wilfulness or perverse self-assertion, compared by his friends and admirers to the despotic dogmatism of Johnson, which both in conversation and in his writings led him into the enunciation and defence of paradoxes; a notable example of this is furnished by the obstinacy with which to the last, in the teeth of evidence, he clung to the doctrine of the impolicy of cheap postage. M'Culloch was deficient in literary taste, and never attained any high degree of excellence in style. His expression is often slipshod, and a certain coarseness in his images sometimes throws an air of vulgarity over his pages. His name will probably be less permanently associated with anything he has written on economic science, strictly so called, than with his great statistical and other compilations. His *Dictionary of Commerce and Commercial Navigation* and his *Statistical Account of the British Empire*—however they may be expanded and altered, as they have already been, in successive editions—will long remain imposing monuments of his extensive and varied knowledge and his indefatigable industry. Another useful work of reference, also the fruit of wide erudition and much labour, is his *Literature of Political Economy*. Though weak on the side of the foreign literature of the science, it is very valuable as a guide to British writers, and, in relation to its entire field, has not yet been superseded by any English book.

The following is as complete a list of his publications as it has been found possible to form:—*An Essay on the Reduction of the Interest on the National Debt*, 1816; *An Essay on the question of Reducing the Interest on the National Debt*, 1816; *A Discourse on the Rise, Progress, Peculiar Objects, and Importance of Political Economy*, 1824; the article POLITICAL ECONOMY in the supplement to the 6th edition of the *Encyclopædia Britannica*, afterwards enlarged into *The Principles of Political Economy, with a sketch of the Rise and Progress of the Science*, 1830, and again 1843, 1849 (translated into French by Augustin Planche, 1851); *Dictionary, Practical, Theoretical, and Historical, of Commerce and Commercial Navigation*, 1832; *Statistical Account of the British Empire*, 1837; *Dictionary, Geographical, Statistical, and Historical, of the various Countries, Places, and Natural Objects in the World*, 1841–42 (several editions of the last three have since appeared, and the first two of them have been reprinted in the United States, and translated into foreign languages); *Statements illustrative of the Policy and probable Consequences of the proposed Repeal of the existing Corn-Laws and the Imposition in their stead of a moderate Fixed Duty on Foreign Corn*, 1841; *Memorandums on the proposed Importation of Foreign Beef and Live Stock*, 1842; *A Treatise on the Principles and Practical Influence of Taxation and the Funding System*, 1845; *The Literature of Political Economy*, 1845; *A Treatise on the Succession to Property Vacant by Death*, 1848; *Treatise on the Circumstances which determine the Rate of Wages and the Condition of the Labouring Classes*, 1851 (an earlier edition had appeared anonymously in 1826); *Considerations on Partnership with Limited Liability*, 1856; perfaces and notes to a select collection, in 4 vols. of scarce and valuable economical tracts, reprinted at Lord Overstone's expense, 1856–59. He united in one volume (2d ed., 1859) a number of his minor *Treatises and Essays on subjects connected with Economic Policy*, many of which had appeared as articles in the *Encyclopædia Britannica*. He also printed, for private distribution amongst his friends, a catalogue of his library,—which contained a fine collection of books on his own special subjects,—adding critical and biographical notices. He had edited in 1828 Smith's *Wealth of Nations*, with a life of the author, an introductory discourse, notes, and supplemental dissertations; this work he greatly enlarged and improved in the editions of 1838 and 1850. In 1846 he edited Ricardo's works, with a notice of the life and writings of the author. (J. K. I.)

MACDONALD, ÉTIENNE-JACQUES-JOSEPH-ALEXANDRE (1765–1840), duke of Taranto, and marshal of France, was born at Sancerre on November 17, 1765. His father came of an old Jacobite family, which had followed James II. to France, and was a near relative of the celebrated Flora Macdonald (1722–1790), the heroine whose courage and fidelity were at one critical period the sole means by which Prince Charles Edward was enabled to elude his enemies after the defeat of Culloden in 1746. In 1784 Macdonald joined the legion raised by the second Marshal Maillebois to support the revolutionary party in Holland against the Prussians, and after it was disbanded he received a commission in the regiment of Dillon. On the breaking out of the Revolution, the regiment of Dillon remained eminently loyal, nearly all its officers emigrating with the princes, with the exception of Macdonald, who was in love with a Mademoiselle Jacob, whose father was enthusiastic for the doctrines of the Revolution. His love was successful, and directly after his marriage he was appointed aide-de-camp to General Dumouriez. He also distinguished himself at Jemmapes, and was promoted colonel in 1794. He refused to desert to the Austrians with Dumouriez, and as a reward was made general of brigade, and appointed to command the leading brigade in Pichegru's invasion of Holland. His knowledge of the country proved most useful, and he was instrumental in the capture of the Dutch fleet by the French hussars. In 1797 he was made general of division, and transferred first to the army of the Rhine and then to that of Italy. When he reached Italy, the peace of Campo Formio had been signed, and General Bonaparte had returned to France; but, under the direction of Berthier, Macdonald first occupied Rome, of which he was made governor, and then in conjunction with Championnet he defeated General Mack, and revolutionized the kingdom of Naples under the title of the Parthenopæan Republic. When Suwaroff invaded northern Italy, and was winning back the conquests of Bonaparte, General Macdonald collected all the troops in the peninsula and moved northwards. With but 30,000 men he attacked, at the Trebbia, Suwaroff with 50,000, and after three days' fighting, during which he held the Russians at bay, and gave time for Moreau to come up, he retired in good order to Genoa. After this gallant behaviour he was made governor of Versailles, and acquiesced in, if he did not co-operate in, the events of the 18th Brumaire. In 1800 he received the command of the army in Switzerland which was to maintain the communications between the armies of Germany and of Italy. He carried out his orders to the letter, and at last, in the winter of 1800–1, he was ordered to march over the Splügen Pass. This achievement is fully described by Mathieu Dumas, who was chief of his staff, and is at least as noteworthy as Bonaparte's famous passage of the Saint Bernard before Marengo, though followed by no such successful battle. On his return to Paris he married the widow of General Joubert, and was appointed French plenipotentiary in Denmark. Returning in 1805 he associated himself with Moreau, and incurred the dislike of Napoleon, who did not include him in his first creation of marshals. Till 1809 he remained without employment, but in that year Napoleon, hard pressed at Aspern, gave Macdonald the command of a division in the army of the viceroy of Italy which was to march from Italy to his help. He led the army from Italy till its junction with Napoleon, and at Wagram commanded the attack on the Austrian centre which won the victory. Napoleon made him marshal of France on the field of battle, and presently created him duke of Taranto. In 1810 he served in Spain, and in 1812 he commanded the left wing of the grand army for the invasion of Russia. After sharing in the battles of Lützen and Bautzen, he was ordered to invade Silesia, where Blücher defeated him with great loss at the Katzbach. After the terrible battle of Leipsic he was ordered with Prince Poniatowski to cover the evacuation of Leipsic, and after the blowing up of the bridge, he managed to swim the Elster, while Poniatowski was drowned. During the defensive campaign of 1814 Macdonald again distinguished himself, and was one of the marshals sent by Napoleon to take his abdication in favour of his son to Paris. When all were deserting their old master, Macdonald remained faithful to him. Macdonald was directed by Napoleon to give in his adherence to the new régime, and was presented by him with the sabre of Murad Bey for his fidelity. He was made a peer of France at the Restoration, and, having once passed his word to the new order of things, remained faithful during the Hundred Days. In 1816 he became chancellor of the Legion of Honour, a post he held till 1831, and took a great part in the discussions in the House of Peers. In 1823 he married Mademoiselle de Bourgony, and at last had a son, Alexander, who succeeded on his death in 1840 as duke of Taranto. From 1830 his life was spent in retirement at his country place Courcelles.

Macdonald had none of that military genius which distinguished Davoust, Masséna, and especially Ney, nor of that military science conspicuous in Marmont and St Cyr, but nevertheless his campaign in Switzerland gives him a rank far superior to such mere generals of division as Oudinot and Dupont. This capacity for independent command made Napoleon, in spite of his defeats at the Trebbia and the Katzbach, trust him with large corps d'armée till the end of his career. As a man, his character cannot be spoken of too highly; no stain of cruelty or faithlessness rests on him. He retained always the frank honour of a soldier of fortune; but he never forgot that he was a gentleman, or disgraced the new nobility of Napoleon by ridiculous pretensions.

Macdonald was especially fortunate in the accounts of his military exploits, Mathieu Dumas and Ségur having been on his staff in Switzerland. See Dumas, *Événements Militaires*; and Ségur's rare tract, *Lettre sur la campagne du Général Macdonald dans les Grisons en* 1800 *et* 1801 (1802). Also consult Pelet's excellent *Campagne de* 1809, and Ségur's *Éloge* (1842).

MACDONALD, Lawrence (1798–1878), sculptor, was born at Gask, Perthshire, Scotland, in 1798, and in early life served as a mason's apprentice. Having shown an aptitude for stone carving, he went while still a youth to Edinburgh as an art student at the Trustees' Academy, finding at the same time a good deal of occasional employment in carving coats of arms and other ornamental figures on the gateways or walls of country houses. By the help of friends he was enabled to visit Rome, whence, after a stay of two or three years, he returned to Edinburgh in 1826. During the next few years he executed a considerable number of commissions for busts, and also devoted a good deal of time to the designing of ideal subjects, in which branch of his art, however, the public interest was comparatively slight. From 1832 until his death on March 4, 1878, his home was in Rome; during the long period of forty-six years his chisel never rested, and the number of works that issued from his studio, chiefly in the department of portrait sculpture, was very great. Among his ideal works may be mentioned Ulysses and his Dog Argos, Andromeda chained to the Rock, Eurydice, Hyacinth, a Siren, and a Bacchante. His busts, while excellent as likenesses, are remarkable for purity and dignity of style; and the ideal works are at once full of grace and carefully correct in form, design, and treatment.

Plate III. MACEDONIA, when that name is taken in its widest signification, is the country between Thrace on the east and Illyria on the west, bounded on the S. by Thessaly and the Ægean Sea, and on the N. by the lands which belong to the basin of the Danube. The most definite limit in its physical geography is that towards Illyria, where the Scardus range, which still bears the name of *Schar*, forms a continuous barrier between the two countries; on the side of Thessaly also, Mount Olympus and the Cambunian mountains constitute a well-marked frontier. In the other two directions its natural limits are less clearly defined. Towards the east, during the greater part of its history, the river Strymon was regarded as its proper boundary; but after the foundation of the city of Philippi it encroached on Thrace, and extended as far as the river Nestus, or even Mount Rhodope. With regard to the features of the country immediately to the north of Macedonia a misconception long prevailed, which has only of late years been dispelled by geographical research. Owing to a misinterpretation of a passage in Strabo (vii. fragm. 10; *cf.* vii. 5, 1), it was long believed that the country between the Danube and the Ægean was divided in the middle by a lofty range of mountains, which formed a continuation of the main chain of the Alps as far as the Euxine; and this mistake is perpetuated in many of our maps at the present day. But since this district has been explored, first by Grisebach, and afterwards by Von Hahn, it has been known that along one important portion of this supposed line, directly to the north of Macedonia and south-east of the modern principality of Servia, the hills do not rise to any considerable elevation, and that affluents of the Margus (Morava), which flows into the Danube, and of the Axius (Vardar), which runs to the Ægean, rise close together in the upland plain of Kossova, the scene of the great battle in which the Servian monarchy was overthrown by Sultan Amurath I. in 1389. This watershed may be regarded as the northern boundary of Macedonia. But the extended limits which have here been given did not belong to the district that bore that name in early times. The original Macedonia was confined to the inland region west of the Axius, between that river and the Scardus mountains, and did not include the northern portion, which was known as Pæonia, or the coast-land which, together with the eastern districts, was inhabited by Thracian tribes, and was regarded by the Greeks at the time of the Peloponnesian war as part of Thrace. The people of this country were not Hellenic, though its rulers ultimately succeeded in claiming that title for themselves, at the time when Alexander I. was admitted as a competitor at the Olympic games. The same thing may be said of the land itself, the appearance of which presents many points of contrast to that of Greece proper. Instead of the delicate, bright, and varied scenery of that country, with its clear atmosphere and sharp outlines, we find in Macedonia broad masses of mountains, extensive sweeps of lowland, and uniformity of colour. The climate of the inland regions also is severe, so that the cypress and other trees which flourish in Greece will not grow there.

The river Axius divides Macedonia into two parts, the eastern of which resembles the neighbouring country of Thrace in the irregularity of its surface; but in the western part there is a succession of valley-plains, generally elevated themselves, though deeply sunk among the rocky walls that surround them. These lie under the flanks of Mount Scardus, and differ in a still more striking manner from the country of Illyria on the further side of that chain, which is made up of a number of irregular, and usually narrow, river-valleys, separated from one another by rugged mountains. The characteristics of these valley-plains are the well-defined basins in which they lie, their rich alluvial soil, and the river which waters each of them respectively, and in each case makes its exit through a narrow passage, which is its only means of escape. The northernmost and smallest of these is now called the Tettovo, and from it the main stream of the Axius issues. At the southern extremity of this a branch detaches itself from the Scardus, and bending southward forms an important secondary chain, which is continued until, under the name of Bermius, it approaches Mount Olympus. This branch, in the upper part of its range, forms the eastern boundary of the second and most important valley-plain, that of Pelagonia (now the plain of Monastir), from which the Erigon (Czerna) forces its way to join the Axius. This plain, which is 40 miles in length by 10 in breadth, and 1500 feet above the sea, was one of the primitive seats of the Macedonian race, and was suited for developing a hardy yet thriving population which might afterwards become a great people. Here is laid the scene of the story of the foundation of the Macedonian monarchy, which Herodotus has related (viii. 137, 138). According to this, three brothers of the family of the Temenidæ of Argos, having entered the service of the king of the country, and having been defrauded by him of their wages, made their escape in a romantic manner, the narrative of which contains numerous fabulous incidents, and ultimately conquered all Macedonia. The southern part of this plain was called Lyncestis, and was the scene of the encounter between Brasidas and the Illyrians, which Thucydides has described (iv. 124–28); the famous retreat of that general was made by the pass at its south-eastern extremity.

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Between Lyncestis and the lowlands, near the coast, is a lake district of somewhat inferior elevation, which bore the name of Eordæa. Again, to the southward of Pelagonia is another extensive plain, from which the Haliacmon (Vistritza) draws its waters; that river ultimately breaks through the Bermian range behind Berrhœa (Verria), and flows into the Thermaic Gulf. The coast district between the Haliacmon and Olympus, as well as the sea-slopes of that mountain, formed Pieria, the original home of the Muses. The chief cities of Pieria were Pydna, where Perseus, the last king of Macedon, was defeated by the Romans, and Dium. From this neighbourhood to the head of the Thermaic Gulf a vast maritime plain extended, which was intersected by the Lydias and the Axius, as well as the Haliacmon.

The Scardus chain, which has been spoken of as separating Macedonia from Illyria, is the northern continuation of Pindus, and the two together form a well-defined backbone, which may be compared to the *spina* of an ancient circus. At its northern extremity, where it rises from the plain of Kossova, stands a lofty peak, which, to carry out the comparison, may be called the *meta* or goal of the circus. This summit, which reaches a height of between 7000 and 8000 feet, had no name in antiquity, but is now known by the Slavonic appellation of Liubatrin, or the "Lovely Thorn." The mountain wall which starts from it presents a most imposing appearance from every point of view, and is broken through at only one point, where the river now called Devol, rising on its eastern side, divides it to its base as it flows to the Adriatic. Here the chain of Scardus ends, and that of Pindus commences. Northward of this it is crossed by two passes,—one near the headwaters of the Axius, between the modern towns of Prisrend and Calcandele; the other farther to the south, leading from the head of the Lacus Lychnitis (Lake of Ochrida) into the Pelagonian plain. At the southern end of this plain another chain diverges from Scardus, and takes an easterly direction through Macedonia; in the region between the Strymon and Nestus this was called Orbelus, and between it and the sea lies Mount Pangæus, which was famed for its gold and silver mines.

The rivers of this country, notwithstanding that they are larger than any that are found in Greece proper, can hardly be called navigable, though barges are floated down them at the present day. The Axius, which is the most important, is celebrated by Homer, on account of its fertilizing water, as "the fairest stream that flows in all the earth" (*Il.*, ii. 850), and the valley in which it runs must always have formed a line of communication between the barbarous districts of the interior and the sea. The point of demarcation between the uplands and the lowlands is marked by the Stena, or, as it is now called, the Iron Gate (Demir Kapu) of the Vardar. Here the river cuts through at right angles the mountains that join the Scardus and Orbelus ranges, and forms a deep ravine, through which it rushes in rapids for the distance of a quarter of a mile, beneath steep cliffs that rise to the height of 600 or 700 feet above; and traces of groovings in the rocks are visible, where a passage has been made in ancient times. At the point in its upper course where it receives its northern tributaries, and begins to bend towards the south, stood the town of Scupi, the name of which was changed by the Byzantines into Scopia, or "the look-out place," and has now been corrupted into Uskiub. The importance of this consisted in its neighbourhood to the pass over the Scardus, by which the barbarian tribes to the west used to descend into the more level and fertile country, and in its commanding the principal line of traffic. Between Scupi and the Stena, at the confluence of the Axius and the Erigon, was Stobi, the ruins of which have recently been discovered by M. Heuzey, of the French "Mission de Macédoine." This town was in Roman times the meeting-point of four great roads—one from the Danube by Scupi; another from Sardica, near the modern Sophia, to the north-east; a third from Heraclea (Monastir) to the south-west; and a fourth from Thessalonica. The Strymon (Struma) follows a direction nearly parallel to the Axius in eastern Macedonia, and, after passing through the chain of Orbelus, enters the rich plain of Serrhæ (Seres), and flows into the Lake of Prasias or Cercinitis, shortly after emerging from which it reaches the sea. On the shores of the Lake Prasias were a number of lacustrine habitations which Herodotus has described, corresponding in their general features to those of which so considerable remains have recently been discovered in Switzerland and elsewhere. At the point where the Strymon leaves the lake was built the important town of Amphipolis, which was surrounded on three sides by the river, thus occupying a very strong position. It was founded by the Athenians in 437 B.C., and was valuable on account of its neighbourhood to the mines of Pangæus, and as furnishing a large supply of timber. Its port, at the mouth of the Strymon, was called Eion. The ancient capital of Macedonia, Ægæ or Edessa (Vodena), stood at the point where the passes from Lyncestis and Eordæa emerge into the lower country. Its situation seems to suggest dominion; for, while it has at its back all the resources of the richest districts, the view from it embraces the wide maritime plain, the mighty mass of Olympus, and a portion of the Thermaic Gulf. The site, which resembles that of Tivoli, is one of extreme beauty, for below the level table of land on which the city is built the rock falls some 200 feet in steep precipices, and the river which passes through it, a tributary of the Lydias, divides into a number of smaller streams, which plunge at various points in cascades down the cliffs. When Philip of Macedon transferred the seat of government to Pella, Edessa continued to be the national hearth of the race, and the burial-place of their kings. Pella, the later capital, occupied a much inferior position, being on low hills at the edge of an extensive marsh in the middle of the maritime plain. This was naturally an unhealthy site, and its only strength lay in its swampy surroundings; so that its nearness to the sea must have been its chief recommendation. The place is now deserted, but the name of Pel is still attached to its vicinity. In Roman times Thessalonica became the chief centre of these parts, which at all times it deserves to be, for it is admirably placed for purposes of communication and trade, as it lies on the innermost bay of the Thermaic Gulf, and forms the natural point of transit for exports and imports. Its appearance recalls that of Genoa, from the way in which the houses rise from the water's edge, and ascend the hill-sides behind. This city was the terminus of the Via Egnatia, the great Roman road which joined the Adriatic and the Ægean, and formed the main line of communication between the West and the East. Starting from Dyrrhachium, it threaded the defiles of Illyria, and, passing the Lacus Lychnitis, crossed the Scardus by the southernmost of its two passes, which descends on Heraclea; thence it traversed Lyncestis and Eordæa, till it reached Edessa, and finally crossed the plain to Thessalonica.

It remains to speak of the maritime district of Macedonia, called Chalcidice, which projects like a trident into the north of the Ægean between the Thermaic and Strymonic Gulfs. When seen on the map, it strikingly resembles the Peloponnese in miniature, from its three southern promontories, with deep intervening bays, and the massive breadth of ground from which these spring. This resemblance is still further borne out in the form of the mountains and their vegetation; and in most respects it corresponds so well to what the Greeks desired for their settlements that we cannot be surprised at finding its shores fringed with Hellenic colonies. Several of these were founded from Chalcis in Eubœa, which city gave its name to the district; but the important town of Potidæa was a Corinthian colony. The most eastern of the three peninsulas, that of Acte, is far the highest, and rises from its isthmus until it forms a steep central ridge, which gradually attains the height of 4000 feet, and finally throws up the vast conical peak of Mount Athos (6400 feet). The isthmus, which is about a mile and a half broad, still shows traces of the canal made by Xerxes for the passage of his fleet, in order to avoid the dangers of shipwreck on the rocks of Athos, which had destroyed the expedition of Mardonius. On the land side of the isthmus stood the city of Acanthus. Separated from Acte by the Singitic Gulf was the promontory of Sithonia, with the town of Toronė; and still farther to the west, beyond the Toronaic Gulf, was that of Pallene. The former of these, though of lower elevation than Acte, is intersected by a well-marked ridge; but the latter is almost level, and from the traces of volcanic action that are found there was called by the Greeks Phlegra, and was said to have been the scene of the conflict between the giants and the gods. On the southern side of Pallene were the towns of Mende and Scione, and its isthmus was occupied by Potidæa, near which, at the head of the Toronaic Gulf, stood Olynthus. The Greek cities on this coast were a continual thorn in the side of the Macedonian monarchs, and caused them to take part against Athens during the Peloponnesian War. The northern part of Chalcidice is mountainous, and beyond these mountains is a considerable depression, in which lies the Lake of Bolbe.

Macedonia first comes into notice in history in the reign of Amyntas (about 500 B.C.) and in that of his son Alexander, who was king at the time of Xerxes's invasion of Greece. But whatever historical interest attaches to it is due rather to the great empire which sprang from it than to the importance of the country itself. During the Peloponnesian War we notice it chiefly as it affects the principal contending parties, but in the time of Demosthenes it attracts our attention as furnishing the keynote of the policy of that statesman, and being the proximate cause of the overthrow of Greek liberty. After the MACEDONIAN EMPIRE (*q.v.*) was subjugated by the Romans in 168 B.C., the country was left with a nominal autonomy, but lost its national unity by being divided into four districts, which were separated from one another by rigid political and social limitations. Before long it was reduced to the form of a province, and this, at the division of the provinces in the time of Augustus, was assigned to the senate. Thenceforward it followed the fortunes of the Roman empire, and, after the partition of that dominion, of the eastern branch of it. In the time of Alaric it was frequently plundered by the Goths, and in the interval which elapsed between Justinian I. and Heraclius a considerable part of it was colonized by Slavonians. During the prosperous period of the great Bulgarian monarchy in the 10th century a large portion of Macedonia was included in that kingdom. After that age extensive depopulation must have ensued, for in the 11th and 12th centuries colonies of various tribes of Asiatic origin—Uzes, Turks, and Patzinaks—were established there by the emperors of Constantinople. In the partition of the Eastern empire, which followed the capture of that city by the Latins at the time of the fourth crusade, in 1204, Macedonia was assigned to Boniface, marquis of Monferrat, who assumed the title of king of Saloniki. This kingdom in turn was brought to an end in 1224 by the Greek despot of Epirus, Theodore I., and by him a Greek empire of Thessalonica was founded, which for a time seemed likely to become the heir of the Byzantine power, but afterwards was merged in that of Nicæa, and on the recapture of Constantinople by Michael Palæologus once more formed part of a united Greek empire. In the latter half of the 14th century the greater part of Macedonia was in the possession of the Servians, whose kingdom was now at the height of its power; but before the middle of the 15th it had passed into the hands of the Ottoman Turks, by whom it has been held ever since. At the present day the population of the inland part of the country is mainly composed of Bulgarian Christians, mixed with Turks, while the Greeks occupy the coasts, the whole of Chalcidice, the plain of Seres, and some other districts. (H. F. T.)

MACEDONIAN EMPIRE, THE. The attention of the Greeks was drawn at an early time to the danger that the northern tribes might combine to invade the south. Sitalces, king of Thrace, spread great alarm by an inroad during the Peloponnesian War, but the real peril was from Macedonia rather than from Thrace. The Macedonians had been gradually pushing their way down towards the coast, and, though Alexander I. was a vassal of Xerxes, the retreat of the Persians, 478 B.C., left these hardy tribes free. They were still in a primitive state, mountain shepherds, ill clothed and ill housed, many of them clad only in skins. They wore the kausia or broad-brimmed hat; they ate and drank from wooden platters and cups; they differed little from what they had been when the first Perdiccas came to the country, when the king's wife baked cakes with her own hand on the hearth. But the peasants were freemen, not serfs like the Penestæ of Thessaly. It was still necessary for the young warrior to slay a foe before he could take his place in the tribe; and Cassander had to sit instead of reclining at the banquet of his father Antipater, because he had not yet killed a wild boar. The drunken bouts at these banquets led to some of the deeds which are a blot on the fame of both Philip and Alexander. The king held large domains, and had a choice body of "companions" around him, but the warriors used much freedom of speech towards him, and the chiefs could only be condemned by the assembled host. When, however, any one was thus convicted of treason, his kindred were also put to death. If any blood guilt was incurred, a dog was cut in two and the soldiers passed between the halves laid out in the open air, that so they might be purified. There were still but few towns, or even strongholds, to which the people could fly when the Illyrians came in over Mount Bermius from the west, or the Thracians across the Strymon from the east, or the Pæonians down the river Axius from the north. The western tribes too were at this time being pushed onward into Macedonia by a migration of the Gauls. Archelaus, son of Perdiccas II., however, built forts, cut straight roads, and collected horses and arms. The cavalry of the richer landowners was good; but the foot soldiers were armed only with wicker shields and rusty swords. Archelaus also courted the friendship of leading Athenian statesmen, philosophers, and poets; and later on the Athenian general Iphicrates did essential service to the royal house.

But the advance made by Archelaus, who died 399 B.C., was almost all lost before Philip II. came to the throne, and the kingdom was reduced to a narrow district round Edessa, shut out from the sea by Greek cities. Olynthus, the chief of these cities, had in the reign of Philip's father, Amyntas II., induced many places to make themselves independent of the king, but the jealousy of Sparta proved fatal to the Olynthian confederacy, and destroyed what would have been a bulwark against the barbarians of the north (379).

Philip himself had the best of all trainings, that of adversity. During the reign of his eldest brother Alexander II., Pelopidas took hostages for the fidelity of Macedonia, and among them was Philip, then about fifteen years old. He remained two or three years at Thebes, profiting by literary training, and above all by the living example of Epaminondas, the ablest organizer and most scientific tactician of the age, who had trained the soldiers that broke through the Spartan line at Leuctra. When Philip returned home, his brother Perdiccas III. entrusted him with the government of a district, where he organized a force on the Theban model. On the death of Perdiccas, though he left an infant son Amyntas, Philip was called to the throne (359), for the reign of a child in an early state of society means anarchy. Philip's energy soon made itself felt. He fortified a new capital, Pella, safe amidst its lake-like marshes, from which he could act against the coast. Greece was at the moment completely disorganized. Sparta had lost, not only her supremacy over the other Greek states, but the control over Messenia and Arcadia, which leant on Thebes for defence against her revenge. Thebes had incurred odium from her conduct towards the free cities of Bœotia, was at feud with Athens, and had but a precarious hold over Phocis and Thessaly; while Thessaly itself, after the fall of the tyrants of Pheræ, was a prey to internal feuds. Athens was the first to come into collision with Philip, owing to her holding possessions on the coast of Macedonia and Thrace, whence she procured ship timber and naval stores. Philip had conciliated her for the time by withdrawing his troops from Amphipolis, her old colony in the bend of the river Strymon, while he was driving off the Illyrians and reducing the tribes to the west as far as the Lake Lychnitis. But Athens was at this moment threatened by the revolt of her allies which led to the Social War, and so lost the chance of reoccupying Amphipolis while Philip was busied in the interior. The moment his hands were free, he retook the place, which was all-important to him, as it was not only the most convenient maritime station in Thrace, but also threw open to him all the country east of the Strymon, and especially the gold region near Mount Pangæus, the productive country facing the island of Thasos; and to secure his conquests he founded a new city in the interior called Philippi. His gold coins, struck on the Attic standard, soon became well known, and even the early gold coins of distant Britain copied the types of the Macedonian money. He also took Pydna and Potidæa, thus depriving Athens of her hold on the Thermaic Gulf, while the occupation of Methone opened the way into Thessaly. Moreover, the Social War had not yet ended when the disastrous Sacred War began, which added religious to political enmity, and benefited only the aggressor from the north. The Amphictyonic League was called into activity to crush the Phocians, who in their despair seized Delphi, and by the use of its treasures collected troops enough to hold Thebes in check for some years. It was the misfortune of Greece that there had arisen mercenary bands, like the condottieri of mediæval Italy, who hired themselves out to any one that would employ them. The citizens became more averse to service as civilization increased, and the work of war was now done by alien hands. Only a standing army could face the standing army of Macedonia, but the industrious and refined citizens naturally disliked continuous service, and it was long before even Demosthenes could arouse Athens to the necessity of the struggle. He was opposed by the old statesmen, by honest men such as Phocion (whose peace policy, however expedient after Chæronea, was impolitic during most of Philip's reign), and by others whom Philip had bribed—for he loved to "plough with a silver ploughshare." The Sacred War gave Philip a pretence for interfering on behalf of the Delphic god. He drove the Phocian mercenaries from Thessaly, incorporated the excellent Thessalian cavalry in his army, and gained a good naval position on the Gulf of Pagasæ (Volo), the great inlet and outlet for the trade of the country. This also opened the way to Eubœa, for the possession of which, however, Athens struggled hard. It was on the Gulf of Pagasæ that Demetrias was afterwards founded, which, with Chalcis and Corinth, became the "fetters of Greece." Philip also laid a strong hand on Epirus, occupied Acarnania, won over the Ætolians by the gift of Naupactus, and thus hemmed in Athens on the land side. It is true that, when he marched on Thermopylæ, B.C. 352, a sudden effort of the Athenians enabled them to reach the pass in time to arrest his progress, and save the Phocians for a while; but Philip had now a large seaboard, and he proceeded to increase his fleet, to extend his dominion in Thrace on both sides of the Hebrus, and secure it by the foundation of Philippopolis, Calybe, Berœa, and Alexandropolis, while the Greek colonies along the Euxine up to Odessus sought his alliance. There was worse to come, for Philip by the year 347 had destroyed Olynthus and thirty-one other free cities in Chalcidice, and sold their inhabitants as slaves, a calamity such as had not happened since the invasion of Xerxes. This struck terror into all the south country, and we find Isocrates, once the champion of Panhellenic freedom, proclaiming Philip the arbiter of Greece, and advising him to use his power for the purpose of conquering Persia. He found himself bitterly deceived, and "that dishonest victory at Chæronea, fatal to liberty, killed with report that old man eloquent." The Thebans were still unwilling to combine with Athens, and even called in Philip to end the Sacred War. This gave him the command of Thermopylæ, and the means of marching into Bœotia and Attica, while the destruction of the Phocians spread the terror still more widely. Philip now became the recognized religious leader of the Amphictyonic League, and began to interfere authoritatively in the Peloponnese. He was also preparing to master the Bosphorus and the Hellespont, the outlets from the Euxine into the Ægean, through which the main supplies of corn came from the country north of the Euxine to Athens, which therefore laid great stress on the possession of the Chersonese. Once again Athens gained a success when she sent Phocion to relieve Byzantium from his attack (339). The Greek cities began again to lean on her, and her trade increased owing to the destruction of Olynthus by Philip, and of Sidon by the Persian king Ochus. The Greeks too began to see that Philip's allies were being swallowed up one by one. Philip himself, when returning through the passes of Hæmus from an attack on the Scythian king, who ruled between the mountains and the Danube, suffered heavily from a surprise by the Triballi. But a second Sacred War against the Locrians of Amphissa, caused by Æschines's troublesome activity, again brought Philip into the heart of Greece. He fortified Elatea in Phocis, and demanded a passage through Bœotia to attack Athens. On this Demosthenes won his greatest triumph, when he induced Thebes to join in the struggle for freedom and independence; and, though the patriots were defeated at Chæronea, 338 B.C., yet their blood was not shed in vain; their example has told on all future time. Philip used his victory moderately, for he wished to leave Greece quiet behind him when he crossed into Asia to assail the great king. He garrisoned the citadel of Thebes, and demanded from Athens an acknowledgment of his leadership in the national war against Darius; and a congress at Corinth recognized him as its chief, and arranged what contingents were to be sent from each state. His assassination in 336, at the early age of forty-seven, hardly delayed the execution of the plan, for he was succeeded by Alexander, who combined the qualities of a king of the heroic ages with all that Greek training could give. Though the Macedonians had a dialect of their own, yet they had neither language for communicating with others nor any literature except what they derived from Greeks, and Philip had taken care to give his son even a better training than he had received himself. Alexander was also as prompt and cruel as his father. He at once rid himself of his cousin and brother-in-law Amyntas and other kinsmen and possible competitors for the throne, or persons otherwise dangerous. Then he dealt some heavy blows against the barbarians east, north, and west, some of whose chiefs he took for further security with him into Asia. He was just south of Lake Lychnitis, on the western side of the range of Scardus or Pindus, when the news reached him that the exiles had roused Thebes to arms, and were besieging his garrison in the Cadmeia or citadel. Striking through a cleft in the main range of mountains, through which the Devol flows, and marching south along the Haliacmon and over the Cambunian ridge, which joins Pindus to Olympus, he reached Bœotia in less than a fortnight, stormed Thebes, sold the citizens as slaves, and destroyed the place. The citadel alone remained as a Macedonian fortress, until Cassander rebuilt the city. Amidst the general terror, Alexander thought it wisest to follow his father's policy here also, and be content with his election as captain-general by the congress of Corinth.

He left Antipater as regent, and at once crossed the Hellespont to Sestus in the spring of 334, before the Persian fleet was ready to intercept him, or the main Persian army had been embodied. What information had he as to the regions beyond the Taurus and beyond the Tigris, and still more as to the great table-land of Asia extending from Persia to the Indus? He had the *Anabasis* of Xenophon, and perhaps the Persian history of Ctesias, but he must have relied mainly on information derived from Greeks who had been in the Persian service, or who had traded in the interior. But he knew one thing for certain, that no force in Asia could resist Philip's veteran army. Philip had formed the local battalions of militia into the phalanx, arrayed sixteen deep, and armed with long two-handed pikes (*sarissæ*); and this steady body of pikemen, with the veterans in the front ranks, had borne down on the open plain of Chæronea the resistance of the Greek hoplites, who were only armed with a much shorter spear. The phalanx was supported on the flanks by the light infantry of the guard (*hypaspists*), by targeteers (*peltasts*) trained after the plan of Iphicrates, by light lancers, and by a strong body of heavy cavalry, headed by the king's companions, and fighting with the short thrusting pike. It was the charge of the cavalry led by Alexander in person, at the head of the "agema" or royal squadron, that decided all his battles. It seems strange, however, to us to hear that the men had neither saddles nor stirrups, nor were the horses shod. The fine native army was largely reinforced by barbarian archers, darters, and slingers, and by regiments of Greek mercenaries; and this systematic combination of different arms and kinds of troops was supported by field and siege artillery of an improved type. Later on, when the main Persian army was broken up, Alexander added to the number of light troops, and made the regiments smaller and more flexible. Philip had moulded his country into a military monarchy, and turned the nobles into a caste of officers. All its strength was devoted to the one object of war, and it became for the time an overmatch for all its neighbours. On the other hand, Persia had deprived the subject peoples of national life and spirit; the retreat of the Ten Thousand had shown how useless her native levies were, and now her defence rested almost entirely on a force of Greek troops under the able Rhodian general Memnon. The Orientals fought mainly with missiles, and were little suited for close combat hand to hand. The Persian satraps, however, had around them some choice horsemen, armed with missile javelins and with scimitars; and they insisted, against Memnon's advice, on fighting at the Granicus, which flows northward from Ida into the Propontis, but is everywhere fordable. A sharp cavalry action at the passage of the river (334 B.C.) gave Alexander all Asia Minor, and the completeness of his victory might seem to justify Livy's saying that he "did but dare to despise an empty show," and the words attributed to his uncle, Alexander of Epirus, that he himself had found the men's chamber in Italy while his nephew had found the women's in Asia. The Greeks had long been conscious of their superiority. "They might," said Aristotle, "govern the world, could they but combine in one political society." Agesilaus of Sparta and Jason of Pheræ had already planned the attack on Persia, and the liberation of the Asiatic Greeks; and Alexander acted in the full consciousness that he was extending Greek rule and civilization over the East. At the news of the battle on the Granicus, Sardis surrendered. It was the centre to which all the routes converged, but Alexander did not (like Cyrus the younger) at once push on into the heart of the empire along the great road that led from Sardis to Susa. His object was to secure a firm base of operations, by occupying the line of coast round the Ægean, and forcing the Phœnician fleet in the Persian service to retire. The Greek colonization of Asia Minor had prepared the way for him; the Greek cities along the western and southern coast threw open their gates, and Alexander restored their popular constitutions. He even recognized the Lycian confederation. Memnon was only able to organize a resistance at Miletus and Halicarnassus. But his real plan was to put troops on board his ships and raise Greece against the Macedonian yoke, especially as the Athenian fleet was still more than a match for that of Alexander. But when Memnon died there was no one left to carry out this able plan, and Darius threw away his best chance by recalling the troops. Then Alexander marched up northwards from Lycia through Pisidia and Phrygia to Gordion on the Sangarius, whence the main road led east across the Halys and through Cappadocia to Cilicia, between the passes of Mount Taurus and those of Mount Amanus. Here Darius tried to throw his army across the Greek line of communication with their supplies, but his host, crowded together in the narrow ground on the river Pinarus near Issus, was hopelessly defeated. The modern name of the Gulf of Issus, "Iskenderun," still preserves the memory of Alexander. Then Parmenio, Alexander's second in command, pushed on and took Darius's treasures and stores at Damascus. Again, however, Alexander deferred his march inland till he had mastered Phœnicia and Egypt, and so gained the command of the sea in the eastern basin of the Mediterranean. Only the brave freemen of two fortified cities, Tyre and Gaza, held out; and when the Phœnician and Cyprian fleet transferred its allegiance to the invader their only effective weapon was wrested from the hands of the Persians. The occupation of Cyprus and Egypt had been one of the boldest conceptions of the age of Pericles and Cimon, and its success would have secured the supremacy of Greek commerce. As the Persians had persecuted the Egyptians for their worship of animals, Egypt welcomed the deliverer, and recognized him as the son of Ammon; while the Greek colonies of Cyrene and its Pentapolis sent to tender submission. Alexandria was founded on the seaboard as a new centre of commerce, from which it was easy to communicate with the Government and with all parts of the empire. The protecting island of Pharos gave the means of forming two good harbours on a coast elsewhere harbourless; while Lake Mareotis, communicating by canals with the Nile, enabled produce to be easily brought down from the interior.

At last the time was come for delivering the final blow to Persia. Alexander passed the Euphrates at Thapsacus ("the passage"), and then marched north-east through the hilly country by Nisibis, to avoid the hot desert of Mesopotamia. He crossed the Tigris unopposed, and defeated Darius's hosts at Gaugamela. The long struggle of two hundred years between Greece and Persia was at an end. The victory converted Alexander into the great king, and Darius into a fugitive pretender; and Babylon and Susa submitted. At Babylon Alexander sacrificed to the native gods, as he had done elsewhere, and this admixture of the religions of all countries largely influenced the later phases of heathenism. The priests recognized the Greek kings, and the later cuneiform inscriptions commemorate Seleucus and Antiochus. When Euemerus's view spread, that the gods were only deified men, a fusion of religions became still easier. The worship of the Sun-god and of Osiris, the god of the dead (especially under his Grecized form at Sinope as Serapis), extended far and wide. In administering these countries, Alexander separated the civil, military, and financial functions, and, where natives were left in office, entrusted taxation and military command to Macedonians. The great power of the satraps had weakened the central government of Persia, and Alexander adopted a wiser plan, but his generals restored the old system after his death. The Persian treasures, dispersed by the conquest, gave a fresh stimulus to commerce, especially as Persia was rich in gold, which was scarce in the West. Alexander had already prepared the way for a universal currency by coining silver didrachms and tetradrachms after the Attic standard, which became current coinage over most of the East; the Ptolemies, however, adopted the Phœnician standard for Egypt. Up to this point the countries conquered admitted of being more or less assimilated and Hellenized; but, when Alexander penetrated through the passes that led up to Persepolis in Persia, and thence to Ecbatana in Media, and again north to secure the defiles that led down to the Caspian, and so skirting the southern flank of the range of Elburz to Hecatompylus in Parthia, the centre of the roads leading to Hyrcania (at the south-east of the Caspian), to Bactria, and to Ariana, and then from Kandahar northwards to Cabul, and through the mighty range of the Hindu-Kush to Bactria (Balkh) south of the Oxus, and Sogdiana (Bokhara) between that river and the Jaxartes, and at last as far as the Indus and the Punjab, his route lay through tribes that still possessed their native strength and power of resistance to foreign influence, though for the moment overborne by the superiority of the Western arms. Alexander saw the danger, and met it by settling Greek colonists in new cities which were to serve as military posts, depôts of commerce, and centres from which to Hellenize the country districts; and many of them are still important points in the East, though the desert has spread, and robber hordes have stopped some of the old caravan routes. Such places are Merv, Herat, Kandahar, Cabul, Samarkand, Khojend. Bactria and Sogdiana were to serve as a frontier against the wild hordes of the north, and thus Alexander's measures determined the fortune of Transoxiana for centuries. Some native rulers also were left to form a sort of barrier in front of the empire to the north and east. Alexander laid the main stress on securing the great rivers, the Euphrates and the Tigris, the Oxus and Jaxartes, the Indus and Hydaspes. In Greece itself the Macedonian kings upheld tyrants or oligarchies, but here freer municipal constitutions were allowed to attract colonists. Alexander further planned to fuse the noble Persian race with the Greeks by intermarriage, and by giving the Persians equal rights in the army and the administration. Common service in these was the best means for Hellenizing the natives. This was a more generous plan than Aristotle's advice as to the way of ruling barbarians would have led to; but Alexander saw that the Eastern peoples were not barbarians like the Illyrians. The culture of Egypt reached far back; the astronomy and art of Babylon could not be despised; the religions of Persia and India afforded matter of interest to Greek inquiry. These lands of ancient civilization might teach as well as learn something from Greece. The Eastern nations responded to the touch, and Persian legend to this day preserves the name of Iskander among the names of their national heroes. Alexander's conquests were to be justified by the result, by the union of East and West, and the diffusion of Western civilization over Asia. Even India should feel something of the new influence. Alexander would have made the nations into one. An old writer says, "The elements of the nations' lives were mixed together as in a love cup, and the nations drank of the same cup, and forgot their old enmity and their own weakness" (Plut., *De Fort. Alex.*, i. 6). There is, it is true, a reverse to the picture. The oppressive conduct of many of the Macedonians thus suddenly put into power was an evil omen of what might happen if their chief was removed; and, if the East was becoming Hellenized, yet Alexander became in turn Orientalized. Could he remain a Western king and also an Oriental despot? a Greek and a Persian? It might be good policy, but Philip's old generals could not help showing their disgust, and Clitus and others paid for it with their lives. The Greek states also felt the difference. Just before his death Alexander required them to worship him as a god, and, without any regard to the rules agreed on at the congress of Corinth, forbade the federal meetings of the Achæans and Arcadians, and issued a decree restoring all exiles to the various states. Greece became practically a province of the Eastern empire, and the patriots who had maintained the fight for freedom were more than justified by the ruin that came on Greece through Alexander's successors. Even if he himself had not been spoilt by success and absolute power, yet he was but a lucky accident. And, though the Hellenizing influence spread over much of the East in a way to which there has been but one parallel, the mixture of German and Roman elements when the barbarians invaded the empire, yet Alexander's conquests, while they Hellenized Asia, tended to Asiatize Hellas; they put an end to the genuine Hellenic spirit, to its productive genius and consummate literary and artistic excellence, as well as to its political freedom. The New Comedy shows how national life and public interests had died out; with all its fine psychological analysis it does but dwell on the characters and situations of daily life and purely domestic feelings. But the braggart soldier is now a common character in the play, and slavery plays a greater part than ever. Last of all, Alexander marched along the Cabul river, and through the pass of Jellalabad to the passage of the Indus by Attock; but when he reached the Hyphasis (Sutlej) the weary troops refused to cross it and press on to the Ganges. He then sent Nearchus down the Indus, to sail round to the mouth of the Euphrates, and explore a route for traffic across the Indian Ocean. Nearchus profited by the monsoons, which thus became known to the Greek sailors. The king himself went down the river to see the great southern ocean with its strange tides, and he planned that an Alexandria on the Indus should communicate with the Alexandria of the Nile valley by an intermediate harbour on the Euphrates. He further planned the circumnavigation of Arabia, if not of Africa also, and a voyage to the north of the Caspian. At the same time Pytheas of Marseilles was exploring the British and Baltic seas. This enlarged and systematic exploration of the earth, combined with increased means of communication among its inhabitants, was beneficial to civilization, if we may define growth in civilization as growth in the amount of services rendered to each other in civil society. The record kept by Alexander's quarter-masters (*bematistæ*) of the length of his marches gave succeeding geographers important information; and it was more useful to Eratosthenes than the vague descriptions in the historians, who were striving after literary effect, and some of whose accounts were very legendary, for legends soon clustered round the name of the great conqueror. Alexander seems also to have had a description (*anagraphe*) of the empire drawn out. After his return through the desert of Baluchistan, along the Indian Ocean, he devoted himself to consolidating the internal administration and checking the oppression exercised by his officers; but he was planning new conquests in the West, from all parts of which he had received ambassadors, when he died of marsh fever at Babylon (323 B.C.), at the early age of thirty-two.

All attempts to keep his empire together inevitably failed, but his work was done, since, whether for good or evil, the Hellenizing of the East determined the whole course of history. The army resolved that his child (not yet born) by his Bactrian wife Roxane, and his imbecile half-brother, Philip Aridæus, should bear rule jointly. First Perdiccas was named regent, but the generals began to combine against him, and he perished in trying to reduce to obedience Ptolemy, the satrap of Egypt, the man who saw most clearly and earliest the tendency of events. Then Antipater, who had with difficulty defeated the gallant attempt of the Greeks under the leadership of Athens to regain their freedom in the Lamian War, was made regent. On his deathbed he transferred the office to Polysperchon, who soon proved unequal to his task, and even gave up Phocion, the leader of the Macedonian party at Athens, to death. Antigonus, the commander-in-chief in Asia, destroyed Eumenes, who was faithful to the royal house but was a Greek from Cardia and not a Macedonian. He then tried to reunite the satrapies; but Ptolemy of Egypt, Lysimachus of Thrace, and Seleucus of Babylon combined with Cassander of Macedon against him, and he fell (301 B.C.) at the battle of Ipsus in Phrygia. This decided the final break up of the empire. Several native princes retained their dominions and formed a kind of neutral zone between the new kingdoms, and the Getæ on the Danube maintained themselves against Lysimachus. The customary feuds in the royal house, and its intrigues with the generals, soon led it to destruction. Roxane, the mother of the child Alexander, began by murdering Alexander's other wife Statira, the daughter of Darius. Alexander's Epirote mother Olympias killed Philip Aridæus and his wife Eurydice, and Cassander killed Olympias herself, and afterwards Roxane with her son. There were similar feuds and murders in the houses of all Alexander's successors, except the early Antigonids. Their marriages, like those of Philip and Alexander, were of a very Oriental character; and "in these families," says Plutarch, "murders of sons, mothers, and wives were frequent, murders of brothers were even common as a necessary precaution for safety." The generals assumed the title of king after Demetrius's defeat of Ptolemy off Cyprus (307 B.C.), and their example was followed by Agathocles at Syracuse, and Dionysius at Heraclea on the Euxine. Demetrius, after his father's death at Ipsus, fled to Greece, and occupied much of the country. His viceroy in Bœotia was the historian Hieronymus of Cardia, the friend and fellow-citizen of Eumenes. Demetrius for a time even gained Macedonia, but his Oriental rule disgusted the people, and he had to fly to Seleucus, who married his daughter Stratonice. Seleucus detained him under honourable guard till his death, perhaps with some idea of using his help if the balance of power should again be threatened. When an empire breaks up, old geographical relations make themselves felt, the great masses and divisions of the land exert their influence and affinities of race begin to show their old power, the natural boundaries of mountain and river tend to reappear; and so it proved now. After Cassander's death, and the defeat of Lysimachus by Seleucus, Seleucus reorganized Asia by breaking up the twelve large satrapies into more than seventy districts of a more manageable size. He then crossed to Europe to reunite Macedonia to Asia, but was murdered by Ptolemy Ceraunus, eldest son of Ptolemy of Egypt—who had chosen his second son Philadelphus as his heir instead of the wild Ceraunus. Seleucus's death ended the generation of Alexander's generals. A new state of things followed. Ceraunus fell in battle against the invading Gauls, whose migrations gave a final blow to the old system. Part of the Gauls passed on into Greece, where the free states destroyed them, while others crossed into Asia and occupied the country named from them Galatia, 276 B.C. Lastly, after Pyrrhus of Epirus, whose sister Deidamia married Demetrius, had more than once nearly gained possession of Macedonia, Antigonus Gonatas, the son of Demetrius, finally secured the succession, and restored the wasted realm to the position of one of the great kingdoms by the side of Egypt and Syria. The last struggle of Athens against him in the war of Chremonides (a pupil of Zeno of Citium) proved fruitless. He also regained the Macedonian frontier on the side of Epirus as it had been in Philip's time, and the Aous became the boundary towards the Dardanians on the north-west. Of the kingdom thus restored his family retained possession till Perseus was overthrown by the Romans at the battle of Pydna (168 B.C.), but the later kings wasted their strength in useless wars instead of doing what might have been done, conquering and Hellenizing the country up to the Danube. The Epirote kings Alexander and Pyrrhus had striven to found a new military empire in Italy, but in vain. The Apennines can be seen from the coast of Epirus, and these kings were always stretching eager hands over the sea to the new lands in the West, but their power proved unequal to the task, and Pyrrhus's position in history is mainly important because his expedition brought Greece and Italy into close connexion. His geniality of character impressed his contemporaries, and has left its impress on Roman and Greek legend.

In Asia Seleucus had in vain tried to preserve the most easterly provinces, for the Eastern nature had at once begun to react against the Macedonian conquest, and the Seleucid kingdom had no true centre or natural limits. Sandracottus, a native chief, founded a great kingdom in India with Indian and "Javanic" (Ionian, *i.e.*, Greek) support; and Seleucus, after one campaign, gave up the eastern districts as far as the Paropamisadæ west of Cabul. Sandracottus was perhaps supported by the Brahmans whom Alexander had opposed, but the Punjab has witnessed more than one revolt against the system of caste, which had its stronghold in the valley of the Ganges; and Buddhism soon became predominant in the new kingdom. The edicts of Asoka, the second successor of Sandracottus, which made Buddhism the state religion (though Brahmanism was tolerated), mention Antiochus Ptolemy and Antigonus (see INDIA, vol. xii. p. 787, for a full account); and Buddhist missionaries began to spread the faith westwards as well as to the south, and some knowledge of the cycle of Eastern story and fable was communicated to the Greeks. But we have not the materials for estimating the influence exercised in Asia by the Greeks on the new kingdom. Similarly a Græco-Bactrian kingdom, which was made independent by Theodotus or Diodotus about 256 B.C., lasted for two centuries. Many of its coins have been found with legends at first purely Greek, but becoming gradually barbarized. Some of the early ones resemble the gold coins of Antiochus II. of Syria, who ruled just before Diodotus made the new state independent. After the first five kings, however, the legends are in Prakrit as well as in Greek. The caravan routes were long kept open, and in this way trade with China was maintained, and silk and other Chinese commodities reached Europe. Farther west native Persian chiefs became practically independent, such as Atropates in the Median district, called from him Atropatene, and elsewhere; for the clan system was suited to these districts, and they preserved the system of Zoroaster till Artaxerxes (Ardshir) restored the Persian monarchy, 226 A.D. (see PERSIA). But even here Greek influence lasted on; nor when Arsaces, about 250 B.C., had set up the kingdom of Parthia and made Hecatompylus his capital, did that influence die out in Parthia. Even the new cities founded by the Parthian kings, such as Dara, were on the Greek model, and largely inhabited by Greeks; and some of the chief cities retained Greek municipal constitutions, such as Ctesiphon, which took the place of Seleucia on the Tigris as Seleucia had taken the place of the old capital Babylon—

> "Of later fame,
> Built by Emathian or by Parthian hands,
> The great Seleucia, Nisibis, and there
> Artaxata, Teredon, Ctesiphon."

So again in Asia Minor native chiefs began to rule in Armenia, Bithynia, Cappadocia, Paphlagonia, and Pontus; and some of them, such as the Cappadocian princes of the Mithridatic family, who afterwards ruled at Amasia, claimed descent from the royal Achæmenid house of Persia, or from leading Persian houses. They, as well as the princes of Pontus, intermarried with the house of Seleucus, to which their help was important. Bithynia and Pontus had an era of independence, from which they reckoned their dates just as the Syrian kings did from the return of Seleucus to Babylon. The independence of Judæa under the Maccabees was established at a later time (see ISRAEL). All these were subject to the Hellenizing influence of the Greek towns; and the Greek language spread everywhere, even among the Galatians, as we see by the inscriptions. Nicomedes of Bithynia founded Nicomedea in 264 B.C., as a Greek town; it soon rivalled Nicæa in importance, and we owe to it Arrian, the historian of Alexander. The barbaric princes often took wives, ministers, officers, engineers, literati, artists, actors, and intermediate agents of all kinds from some neighbouring Greek city, a custom which had begun before the time of Alexander, as we see in the case of Mausolus of Caria. In Pergamon, about 238 B.C., Philetærus, by the help of the royal treasure, made himself independent, and under Eumenes and Attalus the little state showed much political skill in trimming the balance of power between the neighbouring dynasties. Attalus took the title of king after a victory over the Galatians on the Caicus, and this victory was commemorated by the Gigantomachia around the famous altar lately discovered at Pergamon (see Conze, *Beschreibung der Pergamenischen Bildwerke*; Overbeck, *Geschichte der Griechischen Plastik*, 3d ed.). He also sent commemorative statues to Athens; one of which, long celebrated as the Dying Gladiator, is now seen to be the portraiture of a dying Gaulish chief. Greek art, transplanted from Athens and the Peloponnese to Pergamon and Rhodes, though it had acquired a somewhat florid tinge, was yet not unworthy of its descent from the schools of Phidias and Lysippus, and owing to the close alliance of these two cities with Rome, as against Macedon and Syria, this revived Greek art found its way to Italy. Pergamon also became a centre of Greek learning only second to Alexandria; and, when Ptolemy cut off the supply of papyrus from Egypt, Crates of Mallus in Cilicia (whose name was only second to that of Aristarchus) is said to have revived the old Asiatic use of "parchment"—a name which itself preserves the memory of Pergamon. Papyrus, it is true, remained the usual material for books till about the 4th century, when the Christian Church finally adopted the new material due to the invention of Crates (see Birt, *Das antike Buchwesen*).

All along the coast also a number of Greek cities acquired practical independence owing to the division of power among the princes, Greek as well as native, who were further kept in check by the invading Gauls. Such were the cities of Byzantium, Cyzicus, Heraclea, Sinope, and Olbia on the north-west of the Black Sea, and Panticapæum or Bosporus between that sea and the Palus Mæotis. The true Greek spirit survived above all in Rhodes, as it did also at Massalia in the West. All the more did the Syrian kings strive to maintain their power by founding cities under their own rule, which were made attractive to new colonists by something of municipal independence, with the right to bear arms, to coin money, and to manage their own judicial affairs. Each city had its demus, senate, archons, and generals. There were four of these great cities in Syria itself:—two inland, Antioch on the Orontes, the greatest commercial entrepôt in the East, and Apamea, the military centre of the kingdom; two on the coast, Seleucia, with its rock fortress to serve as a refuge in time of trouble, and farther south Laodicea on the sea, among its rich vineyards. They were all named after the royal family. Other towns were named from places in Greece or Macedonia, such as Achaia, Amphipolis, Apollonia, Arethusa, Astacus, Berœa, Callipolis, Chalcis, Edessa, Heræa, Larissa, Maronea, Oropus, Pella, Perinthus, Tegea; for the oppressed Greeks of Greece itself and of Magna Græcia here found an outlet for their energy. Some military colonies were planted on the west and south of Galatia, to keep the Gauls in check, and guard the roads leading from Phrygia, the centre of the commerce of Asia Minor, to the towns on the coast; such were Antioch in Pisidia, Apamea Cibotus, Synnada, and Thyatira. Even Palestine, notwithstanding the temporary success of the Maccabees, was full of Greek towns like the later Cæsarea, and the manufacturing population used the Greek language. We have some traces of the state of things in the *Economics*, a work of this period, though falsely attributed to Aristotle; and the later political literature shows that men had a clear idea of the aims and means of the politics of the day, and that diplomacy and international law had considerably developed. Thus a large influx of new Hellenic blood was poured into the lands on this side of the Tigris, into Asia Minor, Mesopotamia, and Syria; during the century after Alexander's death nearly two hundred cities were founded, and the Greek race became predominant in western Asia, though of course it was differentiated by the various peoples which it undertook to assimilate, and by which it could not but be influenced in turn, especially as the princes found it necessary to conciliate them. The historians of the time are mostly lost; but many inscriptions survive which show what a blending of populations took place. One gives us a rescript of Antigonus on incorporating the people of Lebedus with the Teians. Another shows that Magnesia became absorbed in Smyrna, now restored after it had long lain waste. Others tell us that places like Erythræ and Iasus recovered something like independence owing to the needs of the Syrian kings. Amidst the feuds of the great powers the Ionian states recovered their freedom, and were able to form a kind of federal union. Similarly we hear of the community (*κοινόν*) of Bithynia, of Asia, and the like. A new life of a somewhat different kind from the old Greek life in politics, religion, and science dates from the revolution effected by Alexander's conquests, though in the lower strata of the country population old beliefs still had some hold, as is evident by what Pausanias found existing even in his day in Greece itself. But old distinctions tended to vanish away, only that between poor and rich acquired still greater force, material interests became predominant. We see also that in the manufacturing towns the workmen had formed benefit societies, and secret or public associations of various kinds. And it was in these commercial centres, with their somewhat cosmopolite character, free from old prejudices and ideas, that Christianity found an early home. Greek freedom made a great impression in the East. The Greeks had no system of castes, no close priesthood, no sacred books like those of India to limit their development; their views may almost be called cosmopolitan, and the distinction between "Greek" and "barbarian" already tended to disappear, as Alexander perhaps had wished. Attic speech became the basis of the new written language, and, with Attic customs, prevailed at the courts of Alexandria and Babylon, of Bactra and Pergamon. Attic plays were acted at Ctesiphon down to Roman times; and the later rhetoricians and sophists imitated the masters of Attic oratory. The Greek view as to Philip and Alexander was thus enabled to hold its own against the prevailing Macedonian tone on these matters, especially when Macedonia lost its leading position, for that country produced only soldiers—with the exception of Marsyas of Pella, and of King Ptolemy, who wrote with true military brevity an account of Alexander's campaigns, which Arrian wisely preferred to the more romantic account of Clitarchus. But, though the towns became Hellenized, yet the Hellenistic populations did not possess the highest qualities of the Greek mind, as the surrounding elements and the climate naturally wrought some alteration. Polybius looked with surprise at the Greeks settled in Alexandria. The living forces of Greece —its productive genius, self-organizing power, and active spirit of political life—were weakened and gradually lost their energy. The Attic language became the Hellenistic, Attic eloquence received a florid Asiatic tinge (though Æschines himself taught at Rhodes), but true eloquence can only flourish, as Tacitus points out, in a free state. Literature and art lost their connexion with a true national life. Architecture took another character, and the plastic art of Pergamon, though derived from Athens, and that of Rhodes, though derived from the Sicyonian school, through Chares of Lindus (who modelled the Sun-god, known as the "Colossus"), had lost the self-restraint and dignity of the highest Greek art. But the suppression of political freedom turned the force of the Greek mind all the more strongly into other channels, and science and criticism, and speculation and literary history, made a great advance. Considerable schools were opened at Tarsus and other centres of commerce. As the free state lost its power over the mind, men had recourse to philosophy, and regained in mental fortitude and independence the outward freedom they had lost. Then this feeling reacted on politics, and a generation of patriots like Philopœmen arose, worthy to represent Greece in these her last days. The new teaching of freedom came forth, as was right, from Athens; it was the followers of Arcesilaus, the founder of the new Academy, who freed Megalopolis from its tyrant. The later developments of philosophy were mainly due to Zeno of Citium in Cyprus, and to Epicurus, who finally taught at Mytilene and Lampsacus; but Athens was still the chief home of their teaching. The writings of the great philosophers of this age, however, are mostly lost to us, as well as those of the historians, and after Aristotle there is a strange gap in the tradition up to the Christian era. The Greeks now wished to know the early history of the East, and the Eastern peoples wished to make their history known to the great literary nation. Hence Berosus wrote the history of Babylon for Antiochus II., from the archives in the temple of Belus, Manetho that of Egypt for Ptolemy Philadelphus, Menander of Tyre that of Phœnicia, and Jewish writers the history of their race and religious views, which are finally summed up for us by Philo and Josephus. The sacred books of Egypt, Palestine, and Persia were to be found in the Alexandrian library, and the religious syncretism that resulted from the mixture of races prepared the way for monotheism and for Christianity. The astrology, however, and divination of the East in turn made their way among the Greeks, and led to curious superstitions, and a whole literature of Sibylline books and similar forgeries sprang up. Christianity itself spread chiefly in the Hellenized towns; the country districts were much longer in feeling the new influence.

It was in Egypt, however, that Hellenism was perhaps most highly developed. The Ptolemies gained Cyrene and Cyprus, and struggled hard with the Syrian kings for the possession of Phœnicia; Palestine was as of old the battle-field for the king of the north and the king of the south. The Ptolemies even held Seleucia at the mouth of the Orontes for some time. The history of these times is lost in its detail; the only thing certain is the spread of the Hellenistic spirit in the East. Many Jews were transplanted to Alexandria and Cyrene, occupied large quarters of those cities, and had full civil rights. The Ptolemies also pushed south into Ethiopia, and the African elephants which they trained for war enabled them to oppose the Syrian army with its Indian elephants. A Greek inscription at Adulis, though of later origin, commemorates the conquests of the third king of this line. These kings also secured the route down the Red Sea, reopened the old canal of Necho leading from the Nile into that sea, founded Arsinoe and other important towns, and made discoveries on the route to India. The new information thus gained was recorded in the geographical works of Agatharcides of Cnidus and Artemidorus of Ephesus. The old trade of Egypt had chiefly consisted in the export of corn; now the wares of Arabia, South Africa, and India came through Egypt to Europe, and ships of Alexandria became frequent visitors to the western waters. Even in Asia Minor Egypt won influence as Syria lost it, and a court poet (perhaps Theocritus) was justified in praising the Egyptian king who was master of the sea. The carrying trade had fallen largely into the hands of Egypt from the time when the war between Seleucus and Antigonus stopped the trade of the caravans by land, and the import and export duties formed a large part of the Egyptian revenues. After the return of Pyrrhus from Italy, Philadelphus even made a treaty with Rome. The Sicilian Greeks might be rivals in trade, but the Italians were good customers, and produced the excellent wool which was invaluable for the Egyptian manufactures, as the cultivation of cotton in Egypt had but begun. Puteoli, the first really good port to the south of Rome, was the chief centre of the trade even at this early time. The Egyptian trade was concentrated in Alexandria, which thus became one of the greatest cities on the earth. Science flourished there, and men like Archimedes came thither to study. Much of what was done was done for ever. No mathematician has to redemonstrate the problems of Euclid. Geography was founded by Eratosthenes of Cyrene on a mathematical and astronomical basis; he first calculated the magnitude of the earth by measuring an arc of the meridian, the process employed at the present day. Modern astronomy too is the natural development of the work of Hipparchus and Ptolemy. Erasistratus and Herophilus investigated the structure and functions of the valves of the heart, and the nerves of sensation and motion, and a close connexion was thus formed between anatomy and medicine. The Múseum, a sort of college, numbered Eratosthenes, Callimachus, Aristophanes, and Aristarchus among its members. They fixed the text of the classical writers on critical principles; and grammar assumed the form it kept for centuries. Poetry itself had a kind of second summer with Callimachus and Apollonius Rhodius, and, under Sicilian influences, with

Theocritus, Bion, and Moschus. All the knowledge of the past was treasured up for transmission to a future age.

There was no more unity among the Macedonian monarchies than there had been among the free cities of Greece, and the kings were even less able to combine against Rome than the republics against Philip. When Philip V. tried to keep the Romans out of Greece, he met with no support from Antiochus the Great, and was defeated by Flamininus at Cynoscephalæ, 197 B.C. Antiochus in turn had no help from Philip when Scipio crossed into Asia and defeated the Syrian army at Magnesia, 190 B.C. Last of all, Perseus was overthrown at Pydna (168 B.C.), while Antiochus Epiphanes was trying to plunder Egypt; and Macedonia was divided into four districts, like those out of which the kingdom had been originally formed—Amphipolis, Thessalonica, Pella, Pelagonia. The Romans in many respects carried on the work of spreading Greek culture. They gave the Greek cities of Asia a freer scope for their action on the country; they united the whole Greek race, east and west, under one rule, and opened out the world to their enterprise. We meet with many great names in this later age, such as Posidonius at Rhodes, Galen at Pergamon, Strabo at Amasia. Epictetus was a Greek slave from Phrygia. Cappadocia became so thoroughly Greek that the church itself owed to it such men as Basil and Gregory. The Greek influence even spread to Palmyra in the desert, and its ruin in the third century marks the first great check sustained by Hellenism. But under the rule of Rome it may almost be said that the primitive unity of the Græco-Italian race was restored, and the work of the Macedonian conqueror completed in western Asia.

This article is mainly based on Grote's *Greece*, and Droysen's *Hellenismus*, 2d ed., 1877. For more detailed accounts and for the personal history see ALEXANDER, ANTIGONUS, ANTIOCHUS, ANTIPATER, &c. The original authorities are collected in Didot's *Historici Græci*, and his *Arrianus*, 1877. (C. W. BO.)

MACEDONIUS, a deacon, was raised to the patriarchate of Constantinople as successor of Eusebius of Nicomedia by the Arian bishops in 341 A.D., while the orthodox party elected Paul, whom Eusebius had superseded. The partisans of the two rivals involved the city in a tumultuous broil, murdered Hermogenes, the general whom Constantius II., during his own absence, had empowered to preserve order, and were not quelled until the emperor himself returned to the city and banished Paul. Macedonius was recognized as patriarch in 342. In that year Paul again returned, and was again banished, and Macedonius, amid much tumult and bloodshed, was forcibly installed in his see by the imperial troops. Compelled by the intervention of Constans in 348 to confine his authority again to one church, and to resign the patriarchate in favour of his former opponent, he was reinstalled in 350. He then took vengeance on his opponents by a general persecution of the adherents of the Nicene creed. In 356 he occasioned a disastrous and bloody tumult in Constantinople by causing the ashes of Constantine the Great to be removed from the dilapidated church of the Apostles to that of St Acacius. In 359, on the division of the Arian party into Acacians (or pure Arians) and semi-Arians, Macedonius adhered to the latter, and in consequence was expelled from his see by the council of Constantinople in 360. He now became avowed leader of the sect of Pneumatomachi, Macedonians, or Marathonians, whose distinctive tenet was that the Holy Spirit is but a divine influence pervading the universe and not a person distinct from the Father and the Son. He did not long survive his deposition.

MACEIO, or MACAYO, a city of Brazil, the chief town of the province of Alagoas, and one of the ports open to foreign trade, is situated about 150 miles south of Pernambuco, in 9° 39′ S. lat., on an eminence about a mile from the shore, in the midst of luxuriant vegetation. It possesses a fine cathedral and an elegant house of assembly, as well as a cotton inspection office and a custom-house. As its harbour at Jagudra on the coast is but slightly protected by reefs and a small peninsula, and the water deepens slowly from the sandy beach, vessels cannot approach the piers (of which there are several), and have to be discharged and loaded by lighters. Trade, however, is on the increase, and will develop largely on the completion of the railway to the interior. In 1880 44 British and 35 foreign vessels entered, with a burden respectively of 17,624 and 10,482 tons; and cotton and sugar were exported to the amount of 4181 and 27,810 tons. In 1839 the town became the provincial capital instead of Alagoas. The population is about 20,000.

MACERATA, a city of Italy, the chief town of a province, a bishop's see, and the seat of a court of appeal, lies 22 miles south of Ancona, and 17 miles by road west of Civita Nova, the nearest station on the East Coast Railway. Crowning the top of a hill about 1300 feet in height with a picturesque mass of buildings enclosed by walls and towers, Macerata looks out over the Adriatic and the valleys of the Potenza and the Chienti. The cathedral is a modern structure of but little interest; but some of the churches, and especially some of the palaces,—Palazzo dei Torri, Palazzo Bonaccorsi, &c.,—are fine pieces of architecture; and at a short distance from the town stands the beautiful S. Maria delle Vergini, designed by Galasso da Carpi, but often attributed to Bramante. Besides the university, Macerata contains a communal library founded by Leo XII., and, in the municipal buildings, a collection of antiquities from Helvia Ricina. Its infant schools were the first established in the papal states. Glass and pottery are among the manufactures, and three fairs are held yearly. The population of the commune has increased from 19,283 in 1861 to 20,219 in 1881; that of the town was 10,065 at the former date.

Macerata, as well as Recanati, was founded by the inhabitants of Ricina after the destruction of their city by Alaric in 408. During the Lombard period it was a flourishing town; but it was from comparative insignificance that it was raised by Nicholas IV. to be the seat of the governors of the March. By the viceroy of Frederick II. it was enclosed in the 13th century by a new line of walls more than 2½ miles in circuit; and in the troubles of the next two hundred years it had frequent occasion to learn their value. For the most part it remained faithful to the popes, and in return it was rewarded by a multitude of privileges. Though in 1797 the inhabitants opened their gates to the French, two years afterwards, when the country people took refuge within the walls, the city was taken by storm and delivered to pillage. The bishopric of Macerata dates from the suppression of the see of Recanati (1320). Crescimbeni, the poet of the 13th century, his namesake the founder of the Arcadian Academy at Rome, and Matteo Ricci, the Chinese missionary and scholar, were natives of the city.

MACGILLIVRAY, WILLIAM (1796-1852), a writer on several branches of natural science, but best known as an ornithologist, was born in 1796. He studied as an arts student in King's College, Aberdeen, graduating M.A. in 1815, and also studied medicine, but did not complete the latter course. In 1823 he became assistant to the professor of natural history in Edinburgh University; and in 1831 he was appointed curator of the museum of the Royal College of Surgeons in Edinburgh. In 1841 he became professor of natural history and lecturer on botany in Marischal College, Aberdeen. He died in 1852. He possessed a wide and comprehensive knowledge of natural science in its various departments, gained no less from personal observations in the course of frequent excursions through different parts of Scotland than from a study of the collections under his charge in Edinburgh and of books. His industry and extensive knowledge are amply shown in his published works. He contributed numerous articles on the zoology, botany, and geology of Scotland to the scientific journals in Edinburgh, to the *Magazine of Botany and Zoology*, and to the *Transactions of the British Association.* He also assisted Audubon in his classical works on the *Birds of America*; and he edited Withering's *British Botany.*

His larger works are numerous, and include biographies (of Humboldt, and of zoologists from Aristotle to Linnæus), *Text-books of Botany*, *of Geology*, and *of Conchology*, a *History of British Quadrupeds*, a *History of the Mollusca of Aberdeen, Banff, and Kincardine*, a *Manual of British Ornithology*, and a *History of British Birds*, in 5 vols., 1837–52. The last work holds a high rank from the excellent descriptions of the structure, habits, and haunts of birds, and from the use in classification of characters afforded by their internal organs. In 1850 he spent some time in the Highlands of Aberdeenshire. The results are embodied in the *Natural History of Deeside*, published after his death by command of the queen.

He made considerable collections, alike for the instruction of his students and to illustrate the zoology, botany, and geology of the parts of Scotland examined by him, especially around Aberdeen. His success in enlisting the interest and co-operation of his students is shown by the assistance acknowledged by him in his work on the mollusca of that district. His devotion to his favourite sciences made him apt to be careless of risk to health, and seems to have led to the illness that proved fatal. Though his reputation rests chiefly on his works on birds and on mollusca, his other writings are also of interest and value. In some respects he was in advance of most of his contemporaries, *e.g.*, in the opinions in regard to species published in his *Text-book of Botany* (pp. 210, 211) in 1840.

His reputation might have been greater as a specialist had he restricted his investigations within narrower limits, but this he was prevented from doing as much by the wide range of subjects that he had to teach as by his natural inclination. He had to encounter great difficulties in ascertaining what had been already accomplished by naturalists elsewhere from the want of a good library and of named collections for reference. To this fact may be traced a tendency to regard as undescribed and to name whatever animals he was unable to identify from books within his reach, as well as occasional apparent neglect of work done by others and some peculiar views on nomenclature and classification.

Throughout his life pecuniary difficulties, in part arising from the publication of his books, pressed on him; and to this it was probably due, at least in part, that, despite an amiable nature, he at times expressed himself in controversy in a way that made him keen opponents. His books show that from all troubles he found relief in tracing the proofs of wisdom and of goodness in nature. Throughout his was a laborious life, and just before his death he completed his *History of British Birds*, an enduring and worthy memorial of an earnest and true-hearted naturalist.

His family inherited a taste for similar pursuits. One son, John, contributed several articles to magazines on the natural history of Scotland, and published an account of the voyage round the world of H.M.S. "Rattlesnake," on board which he was naturalist. Another son, Paul, published an *Aberdeen Flora* in 1853.

MACHIAVELLI, Niccolò (1469–1527), was born at Florence on the 3d of May 1469. His ancestry claimed blood relationship with the lords of Montespertoli, a fief situated between Val di Pesa and Val d'Elsa, at no great distance from the city. In 1393 the castle of Montespertoli became the property of Niccolò's great-grandfather. At this date the Machiavelli, like other nobles of the Florentine *contado*, had been absorbed into the body of the burghers, and had begun to seek distinction as officers of the republic. They counted numerous priors and gonfaloniers of justice in the generations which preceded the illustrious secretary. Niccolò's father, Bernardo, who was born in 1428, followed the profession of a jurist. He held landed property, chiefly near the village of San Casciano, which was worth, according to a recent calculation, something like £250 a year of our money. His son, though not wealthy, was never wholly dependent upon official income.

Of Niccolò's early years and education little is known. He is said to have studied under the grammarian Marcello Virgilio Adriani; and his works show wide reading in the Latin and Italian classics. But it is almost certain that he had not mastered the Greek language. In that age of humanistic erudition, it is noticeable that the three most eminent writers of the Renaissance—Machiavelli, Ariosto, and Guicciardini—owed their training to the literature of their own nation. To the defects of Machiavelli's education, as it appeared to men of Giovio's stamp, we may, in part at least, ascribe the peculiar vigour of his style and his speculative originality. He is free from the scholastic trifling and learned frivolity which tainted the rhetorical culture of his century. He made the world of men and things his study, learned to write his mother-tongue with idiomatic conciseness, and nourished his imagination on the masterpieces of the Romans. Machiavelli shared the enthusiasm of his race and period for antiquity; but the antiquity he worshipped was confined to the commonwealth of Rome. Not the arts, the letters, and the philosophy of the Greeks, but the Latin histories in which the statecraft and organization of the Romans are described, arrested his attention. His habit of thought is marked throughout by a strong Latin bias.

The year 1494, the year of Charles VIII.'s invasion and of the Medici's expulsion from Florence, saw Machiavelli's first entrance into public life. He was appointed clerk in the second chancery of the commune under his old master Marcello Virgilio Adriani. Early in 1498 Adriani became chancellor of the republic, and Machiavelli received his vacated office with the rank of second chancellor and secretary. This post he retained till the year 1512. The masters he had to serve were the Dieci di Libertà e Pace, who, though subordinate to the signoria, exercised a separate control over the departments of war and the interior. They sent their own ambassadors to foreign powers, transacted business with the cities of the Florentine domain, and controlled the military establishment of the commonwealth. The next fourteen years of Machiavelli's life were fully occupied in the voluminous correspondence of his bureau, in diplomatic missions of varying importance, and in the organization of a Florentine militia. It would be tedious and uninstructive to follow him through all his embassies to petty courts of Italy, the first of which took place in 1499, when he was sent to negotiate the continuance of a loan to Catherine Sforza, countess of Forlì and Imola. A more important mission followed in 1500, when Machiavelli travelled into France, to deal with Louis XII. about the affairs of Pisa. It is enough to say in general that these embassies were the school in which Machiavelli formed his political opinions, and gathered views regarding the state of Europe and the relative strength of nations. They not only introduced him to the subtleties of Italian diplomacy, but also extended his observation over races very different from the Italians in their social and constitutional development. He thus, in the course of his official business, gradually acquired principles and settled ways of thinking which he afterwards expressed in writing. He was at no time a philosopher or man of letters by profession, and when he came to write he gave to the world the condensed result of practical experience, combined with meditations on the Latin historians, rather than a methodical system.

His office obliged him from time to time to draw up proposals and memorials on questions of the day, which he presented to the Dieci. One of these, on the affairs of Pisa, belongs to 1499; a second, on the condition of Pistoia, to 1501; a third, of more general importance, on the right way of dealing with the rebels of Valdichiana, to 1502. In this last-named document some of the points of view which stamp his later works with a distinctive character emerge into prominence. We find him seeking parallels and precepts in Roman history, laying down the axiom that human nature is identical throughout the ages, exposing the futility of half measures, and finally appealing to Cesare Borgia as a model of political sagacity. It is clear from this brief and early composition that Machiavelli had already formed the habits of thought which distinguish him. He has begun to idealize Borgia's policy. He interweaves historical reflexions with contemporary analysis, using the past to illustrate the present, and expounding practical doctrine from texts derived from Livy. There is also noticeable the uncompromising spirit of the man, who was destined afterwards in the *Principe* to subordinate all minor considerations of morality and conduct to the one object of political attainment.

In the year 1502 Machiavelli married Marietta Corsini, the wife who bore him several children, with whom, in spite of his own infidelities, he lived on good terms, and who survived him twenty-six years. In the same year Piero Soderini was chosen gonfalonier for life, in accordance with certain changes in the constitution of the state, which were intended to bring Florence closer to the Venetian type of government. This was an important event in Machiavelli's career, for he now became intimately connected with Soderini, assisted him in carrying out his policy, suggested important measures of military reform which Soderini adopted, and finally was involved in ruin by his fall. Machiavelli, it may be said in passing, had the qualities of a good servant and a practical official. He remained faithful to Soderini through the difficulties of his later years of power, and spoke well of him subsequently. Yet he was a severe critic, blaming the gonfalonier for weakness of administration and half measures; and, when he died, he indulged in a sarcastic epigram on his old master which does less honour to his loyalty than to his wit.

The year 1502 was marked by yet another decisive incident in Machiavelli's life. In October he was sent, much against his will, as envoy to the camp of Cesare Borgia, or duke of Valentino, as he was now called. The duke was then in Romagna, and it was Machiavelli's duty to wait upon and watch him. He was able now to observe those intricate intrigues which culminated in Cesare's seizure of Sinigaglia and the treacherous murder of his disaffected captains. From what remains of Machiavelli's letters to the Dieci during this period, and from his tract upon the *Modo tenuto dal Duca Valentino nell' ammazzare Vitellozzo Vitelli*, we are able to appreciate the actual relations which existed between the two men, and the growth in Machiavelli's mind of a political ideal based upon his study of the duke's character. Machiavelli was a mere spectator and critic, by no means an adviser of the duke. He seems to have been even weary and uneasy in the network of hypocrisy and crime in which he found himself,—refreshing his spirits with jocular letters to his private friends, and with the study of a Plutarch which they sent him. He was also able to stigmatize the Borgia's conduct from a conventional point of view, as is proved by his calling him a "basilisk" and "hydra" in his *Decennali*. Yet he conceived the strongest admiration for his combination of audacity with diplomatic prudence, for his adroit use of cruelty and fraud, for his self-reliance, avoidance of half measures, employment of native troops, and firm administration in conquered provinces. More than once, in letters to his friend Vettori, no less than in the pages of the *Principe*, he afterwards expressed his belief that Cesare Borgia's behaviour in the conquest of provinces, the cementing of a new state out of scattered elements, and the dealing with false friends or doubtful allies, was worthy of all commendation and of scrupulous imitation. Hydra and basilisk were terms, not of reproach, but of panegyric, on the lips of the writer who warned his prince to acquire the nature of the fox and of the lion, who spoke familiarly of *frodi onorevoli, scelleratezze gloriose*, and whose conception of *Virtù* was self-reliant ability. As he watched Cesare Borgia at this, the most brilliant period of his adventurous career, the man became idealized in his reflective but imaginative mind. Round him, as a hero, he allowed his own conceptions of the perfect prince to cluster. There was so much in the conduct of the duke which exactly fitted with those conceptions, so much of that ideal had conversely been derived at first hand from the duke himself, that the hero and the adventurer were, as it were, confounded. That Machiavelli separated the actual Cesare Borgia, whom he afterwards saw, ruined and contemptible, at Rome, from this radiant creature of his political fancy, is probable. That the Cesare of history does not exactly match the Duca Valentino of Machiavelli's writings is certain. Still the fact remains that henceforth Machiavelli cherished the ideal image of the statesman which he had modelled upon Cesare, and called this by the name of Valentino.

On his return to Florence early in January 1503, Machiavelli began to occupy himself with a project he had long since formed, and which his recent attendance upon Cesare Borgia had strengthened in his mind. The duties of his office obliged him to study the conditions of military service as they then existed in Italy. He was familiar with the disadvantages under which republics laboured when they engaged professional captains of adventure and levied mercenary troops. The bad faith of the condottiere Paolo Vitelli (beheaded at Florence in 1499) had deeply impressed him. In the war with Pisa he had observed the insubordination and untrustworthiness of soldiers gathered from the dregs of different districts, serving under egotistical and irresponsible commanders. His reading in Livy taught him to admire the Roman system of employing armies raised from the body of the citizens; and Cesare Borgia's method of gradually substituting the troops of his own duchy for aliens and mercenaries showed him that this plan might be adopted with success by the Italians. He was now determined, if possible, to furnish Florence with a national militia. The gonfalonier Soderini entered into his views. But obstacles of no small magnitude arose. First came the financial difficulties in which the Government was then involved. The suspicion and jealousy of the Florentines had also to be encountered. Some of them feared lest Soderini, if he armed the commonwealth, would aspire to tyranny. All alike were adverse to arming the population of subject cities like Arezzo and Cortona; for it must be remembered that an Italian republic ruled its province with the despotism of an autocrat, and the towns beneath its sway were always panting for independence. The question of money was immediately pressing. Early in 1503 Machiavelli drew up for Soderini a speech, *Discorso sulla provisione del Danaro*, in which the duty and necessity of liberal expenditure for the protection of the state were expounded upon principles of sound political philosophy. Between this date and the last month of 1506 Machiavelli laboured at his favourite scheme, working out memorials on the subject for his office, and suggesting the outlines of a new military organization. On the 6th of December 1506 his plan was approved by the signory, and a special ministry, called the *Nove di Ordinanza e Milizia*, was appointed. Machiavelli immediately became their secretary. The country districts of the Florentine dominion were now divided into departments, and levies of foot soldiers were made in order to secure a standing militia. A commander-in-chief had to be chosen for the new troops. Italian jealousy shrank from conferring this important office on a Florentine, lest one member of the state should acquire a power dangerous to the whole. The choice of Soderini and Machiavelli fell, at this juncture, upon an extremely ineligible person, none other than Don Micheletto, Cesare Borgia's cut-throat and assassin. It is necessary to insist upon this point, since it serves to illustrate a radical infirmity in Machiavelli's genius. While forming and promoting his scheme, he was actuated by principles of political wisdom and by the purest patriotism. But he failed to perceive that such a ruffian as Micheletto could not inspire the troops of Florence with that devotion to their country and that healthy moral tone which should distinguish a patriot army. Here, as elsewhere, he revealed his insensibility to the ethical element in human nature. Knowing that Don Micheletto had worked well for Cesare Borgia, accustomed to disregard private morality as insignificant in public conduct, he was satisfied to entrust the discipline and education of his raw militia to a notorious villain. His indifference to personal ethics led him now into a practical blunder, as it afterwards vitiated his political writings with a philosophical error.

Meanwhile Italy had been the scene of memorable events, in most of which Machiavelli took some part. Alexander VI. had died suddenly of fever. Julius II. had ascended the papal chair. The duke Valentino had been checked in mid-career of conquest. Machiavelli was sent to Rome during the conclave, when he renewed his intercourse with Cesare Borgia. On this occasion he seems to have felt nothing but contempt for the hero of his dreams, who had sunk into insignificance and almost abject submission. The collapse of the Borgias threw Central Italy into confusion; and Machiavelli had, in 1505, to visit the Baglioni at Perugia and the Petrucci at Siena. In the following year he accompanied Julius upon his march through Perugia into the province of Emilia, where the fiery pope subdued in person the rebellious cities of the church. Upon these embassies Machiavelli represented the Florentine Dieci in quality of envoy. It was his duty to keep the ministry informed by means of frequent despatches and reports. All this while the war for the recovery of Pisa was slowly dragging on, with no success or honour to the Florentines. Machiavelli had to attend the camp and provide for levies amid his many other occupations. And yet he found time for private literary work. In the autumn of 1504 he began his *Decennali*, or *Annals of Italy*, a poem composed in rough terza rima, and now remembered only for one line describing the courage of Piero Capponi, when he defied Charles VIII. to his face in 1495 :—

> "Lo strepito dell' armi e de' cavalli,
> Non potè far che non fosse sentita
> La voce d'un Cappon fra cento Galli."

About the same time he composed a comedy on the model of Aristophanes, which is unfortunately lost. It seems to have been called *Le Maschere*. Giuliano de' Ricci tells us it was marked by stringent satire upon great ecclesiastics and statesmen, no less than by a tendency to "ascribe all human things to natural causes or to fortune." That phrase accurately describes the prevalent bias of its author's mind.

The greater part of 1506 and 1507 was spent in organizing the new militia, corresponding on the subject, and scouring the country on enlistment service. But at the end of the latter year European affairs of no small moment diverted Machiavelli from these humbler duties. Maximilian was planning a journey into Italy in order to be crowned emperor at Rome, and was levying subsidies from the imperial burghs for his expenses. The Florentines thought his demands excessive. Though they already had Francesco Vettori at his court, Soderini judged it advisable to send Machiavelli thither in December. He travelled by Geneva, all through Switzerland, to Botzen, where he found the emperor.

This journey was an important moment in his life. It enabled him to study the Swiss and the Germans in their homes; and the report which he wrote on his return, *Rapporto di Cose della Magna*, reckons among his most effective political studies. Instead of confining his attention to the analysis of parties or the portraits of eminent persons in the countries he had traversed, Machiavelli strove to estimate the essential elements of national success or failure. The antique sobriety of the Swiss, their absolute equality and independence, their efficient national militia, inspired him with such admiration that henceforth the Swiss appeared to him the model of modern nations and the most formidable among the neighbours of the Italians. He pointed out that the strength of Germany lay in the free cities, while the emperor was weakened, not only by his own indecisive character and want of funds, but by the jealousy of the feudal princes. The German princes, the burghs, and the empire being ill-accorded, and the Swiss being hostile to all alike, this vast nation lacked the force which its excellent morality, sober living, and vigorous military organization ought to have secured it. What is most remarkable in Machiavelli's report is his concentrated effort to realize the exact political weight of the German nation, and to penetrate the causes of its strength and weakness. He attempts to grasp the national character as a whole, and thence to deduce practical conclusions. Certain mistakes he undoubtedly made. He treated the Swiss, for example, too much as though they were a part of Germany. He exaggerated the simplicity and sobriety of the race at large, seemingly inspired by Tacitus, and inflamed in his own imagination by sympathy with a people who realized his cherished dreams of national health. His indifference to ecclesiastical questions prevented him from discerning the crisis of the Reformation, which was on the verge of precipitating Germany into the discord of religious wars. Yet, allowing for these drawbacks, we are astonished by the insight into details and the co-ordinating faculty which enabled this Italian to draw so discriminating and animated a portrait of the Germans for the benefit of his republic.

The same great qualities are noticeable in his *Ritratti delle Cose di Francia*, which he drew up after an embassy to Louis XII. at Blois in 1510. These notes upon the French race are more scattered than the report on German affairs. But they reveal no less acumen combined with imaginative penetration into the very essence of national existence. He points out that the special strength of France lies in her centralization. The monarch is surrounded by obedient feudal vassals, the most powerful of whom are of the royal blood. They in their turn draw their wealth from the people. Feudalism, an element of discord in Germany, has been converted into monarchy, and become the cohesive bond of society in France. On the other hand, this centralization contains a grave element of danger for the future of France. The people are ground down and have no liberty. Machiavelli points out how, in these circumstances, the pith of the French army is its chivalry, and why the king is always obliged to hire German and Swiss infantry for his wars. The *Ritratti* abound in pointed observations upon the French character which is well contrasted with that of the Spaniards. But what constitutes the originality of this tract is Machiavelli's determination to realize to himself and to his readers the political value of the French people as a whole, and thus to form a solid basis for judging of its probable behaviour in the future. In this case, as in the case of Germany, he attempts to estimate the physical, moral, and intellectual capacity of an antagonist with whom his country has to grapple. It may be said that, with France as with Germany, he wholly omits the possibilities of religious perturbation.

While engaged upon this topic, it may be well to mention that Machiavelli displayed exactly the same force of analysis in laying bare the central causes of weakness in Italy itself. The disarmament of the population by selfish despots and indolent republics; the consequent growth of a vicious mercenary system; the dismemberment of the nation into petty, mutually jealous parcels, due for the most part to the selfishness of Rome; the loss of antique sobriety in manners, and the almost total corruption of the people, fostered and encouraged by their debauched spiritual leaders,—these, he says, are the causes which have made Italy "more enslaved than the Hebrews, more downtrodden than the Persians, more disunited than the Athenians." This is not the place to discuss his policy for the Italians. Suffice it to say that the same method which he applied to Germany and France supplied him with general conclusions about Italy, and enabled him to view with a truly terrible clairvoyance that desperate disease of his country for which he afterwards invented remedies as desperate.

Machiavelli returned from Germany in June 1508. The rest of that year and a large part of 1509 were spent in the affairs of the militia and the war of Pisa. Chiefly through his exertions the war was terminated by the surrender of Pisa in June 1509. Meanwhile the league of Cambray had disturbed the peace of Italy, and Florence found herself in a perilous position between Spain and France. Soderini's Government grew weaker. The Medicean party lifted up its head. To the league of Cambray succeeded the Lega Santa. The battle of Ravenna was fought, and the French retired from Italy. The Florentines had been spectators rather than actors in these great events. But they were now destined to feel the full effects of them. The cardinal Giovanni de' Medici, who was present at the battle of Ravenna, brought a Spanish army into Tuscany. Prato was sacked in the August of 1512. Florence, in extreme terror, deposed the gonfalonier, and opened her gates to the princes of the house of Medici.

The Government on which Machiavelli depended had fallen, never to rise again. The national militia in which he placed unbounded confidence had proved inefficient to protect Florence in the hour of need. He was surrounded by political and personal enemies, who regarded him with jealousy as the ex-gonfalonier's right hand man. Yet at first it appears that he still hoped to retain his office. He showed no repugnance to a change of masters, and began to make overtures to the Medici. The Nove della Milizia were, however, dissolved; and on November 7, 1512, Machiavelli was deprived of his appointments. He was exiled from Florence and confined to the dominion for one year, and on November 17 was further prohibited from setting foot in the Palazzo Pubblico. Ruin stared him in the face; and, to make matters worse, he was implicated in the conspiracy of Pier Paolo Boscoli in February 1513. Machiavelli had taken no share in that feeble attempt against the Medici, but his name was found upon a memorandum dropped by Boscoli. This was enough to ensure his imprisonment. He was racked, and only released upon Giovanni de' Medici's election to the papacy in March 1513. When he left his dungeon, he retired to a farm near San Casciano, and faced the fact that his political career was at an end.

Machiavelli now entered upon a period of life to which we owe the great works that have rendered his name immortal. But it was one of prolonged disappointment and annoyance. He had not accustomed himself to economical living; and, when the emoluments of his office were withdrawn, he had but barely enough to support his family. The previous years of his manhood had been spent in continual activity. Much as he enjoyed the study of the Latin and Italian classics, literature was not his business; nor had he looked on writing as more than an occasional amusement. He was now driven in upon his books for the employment of a restless temperament; and to this irksomeness of enforced leisure may be ascribed the production of the *Principe*, the *Discorsi*, the *Arte della Guerra*, the comedies, and the *Storia Fiorentina*. The uneasiness of Machiavelli's mind in the first years of this retirement is brought before us by his private correspondence. The letters with Vettori paint a man of vigorous intellect and feverish activity, dividing his time between studies and vulgar dissipations, seeking at one time distraction in low intrigues and wanton company, at another turning to the great minds of antiquity for solace. It is not easy for a modern gentleman to understand the spirit in which the author of the *Principe* sat down to exchange obscenities with the author of the *Sommario della Storia d'Italia*. Nor can it be urged that Machiavelli plunged into dissipation at this crisis to escape from care, or that he penned filth because he had no other occupation for his thoughts. From the camp of Borgia in 1502, when his mind was on the stretch, and he was watching history in the making, he had written similar trash to his acquaintances at home. At the same time this coarseness of taste did not blunt his intellectual sagacity. His letters on public affairs in Italy and Europe, especially those which he meant Vettori to communicate to the Medici at Rome, are marked by extraordinary fineness of perception, combined, as usual in his case, with philosophical breadth. In retirement at his villa near Percussina, a hamlet of San Casciano, Machiavelli completed the *Principe* before the end of 1513. This famous book is an analysis of the methods whereby an ambitious man may rise to sovereign power. It appears to have grown out of another scarcely less celebrated work, upon which Machiavelli had been engaged before he took the *Principe* in hand, and which he did not finish until some time afterwards. This second treatise is the *Discorsi sul primo libro delle Deche di Tito Livio*, which will henceforth be mentioned in this article as the *Discorsi*.

Cast in the form of comments on the history of Livy, the *Discorsi* are really an inquiry into the genesis and maintenance of states,—how states come into being, prosper, and decline—in what forms they can be modelled and maintained. The *Principe* is an offshoot from the main theme of the *Discorsi*, setting forth Machiavelli's views at large and in detail upon the nature of principalities, the method of cementing them, and the qualities of a successful autocrat. Being more limited in subject and more independent as a work of literary art, this essay detaches itself from the main body of the *Discorsi*, and has attracted far more attention. We feel that the *Principe* is inspired with greater fervency, as though its author had more than a speculative aim in view, and brought it forth to serve a special crisis. The moment of its composition was indeed decisive. Machiavelli judged the case of Italy so desperate that salvation could only be expected from the intervention of a powerful despot. The unification of Italy in a state protected by a national army was the cherished dream of his life; and the peroration of the *Principe* shows that he meant this treatise to have a direct bearing on the problem. We must be careful, however, not to fall into the error of supposing that he wrote it with the sole object of meeting an occasional emergency. Together with the *Discorsi*, the *Principe* contains the speculative fruits of his experience and observation combined with his deductions from Roman history. The two works form one coherent body of opinion, not systematically expressed, it is true, but based on the same principles, involving the same conclusions, and directed to the same philosophical end. That end is the analysis of the conception of the state, studied under two main types, republican and monarchical. Up to the date of Machiavelli, modern political philosophy had always presupposed an ideal. Mediæval speculation took the church and the empire for granted, as divinely appointed institutions, under which the nations of the earth must flourish for the space of man's probation on this planet. Thinkers differed only as Guelfs and Ghibellines, as leaning on the one side to papal on the other to imperial supremacy. In the revival of learning, scholarship supplanted scholasticism, and the old ways of mediæval thinking were forgotten. But no substantial philosophy of any kind emerged from humanism; the political lucubrations of the scholars were, like their ethical treatises, for the most part rhetorical. Still the humanists effected a delivery of the intellect from what had become the bondage of obsolete ideas, and created a new medium for the speculative faculty. Society in Europe had outgrown the conditions of the Middle Ages, and this new humanistic atmosphere corresponded to the new phase upon which the modern nations were entering. Simultaneously with the revival, Italy had passed into that stage of her existence which has been called the age of despots. The yoke of the empire had been shaken off. The church had taken rank among Italian tyrannies. The peninsula was, roughly speaking, divided into principalities and sovereign cities, each of which claimed autocratic jurisdiction. These separate despotisms owned no common social tie, were founded on no common *jus* or right, but were connected in a network of conflicting interests and changeful diplomatic combinations. A keen and positive political intelligence emerged in the Italian race. The reports of Venetian and Florentine ambassadors at this epoch contain the first germs of an attempt to study politics from the point of view of science. At this moment Machiavelli intervenes. He was conscious of the change which had come over Italy and Europe. He was aware that the old strongholds of mediæval thought must be abandoned, and that the decaying ruins of mediæval institutions furnished no basis for the erection of solid political edifices. He felt the corruption of his country, and sought to bring the world back to a lively sense of the necessity for reformation. His originality consists in having extended the positive intelligence of his century from the sphere of contemporary politics and special interests to man at large regarded as a political being. He founded the science of politics for the modern world, by concentrating thought upon its fundamental principles. Much that is unnatural in the forced severance of politics from ethics, much that we know now to be untrue in the conception of national development, much that offends our moral sense in the justification of iniquity for public ends, much that the experience of the last three centuries has shown to be mistaken in the theory of the state considered as a work of plastic art, much that belongs to the Renaissance, and has perished with that period of transition, much that is wrongly applied from the experience of Italian diplomacy to politics in general, can be noted by the students of Machiavelli. We feel the want in him of a thorough philosophical education, the continual oscillation between speculative and practical points of view, the lack of system and the negligence of stringent definition. We surmise that, had he studied Plato's *Republic* or the first chapters of Aristotle's *Politics* and *Ethics*, he might perhaps have avoided what has been the stumbling-block to generous readers—his indifference to moral righteousness as indispensable to states no less than individuals. We regret his unqualified inculcation of the doctrine that means are justified by ends,—a doctrine rendered odious by Jesuitry to the modern mind, and incompatible with any sound science of humanity. We know that ethics cannot be severed, as he severed them, from politics; that, though national differs from private duty, both are based upon the same immutable principles; that the former tends, with the growth of the race, to approach ever more nearly to the former; and that it is the function of the political philosopher to keep this steadily in view. We have learned to regard nations, not merely as materials to be moulded by a lawgiver, but as total organisms, which, however modified by men of genius, obey their own laws of evolution. We have outgrown his admiration of antiquity, and do not believe that modern states should seek to model themselves upon the type of Rome. We perceive that his ideal of a prince, working by force, fraud, cruelty, dissimulation to a certain end, was the creature of circumstances, which caused him to advocate the opposition of violence to anarchy as the only possible resort. These are deductions to be made from Machiavelli's teaching, regarded as final, or as instructive for the times in which we live. But, when we have made these deductions, there remains the fact of his achievement. He began to study men, not according to some preconception, but as he found them,—men, not in the isolation of one century, but as a whole in history. He drew his conclusions from the nature of mankind itself, "ascribing all things to natural causes or to fortune." In this way he restored the right method of study, a method which had been neglected since the days of Aristotle. He formed a conception of the modern state, which marked the close of the Middle Ages, and anticipated the next phase of European development. His prince, abating those points which are purely Italian or strongly tinctured with the author's personal peculiarities, prefigured the monarchs of the 16th and 17th centuries, the monarchs whose motto was *L'état c'est moi!* His doctrine of a national militia foreshadowed the system which has given strength in arms to France and Germany. His insight into the causes of Italian decadence was complete; and the remedies which he suggested, in the perorations of the *Principe* and the *Arte della Guerra*, have since been applied in the unification of Italy. Lastly, when we once have freed ourselves from the antipathy engendered by his severance of ethics from the field of politics, when we have once made proper allowance for his peculiar use of phrases like "frodi onorevoli" or "scelleratezze gloriose," nothing is left but admiration for his mental attitude. That is the attitude of a patriot, who saw with open eyes the ruin of his country, who burned above all things to save Italy and set her in her place among the powerful nations, who held the duty of self-sacrifice in the most absolute sense, whose very limitations and mistakes were due to an absorbing passion for the state he dreamed might be reconstituted. It was Machiavelli's intense preoccupation with this problem—what a state is and how to found one in existing circumstances—which caused the many riddles of his speculative writings. Dazzled, as it were, with the brilliancy of his own discovery, concentrated in attention on the one necessity for organizing a powerful coherent nation, he forgot that men are more than political beings. He neglected religion, or regarded it as part of the state machinery. He was by no means indifferent to private virtue, which indeed he judged the basis of all healthy national existence; but in the realm of politics he postponed morals to political expediency. He held that the people, as distinguished from the nobles and the clergy, were the pith and fibre of nations; yet this same people had to become wax in the hands of the politician,—their commerce and their comforts, the arts which give a dignity to life and the pleasures which make life liveable, neglected,—their very liberty subordinated to the one tyrannical conception. To this point the segregation of politics from every other factor which goes to constitute humanity had brought him; and this it is which makes us feel his world a wilderness, devoid of atmosphere and vegetation. Yet some such isolation of the subject-matter of this science was demanded at the moment of its birth, just as political economy, when first started, had to make a rigid severance of wealth from other units. It is only by a gradual process that social science in its whole complexity can be evolved. We have hardly yet discovered that political economy has unavoidable points of contact with ethics.

From the foregoing criticism it will be perceived that all the questions whether Machiavelli meant to corrupt or to instruct the world, to fortify the hands of tyrants or to lead them to their ruin, are now obsolete. He was a man of science—one who by the vigorous study of his subject-matter sought from that subject-matter itself to deduce laws. The difficulty which remains in judging him is a difficulty of statement, valuation, allowance. How much shall we allow for his position in Renaissance Italy, for the corruption in the midst of which he lived, for his own personal temperament? How shall we state his point of departure from the Middle Ages, his sympathy with prevalent classical enthusiasms, his divination of a new period? How shall we estimate the permanent worth of his method, the residuum of value in his maxims?

After finishing the *Principe*, Machiavelli thought of dedicating it to one of the Medicean princes, with the avowed hope that he might thereby regain their favour and find public employment. He wrote to Vettori on the subject, and Giuliano de' Medici, duke of Nemours, seemed to him the proper person. The choice was reasonable. No sooner had Leo been made pope than he formed schemes for the aggrandizement of his family. Giuliano was offered and refused the duchy of Urbino. Later on, Leo designed for him a duchy in Emilia, to be cemented out of Parma, Piacenza, Reggio, and Modena. Supported by the power of the papacy, with the goodwill of Florence to back him, Giuliano would have found himself in a position somewhat better than that of Cesare Borgia; and the Borgia's creation of the duchy of Romagna might have served as his model. Machiavelli therefore was justified in feeling that here was an opportunity for putting his cherished schemes in practice, and that a prince with such alliances might even advance to the grand end of the unification of Italy. Giuliano, however, died in 1506. Then Machiavelli turned his thoughts towards Lorenzo, duke of Urbino. The choice of this man as a possible Italian liberator reminds us of the choice of Don Micheletto, as general of the Florentine militia. To Lorenzo the *Principe* was dedicated, but without result. The Medici, as yet at all events, could not employ Machiavelli, and had not in themselves the stuff to found Italian kingdoms.

Machiavelli, meanwhile, was reading his *Discorsi* to a select audience in the Rucellai gardens, fanning that republican enthusiasm which never lay long dormant among the Florentines. Towards the year 1519 both Leo X. and his cousin the cardinal Giulio de' Medici were much perplexed about the management of the republic. It seemed necessary, if possible, in the gradual extinction of their family, to give the city at least a semblance of self-government. They applied to several celebrated politicians, among others to Machiavelli, for advice in the emergency. The result was his *Discorso sopra il Riformar lo Stato di Firenze*, a treatise in which he deduces practical conclusions from the past history and present temper of the city, blending these with his favourite principles of government in general. He earnestly admonishes Leo, for his own sake and for Florence, to found a permanent and free state system for the republic, reminding him in terms of noble eloquence how splendid is the glory of the man who shall confer such benefits upon a people. The year 1520 saw the composition of *I sette Libri dell' Arte di Guerra*, and of the *Vita di Castruccio*.

The first of these is a methodical treatise, setting forth Machiavelli's views on military matters, digesting his theories respecting the superiority of national troops, the inefficiency of fortresses, the necessity of relying upon infantry in war, and the comparative insignificance of artillery. It is strongly coloured with his enthusiasm for ancient Rome; and specially upon the topic of artillery it displays a want of insight into the actualities of modern warfare. We may regard it as a supplement or appendix to the

Principe and the *Discorsi*, since Machiavelli held it for a fundamental axiom that states are powerless unless completely armed in permanence. The peroration contains a noble appeal to the Italian liberator of his dreams, and a parallel from Macedonian history, which, read by the light of this century, sounds like a prophecy of Piedmont.

The *Vita di Castruccio* was composed at Lucca, whither Machiavelli had been sent on a mission. This so-called biography of the mediæval adventurer who raised himself by personal ability and military skill to the tyranny of several Tuscan cities must be regarded in the light of an historical romance. Dealing freely with the outline of Castruccio's career, as he had previously dealt with Cesare Borgia, he sketched his own ideal of the successful prince. Cesare Borgia had entered into the *Principe* as a representative figure rather than an actual personage; so now conversely the theories of the *Principe* assumed the outward form and semblance of Castruccio. In each case history is blent with speculation in nearly the same proportions. But Castruccio, being farther from the writer's own experience, bears weaker traits of personality.

In the same year, 1520, Machiavelli, at the instance of the cardinal Giulio de' Medici, received commission from the officers of the Studio Pubblico to write a history of Florence. They agreed to pay him an annual allowance of 100 florins while engaged upon the work. The next six years were partly employed in its composition, and he left a portion of it finished, with a dedication to Clement VII., when he died in 1527. In the *Istorie Fiorentine* Machiavelli quitted the field of political speculation for that of history. But, having already written the *Discorsi* and the *Principe*, he carried with him to this new task of historiography the habit of mind proper to political philosophy. In his hands the history of Florence became a text on which at fitting seasons to deliver lessons in the science he initiated. This gives the work its special character. It is not so much a chronicle of Florentine affairs, from the commencement of modern history to the death of Lorenzo de' Medici in 1492, as a critique of that chronicle from the point of view adopted by Machiavelli in his former writings. Having condensed his doctrines in the *Principe* and the *Discorsi*, he applies their abstract principles to the example of the Florentine republic. His favourite topics reappear—the dismemberment of Italy by the papacy (bk i. 9, 23); the ruin of her national militia (bk. i. 34, 38; bk. v. 1; bk. vi. 1); the enervation of her commonwealths by commerce (bk. i. 39; bk. ii. 42); her corrupt morality (bk. iii. 1); the reference of Italian circumstances to Roman precedents (bk. iii. 1); the theory of the intervenient "nomothetes" in states (bk. iv. 1); and the theory of human vicissitudes (bk. v. 1). This gives to his history a deductive and illustrative quality which men of less imaginative mind, like Guicciardini, or the exact students of our own days may criticize. But the *History of Florence* is not a mere political pamphlet. It is the first example in Italian literature of a national biography, the first attempt in any literature to trace the vicissitudes of a people's life in their logical sequence, deducing each successive phase from passions or necessities inherent in preceding circumstances, reasoning upon them from general principles, and inferring corollaries for the conduct of the future. In his prooemium Machiavelli taxes Poggio and Lionardo Bruni with having neglected civic affairs for the record of wars and alliances. It is to the analysis of the republic's inner life that he directs attention, showing how her acts were the phenomena of this organic force. At the same time he does not omit the narrative of external events, but places the portrait of Florence in the centre of an animated group of pictures drawn from Italian history. Approaching his own times, he enlarges on the part played by the Medici; for it was one of the conditions of the task imposed on him that he should celebrate the ancestors of Giulio. This portion of the work is executed in no servile spirit, and the subsequent destiny of Florence fully justified the prominence here given to the elder Cosimo and Lorenzo. In point of form the *Florentine History* is modelled upon Livy. In contains speeches in the antique manner, which may be taken as partly embodying the author's commentary upon situations of importance, partly as expressing what he thought dramatically appropriate to prominent personages. The style of the whole book is nervous, vivid, free from artifice and rhetoric, obeying the writer's thought with absolute plasticity. Machiavelli had formed for himself a prose style, equalled by no one but by Guicciardini in his minor works, which was far removed from the emptiness of the Latinizing humanists and the trivialities of the Italian purists. Words in his hands have the substance, the self-evidence of things. It is an athlete's style, all bone and sinew, nude, without superfluous flesh or ornament.

It would seem that from the date of Machiavelli's discourse to Leo on the government of Florence the Medici had taken him into consideration. Writing to Vettori in 1513, he had expressed his eager wish to "roll stones" in their service; and this desire was now gratified. In 1521 he was sent to Carpi to transact a petty matter with the chapter of the Franciscans, the chief known result of the embassy being a burlesque correspondence with Francesco Guicciardini. Four years later, in 1525, he received a rather more important mission to Venice. But Machiavelli's public career was virtually closed; and the interest of his biography still centres in his literary work. We have seen that already, in 1504, he had been engaged upon a comedy in the manner of Aristophanes, which is now unfortunately lost. A translation of the *Andria*, and three original comedies from his pen are extant, the precise dates of which are uncertain, though the greatest of them was first printed at Rome in 1524. This is the *Mandragola*, which may be justly called the ripest and most powerful single play in the Italian language.

The plot is both improbable and unpleasing. But, having granted this, literary criticism is merged in admiration of the wit, the humour, the vivacity, the satire of a piece which brings before us the old life of Florence in a succession of brilliant scenes. If Machiavelli had any moral object when he composed the *Mandragola*, it was to paint in glaring colours the corruption of Italian society. It shows how a bold and plausible adventurer, aided by the profligacy of a parasite, the avarice and hypocrisy of a confessor, and a mother's complaisant familiarity with vice, achieves the triumph of making a gulled husband bring his own unwilling but too yielding wife to shame. The whole comedy is a study of stupidity and baseness acted on by roguery. About the power with which this picture of domestic immorality is presented there can be no question. But the perusal of the piece obliges us to ask ourselves whether the author's radical conception of human nature was not false. The same suspicion is forced upon us by the *Principe*. Did not Machiavelli leave good habit, as an essential ingredient of character, out of account? Men are not such absolute fools as Nicia, nor such compliant catspaws as Ligurio and Timoteo; women are not such weak instruments as Sostrata and Lucrezia. Somewhere, in actual life, the stress of craft and courage acting on the springs of human vice and weakness fails, unless the hero of the comedy or tragedy, Callimaco or Cesare, allows for the revolt of healthier instincts. Machiavelli does not seem to have calculated the force of this recoil. He speculates a world in which *Virtù*, unscrupulous strength of character, shall deal successfully with frailty. This, we submit, was a deep-seated error in his theory of life, an error to which may be ascribed the numerous stumbling-blocks and rocks of offence in his more serious writings.

Some time after the *Mandragola*, he composed a second comedy, entitled *Clizia*, a portion of the plot of which is borrowed from the *Casina*. Though modelled on the art of Plautus, the *Clizia* is even homelier and closer to the life of Florence than its predecessor. It contains incomparable studies of the Florentine housewife and her husband, a grave business-like citizen, who falls into the senile folly of a base intrigue. The device by which Nicomaco is brought back to a sense of duty is presented in scenes of solid humour which recall the manner of Ben Jonson. On the whole, the *Clizia* is a pleasanter and wholesomer play than the *Mandragola*. It served as model to a school of later playwrights. There remains a short piece without title, the *Commedia in Prosa*, which, if it be Machiavelli's, as internal evidence of style sufficiently argues, might be accepted as a study for both the *Clizia* and the *Mandragola*. It seems written to expose the corruption of domestic life in Florence, and especially to satirize the friars in their familiar part of go-betweens, tame cats, confessors, and adulterers. The Fra Alberigo of this comedy is a vigorous piece of realistic portraiture, anticipating, if not surpassing, the Fra Timoteo of the *Mandragola*.

Of Machiavelli's minor poems, sonnets, capitoli, and carnival songs, there is not much to say. Powerful as a comic playwright, he was not a poet in the proper sense of the term. The little novel of *Belfagor* claims a passing word, if only because of its celebrity. It is a good-humoured satire upon marriage, the devil being forced to admit that hell itself is preferable to his wife's company. That Machiavelli invented it to express the irritation of his own domestic life is a myth without foundation. The story has a mediæval origin, and it was almost simultaneously treated in Italian by Machiavelli, Straparola, and Giovanni Brevio.

In the spring of 1526 Machiavelli was employed by Clement VII. to inspect the fortifications of Florence. He presented a report upon the subject, and in the summer of the same year received orders to attend Francesco Guicciardini, the pope's commissary of war in Lombardy. Guicciardini sent him in August to Cremona, to transact business with the Venetian provveditori. Later on in the autumn we find him once more with Guicciardini at Bologna. Thus the two great Italian historians of the

16th century, who had been friends for several years, were brought into relations of close intimacy. It would be interesting to know the topics of their conversation, and to possess some fragments of the debates they undoubtedly held upon the grave affairs of Italy at this decisive juncture. In the next year Rome was destined to be sacked by an imperial army. Florence was to rise in rebellion against the Medici. Four years later Charles V. was to lay the iron hand of Spain upon the remnants of Italian liberty. But nothing survives of Machiavelli's and Guicciardini's discourse. We can only form an opinion of what it must have been from the commentaries written by the latter on the political philosophy of Machiavelli—commentaries which sufficiently explain the different methods of the two great thinkers. Guicciardini, more positive even than Machiavelli in his criticism, averse to theory, satisfied with a policy of public temporizing and expediency, accepting Italian decadence with the tranquillity of egotism, looked on Machiavelli as a dreamer. "Nothing," he says, "can cure the diseases of our century but the knife of Lycurgus, and the knife of Lycurgus may not be expected." Machiavelli was always hoping against hope that this knife in the hands of some superior Cesare might still be used. Guicciardini, as events proved, had taken a sounder view of the situation; or rather it was men like Guicciardini who made the situation. Machiavelli to the last remained a patriot, with darkly bright impracticable visions in his brain.

After another visit to Guicciardini in the spring of 1527, Machiavelli was sent by him to Civita Vecchia. It seemed that he was destined to be associated in the papal service with Clement's viceroy, and that a new period of diplomatic employment was opening for him. But soon after his return to Florence he fell ill. His son Piero said that he took medicine on the 20th of June which disagreed with him; and on the 22d he died, having received the last offices of the church. There is no foundation for the legend that he expired with profane sarcasms upon his lips. Yet we need not run into the opposite extreme, and try to fancy that Machiavelli, who had professed paganism in his life, proved himself a believing Christian on his death-bed. That he left an unfavourable opinion among his fellow-citizens is very decidedly recorded by the historian Varchi. The *Principe*, it seems, had already begun to prejudice the world against him; and we can readily believe what Varchi sententiously observes, that "it would have been better for him if nature had given him either a less powerful intellect or a mind of a more genial temper." There is in truth a something crude, unsympathetic, cynical in his mental attitude toward human nature, for which, even after the lapse of more than three centuries, we find it difficult to make allowance. The force of his intellect renders this want of geniality repulsive. We cannot help objecting that one who was so powerful could have been kindlier and sounder if he willed. We therefore do him the injustice of mistaking his infirmity for perversity. He was colour-blind to commonplace morality; and we are angry with him because he merged the hues of ethics in one grey monotone of politics. In person Machiavelli was of middle height, black-haired, with rather a small head, very bright eyes, and slightly aquiline nose. His thin close lips often broke into a smile of sarcasm. His activity was almost feverish. When unemployed in work or study, he was not averse to the society of boon companions, gave himself readily to transient amours, and corresponded in a tone of cynical bad taste. At the same time he lived on terms of intimacy with worthy men. Varchi says of him that "in his conversation he was pleasant, obliging to his intimates, the friend of virtuous persons." Those who care to understand the contradictions of which such a character was capable should study his correspondence with Vettori. It would be unfair to charge what is repulsive in their letters wholly on the habits of the times; for wide familiarity with the published correspondence of similar men at the same epoch brings one acquainted with little that is so disagreeable.

For complete editions of Machiavelli's works, that of Italia, 8 vols., 1813, and the more comprehensive by Usigli, Florence, 1853, may be cited. The best biography is by Professor Pasquale Villari, 3 vols., Florence, 1877–82. This work contains a copious critique of all the most important studies which have been made of Machiavelli's works. An English translation of this life, finished by Madame Villari under the guidance of Professor Villari, is being published. (J. A. S.)

MACHINE TOOLS. The very small degree of antiquity to which machine tools can lay claim appears forcibly in the sparse records of the state of the mechanical crafts a century ago. A few tools of a rude kind, such as tilt-hammers, and a few special ones which aimed at accuracy, but were of very limited application, such as "mills" for boring cannon, or "engines" for cutting the teeth of clock wheels, were almost their only representatives. Machine tools of the modern type indeed would not then have been likely to have found much favour even if they had been invented, owing to the difficulty of providing sufficient power for driving them, except in the comparatively few positions where water-power was available. The transmission of power was unthought of, except for the very limited distances which were possible with the ill-fitted "gudgeons" and "lanterns and trundles" of the old millwrights.

The steam-engine, however, changed all this. On the one hand the hitherto unheard-of accuracy of fit required by its working parts created a demand for tools of increased power and precision, and on the other it rendered the use of such tools possible in almost any situation. Thus, acting and reacting on each other, machine tools and steam-engines have grown side by side, till our workshops have become peopled with a race of giants, capable of uncomplainingly performing tasks altogether beyond the powers of the easily wearied hands which have brought them into existence. But the first steps in the process were costly and difficult to a degree which it is not now easy to realize. James Watt, for instance, in 1769, was fain to be content with a cylinder for his "fire-engine" of which, though it was but 18 inches in the bore, the diameter in one place exceeded that at another by about $\frac{3}{8}$ (·375) of an inch; its piston was not unnaturally leaky, though he packed it with "paper, cork, putty, pasteboard, and old hat." In the bore of a cylinder of 120 inches there would not now be admitted an error of $\frac{1}{100}$ of an inch, and the leakage past the piston is practically *nil*. Even this must by no means be taken to represent the extreme limit attainable in respect of size and accuracy.

Machine tools present so many points of difference that no classification of them will be attempted beyond a broad division into general and special tools,—those included under the latter head being such as are intended to perform repeatedly one single operation (or one of a small number of varieties of that operation), or are mainly employed in particular processes or manufactures.

As an instance of special tools working successively in a series,—which is a frequent arrangement with special tools,—the *block machinery*, for making ships' blocks at Portsmouth dockyard, may be mentioned. Erected in 1807 by Mr H. Maudslay from designs by Mr (afterwards Sir Marc) Brunel, on the recommendation of Sir S. Bentham, it enabled ten men to do in a superior manner work which previously required one hundred and ten, and effected in the annual expenditure of the nation a saving of about £24,000. Into the particulars of the beautifully arranged sawing, mortising, shaping, and other machines by which this was accomplished we cannot enter, but they are of great interest, not only from their intrinsic merits, but also as being, if not the very first, certainly superior to any which had previously been used. Our limited space, however, will be more profitably devoted to giving a few examples of the general tools used in engineers' workshops.

The *Steam-Hammer*, which in some respects may be regarded as the most important of machine tools, has already been noticed (see HAMMER, vol. xi. p. 425). Second only to it in importance, and long anterior to it in date, stands the *lathe.* At what exact point of its development from the simple foot lathe it first became entitled to rank as a machine tool we will not stop to inquire, for the origin of this, as of most of the mechanical legacies which have been handed down to us by successive inventors and improvers, is involved in much obscurity. But as far as tools laying any claim to precision are concerned it appears certainly to have been the first to come into existence. On the Continent, mechanism to be used in conjunction with it for oval turning, and for producing mouldings oblique to the axis of the work, had been devised as early as 1569, in which year one Jacques Besson published drawings of two lathes so arranged. Whether much additional beauty was obtained by thus departing from the circular sections producible with the simple lathe, and converting them into distorted ones, such as that sketched in fig. 1 (reduced from Besson), may perhaps be questioned, but the taste for this "swash" work, as it is called, ere long extended also to England. Moxon, the first English writer on the subject, gives a drawing of a very similar lathe, and he mentions the name of an established London maker whose oval engines and swash engines, and all other engines, were "excellently well made," so they were apparently in some demand at the time of his writing (1680).

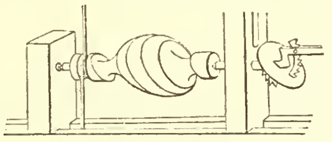


FIG. 1.—Swash Work.

Screw cutting in the lathe was another problem—and a more worthy one—which occupied the attention of inventors at the same early period. A curious but mechanically very imperfect arrangement for accomplishing it (with which, however, threads either right or left handed could be cut on tapered and oval as well as on cylindrical work) is given in another of Besson's engravings. In this the tool is entirely supported and its movements are controlled by the machine instead of being held in the hand,—an arrangement of which the great advantage appears to have been but tardily appreciated, though it contains the germ of the principle which, applied first in the slide-rest of the lathe, and subsequently in machine tools of almost every type, has enabled tasks of constantly increasing severity to be successfully dealt with.

Nearly two centuries seem to have elapsed before what we now know as the *slide-rest* became a recognized adjunct to the turning lathe, though in the meantime arrangements had been devised for controlling the motion of the tool by attaching it to some portion of the mechanism in some special cases,—as in that of two curious lathes for turning hyperbolic, spherical, or plane mirrors for optical purposes, of which engravings were published at Rome in 1648. Its first definite appearance in print occurs in the great French *Encyclopédie*, published in 1772. Detail drawings of an admirable slide-rest are given in one, and evidence of its being then in regular use occurs in several of the very interesting engravings of that ponderous work, which gives so clear an insight into the methods then employed in France in the various crafts. The description, however, by no means settles the question of its origin.

It is pretty certain that the slide-rest was reinvented in England by the ingenious Henry Maudslay, when he was employed in Mr Bramah's workshop in London, where "Maudslay's go-cart" (as it was at one time derisively called) was first set to work in 1794. That he had not previously seen the drawings just mentioned cannot of course be proved, but the high price at which the *Encyclopédie* was published makes it very probable that no copy of it had at that time come under the notice of a hard-working English mechanic. The intrinsic differences of the two slide-rests tend towards a similar conclusion. Whoever may have been its first inventor, the slide-rest has certainly proved itself to be the most invaluable of all the additions made to the turning lathe. Its indispensability to the modern power-lathe will be readily appreciated from the following examples.

An engraving of a simple slide-rest for use with a foot lathe has already been given (see LATHE), and its effect in reducing the labour of the turner was then pointed out. The *self-acting slide-rest* (fig. 2) carries this reduction still farther; and, by deriving from the lathe itself the small "feed" movement necessary for bringing the tool to bear on successive portions of the work, it dispenses wholly with the need for physical exertion on the part of the workman, and does not even demand his continuous supervision. One result of this is that the slide lathe (for so complete is the union between the slide-rest and the lathe that they must now be regarded as one machine) affords a complete solution of the screw-cutting problem, since, by varying the extent to which the rest traverses the lathe bed during each revolution of the mandrel, a screw thread of any desired pitch can be cut with a single tool.

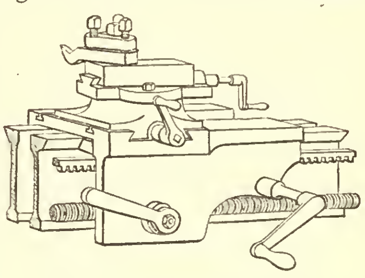


FIG. 2.—Self-Acting Slide-Rest.

In fig. 3, which shows a self-acting *screw-cutting lathe* with double-geared headstock, of a type now well established, the arrangements for obtaining and varying this traversing motion may be observed. A steel *leading screw* runs along the front of the lathe bed, and with it the slide-rest can be connected at pleasure. Two or more *change wheels*, properly proportioned as to the number of their teeth, connect the head of the screw with the hinder end of the mandrel.

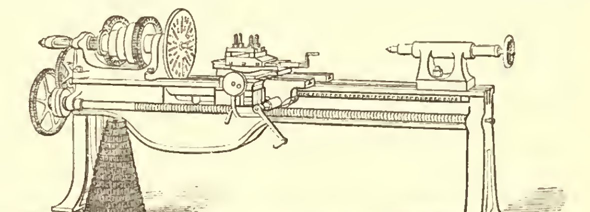


FIG. 3.—Self-Acting Screw-Cutting Lathe.

Although a leading screw is not the only nor in all cases the best mode of rendering a lathe self-acting, ordinary screw-cutting lathes are very largely used for other purposes than that implied by their name. The advantage of perfect regularity in the feed is very great even for plain turning, and this can only be secured when it is independent of human vigilance. The feed in a direction transverse to the bed is also very commonly rendered automatic by means into which we cannot here enter, lathes so provided being distinguished as self-acting *surfacing* lathes. In this case, however, the varying diameter of the successive cuts introduces serious objections to a uniform rate of feed. These were remedied as long ago as 1827 by that excellent mechanician Joseph Clement, —who was one of the greatest improvers of the power lathe; but his arrangement has never come into general use.

To enable a comparatively small lathe to be used for surfacing work of larger diameter than it would naturally admit, a portion of the bed is frequently made removable so as to leave a "gap" close to the fixed headstock. An 8-inch *gap lathe*, for instance, such as fig. 3, can thus admit an article of 26 inches diameter instead of 16 inches only.

Break lathes, such as fig. 4, carry the same principle still farther, so that they can take in work of considerable length as well as of large diameter,—the treble-geared headstock and all other parts being in their case made of sufficient strength to bear the heavy strains which result from the increased size and weight of the work, a quality

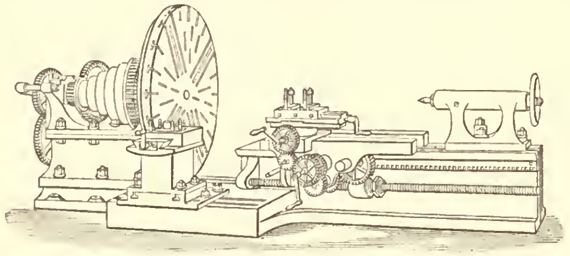


Fig. 4.—Self-Acting Break Lathe.

in which gap lathes are not unfrequently deficient. Lathes of this kind were made by Mr (now Sir Joseph) Whitworth as long ago as 1840, and the type is still the accepted one for general heavy turning. The face plates on which large work is chucked in these lathes are sometimes as much as 15 feet in diameter.

Face lathes, of which the main duty is surfacing articles whereof the diameter is great but the length small, are very similar to the foregoing minus the entire right-hand portion of the bed and all that it carries. They have occasionally been made for work of very large diameter,—such as turning the roller paths of 40 feet railway turntables,—though it is now found preferable to turn such things in a horizontal position, in lathes of which the mandrels are vertical.

But the point to which the growth of power-lathes has now attained will be best illustrated by the following interesting particulars of two which have been quite recently designed and made in the Royal Gun Factories at Woolwich. Each of these can take in a piece of work having a maximum diameter of 12 feet and a total length of 36 feet,—which represents a truly appalling weight of metal to have to deal with,—their main dimensions, &c., being

Height of centre of mandrel above the bed	6 ft.
Total length of bed....................................	60 ,,
Length of fixed headstock..........................	12 ,,
Diameter of front bearing of mandrel in do. ...	18 in.
Length of do. do.	36 ,,
Length of leading screw over all............... ...	52 ft. 3 in.
Diameter of do. do.	7 in.
Weight of fixed headstock, about..................	55 tons
Do. movable do., about..................	18 ,,
Do. slide-rest and saddle, about...........	15½ ,,
Total weight, nearly..................................	300 ,,

In lathes of this enormous size—as in all machine tools of the heaviest class—great weight and a proper disposal of it on a thoroughly secure foundation are necessary for obtaining the rigidity which is a first essential to success. When, however, this and all other conditions have been fulfilled, and the tool and the speed have been suitably adjusted, the operation of paring off great shavings from the revolving mass becomes one of such apparent facility that it is almost difficult for a stranger to believe that it is not lead or even some yet softer substance, rather than wrought iron or steel, which is under treatment.

It has been found that in heavy turning the best results are obtained by taking deep cuts at a low rate of speed, fast driving bringing no corresponding increase in the amount of work got through. Various other means have therefore been devised for accelerating operations. Each of the Woolwich lathes just mentioned is furnished with two slide-rests, so that two independent cuts can be taken at once at different parts of the work. The *duplex system* effects the same thing in a different way, two slide-rests (one in front and the other at the back of the lathe) being mounted on one saddle and adjusted simultaneously by a single right and left handed screw,—a plan which has the advantage of subjecting the work to two opposite strains which either wholly or partially balance each other. In some instances both the above advantages are combined by using two duplex rests at different parts of the bed. A *quick hand traverse* is another time-saving arrangement, now common to almost all screw cutting lathes. It enables the slide-rest to be run quickly back from the end of one cut to the starting point of the next. In turning up a number of similar articles upon each of which several different tools have to be used in succession, the time which would be lost in changing the tools is sometimes saved by employing a *capstan rest*, in which the whole series of tools is so fixed once for all that each in turn can be brought to bear upon the work without further adjustment.

Three examples of turning tools are given in fig. 5, the middle one being an ordinary *hook tool*, suited for outside work on wrought iron or steel, and the one above it a *left-hand tool* which can be used also for inside. Their cutting edges are of course forged and ground straighter or more pointed or otherwise varied according to circumstances, and for cast iron or brass the angle of the edge is made much less acute, as in the lowest of the three in the engraving. The size of the steel from which they are made also varies, 2 inches square being by no means exceptionally large, so that the weight of it uselessly employed in the shanks is very considerable, and altogether disproportionate to that required for the cutting edges. The plan of fixing a short steel cutter in an iron tool-holder, suggested many years ago by Mr Babbage (which has already been mentioned in connexion with foot lathes), has, however, not found the favour which at first sight might have been expected for it, in spite of the saving which it effects in this respect.

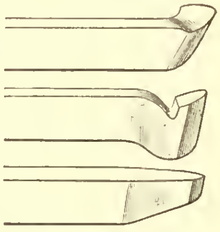


Fig. 5.—Slide-Rest Tools.

For chasing long or coarse-threaded screws the above-mentioned screw-cutting lathes leave little or nothing to be desired. But for producing the large number of screwed bolts, studs, &c., now required in mechanical workshops more rapid methods must be had recourse to, and special machines for forging, turning, screwing, and finishing them have accordingly come into common use. Of these one example only can be given—the *screwing machine*, fig. 6—with which the threads of bolts or nuts are cut to the "standard pitch" which now (happily) is almost universally accepted. Immense loss and inconvenience were formerly caused by the absence of uniformity in this respect, but, thanks to the persevering manner in which the efforts of Maudslay and Clement to put an end to this evil have been followed up by Whitworth, it has now almost ceased to exist, and any bolt or nut can be substituted for any other of a like size, however different the processes by which the two have been manufactured. The machine (fig. 6) is in fact a lathe with a few special features, such as the hollow mandrel, which enables it to operate upon a bar of any length. Dies mounted on a modified form of slide-rest cut the thread to the full depth at a single traverse, and a simple arrangement enables nuts to be tapped with equal facility. In some other varieties of screwing machines, more particularly those intended for hand power only, the outward resemblance to the turning lathe is less apparent, but if their action is looked into it will be found that in them as in almost all machine tools it is the principle of the slide which is mainly conducive to their success.

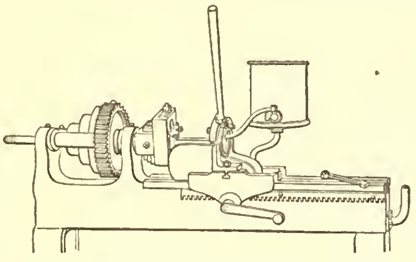


Fig. 6.—Screwing Machine.

Second only to the lathe in its importance stands the *planing machine*. Just as the slide lathe renders it easy to turn a cylindrical surface true from end to end, a task which before its introduction had been one of extreme difficulty, even for the most highly skilled workman, so the planing machine supersedes, by a method giving vastly superior results, the difficult and costly process of hand chipping and filing, by which flat surfaces of metal were formerly produced. Although it is a comparatively modern invention, its real origin is obscure. No drawings or description of any planing machine at all resembling those now in use were published in England previously to those of one made by Clement in 1825, which appeared in the *Transactions of the Society of Arts*. With this beautiful machine, which was of considerable size, being capable of admitting articles measuring as much as 6 feet in height or width, he obtained results which would satisfy all ordinary requirements at the present day.

The ordinary self-acting planing machine is shown in fig. 7. Its action bears no resemblance to the familiar

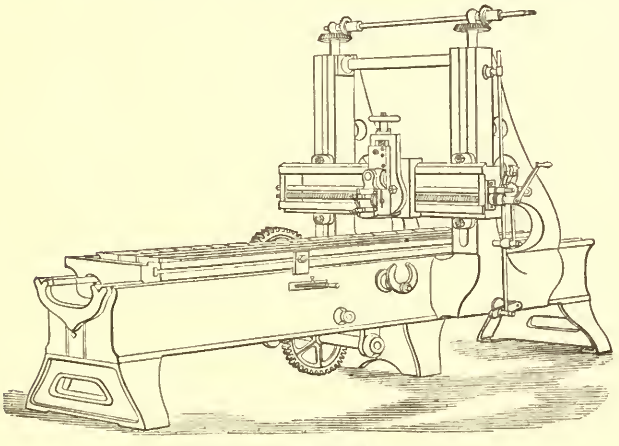


Fig. 7.—Planing Machine.

process of wood planing, but is analogous to that by which the successive cuts of a narrow tool produce a cylindrical surface in a slide lathe. A traversing table carries the work and forces it against the tool, which is stationary while making its cut, but between the cuts has a slight "feed" motion along its horizontal slide. Perfectly parallel cuts are thus taken from every portion of the work in succession, the result being a surface, not indeed perfectly smooth and free from scores, but (what is generally far more important) possessing a general flatness and freedom from twist which can be obtained only with a great expenditure of time and trouble by hand labour. The extent to which machinery has cheapened work of this kind will be appreciated from the fact that in 1826 the cost of rendering a square foot of surface true by hand chipping and filing was 12s., whereas in 1856 it could be done in the planing machine at a cost of less than one penny.

Planing machines, equally with lathes, are required not only to give good results but to give them quickly. Provision is therefore made for regulating the traverse of the table to suit the length of the cut, and for utilizing or accelerating its return journeys. The former is sometimes done by fixing the tool in a *revolving tool-holder* or "jim crow," so that its face can be always turned towards its cut, and for accomplishing the latter there are various arrangements which give a "quick return" to the table. It is also a common practice to use two tools at once, as in turning. It will be observed that the size of the work which can be treated in a planing machine, such as fig. 7, is strictly limited by the clear width between the standards, and the height of the horizontal slide above the table when at its highest point. Although these dimensions are very considerable in the larger sizes, which can occasionally take in articles over 9 feet in width and height and 50 feet in length, yet it is sometimes desirable to be able to exceed them, and in these large machines the weight of the table and the power consumed in driving and reversing it become a serious consideration. It is therefore mechanically preferable to keep the work at rest when it is large or heavy, and to give all the requisite movements to the tool. This view is now gradually gaining favour, and the makers of some recent machines have adopted a form of construction entirely different from the above, which has the advantage of enabling cuts either horizontal or vertical to be taken from any piece of work which can be secured to the base-plate, so that its full size is almost immaterial.

An ordinary *vertical drilling machine* is represented in fig. 8, one of comparatively small size and single-geared having been chosen rather than a larger example with greater complication. When once properly started, this machine is self-acting, but for each hole the work has to be adjusted by hand so as to bring the required portion exactly under the drill spindle, and the small size of the table prevents its being at any great distance from the edge. These objections are remedied in larger machines, either by making the table capable of horizontal adjustment,—a good way of doing this being to pivot a circular table at the end of an arm which can revolve round the main standard of the machine,—or by mounting the drill spindle on a radial arm, and enabling its distance from the standard to be varied. In the first case the tool is than distinguished as a "pillar" and in the second as a "radial" drilling machine. Either of these methods enables the drill to be brought to bear exactly upon the desired spot

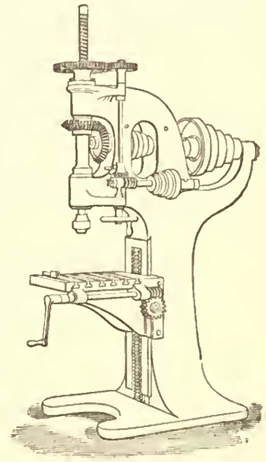


Fig. 8.—Vertical Drilling Machine.

(within certain limits as to distance from the edge, &c.), the first by adjusting the work below the drill, the second by adjusting the drill over the work. A *wall drill* dispenses with a table altogether, and gives great facilities for operating on large pieces of work, especially if the means of adjustment is secured by the radial arm just mentioned. *Multiple* drilling machines, with which a series of holes can be drilled at once, are serviceable tools for some purposes, mainly on account of the saving of time which they effect. Three drills are shown in fig. 9, the first the old, bad, but not yet quite superseded pattern, which is incapable of making a straight or clean hole of any considerable depth, and which loses its original diameter both in wear and in sharpening; the second the *twist drill*, which compares favourably with it in every one of these respects; and the third a *pin drill*, for enlarging a hole already existing.

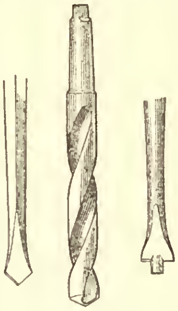


Fig. 9.—Drills.

Boring machines deal chiefly with apertures of large diameter, for which great straightness and accuracy are required, such as the cylinders of pumps, steam-engines, &c., or the bores of guns. The latter object brought them very early into existence, as already mentioned, and the general principle upon which the rude machinery of more than a century ago bored out the old cast iron mortars is still used for the powerful weapons of our own day. It consists in the employment of a *boring bar* formed by mounting a series of cutters (or a combination of guides and cutters) round the periphery of a cylindrical "head" somewhat less in diameter than the required bore. Fig. 10 will render evident the great similarity which exists between the oldest and the most recent gun-boring heads, the one being taken from the *Encyclopédie* already referred to, and the other from a drawing of a boring-bar used for a similar purpose at Woolwich. The head may be either a fixture at the end of its bar, in which case it forms a kind of drill with several cutting edges, or it may be so arranged as to traverse the bar to a small extent at each revolution,—a plan which is generally preferred for all open-ended cylinders, &c., and which admits of the work being kept stationary throughout the operation. The bar when in use is mounted either vertically or horizontally, according to circumstances, in a lathe or boring machine. The excellent results obtainable in this manner will be appreciated from the fact that with the gun-boring machinery at Woolwich a hole 10 inches in diameter and 10 feet deep can be bored in solid steel at a single operation, and holes have been carried to a depth of 24 feet with a variation of less than $\frac{1}{100}$ of an inch in the diameter. The accuracy of modern machine work indeed not unfrequently brings into prominence sources of error which were previously unsuspected. The boring of large cast iron cylinders affords an instance of this, for it has been found that, however true the boring tool may be, the distortion of the cylinder itself, through being laid on its side, is sufficient to mar the results obtained with it; consequently it has been found necessary always to bore a large cylinder in the vertical position which it will occupy when in use.

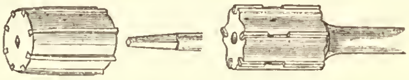


Fig. 10.—Gun-Boring Heads.

In the construction of modern machinery, &c., it is often necessary to depart from the simple geometric forms to the production of which the tools which have thus far occupied our attention are mainly adapted. We will now glance at some of the labour-saving contrivances applicable to other cases.

The *slot-drilling machine* effects (by a method said to have been first used about the year 1848) the conversion of the circular cavity producible with an ordinary drilling machine into an elongated "slot" or slit. The extent of the elongation can be varied by increasing or diminishing the reciprocating movement of the slide which carries the rotating drill. An example of it is given in fig. 11, and the cutting end of a *roughing drill* is shown to an enlarged scale. Where smoothness of the sunken surface is required this is followed by a *rose* or some other *finishing tool.*

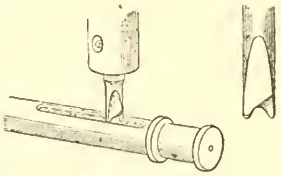


Fig. 11.—Slot Drilling.

The *slotting machine* (fig. 12) also cuts grooves and slots, but in an entirely different manner. Those who are acquainted with the wood mortising machine, from which the idea of this tool was derived by Roberts of Manchester, will at once understand its principle, and will appreciate the good service which can be rendered by this powerful paring tool. A large proportion of the shaping, &c., required in heavy work is now done in these machines, which are sometimes of great size and power. The table on which the work is placed is pivoted and mounted on a compound slide, and a self-acting horizontal transverse or circular movement can thus be given to it.

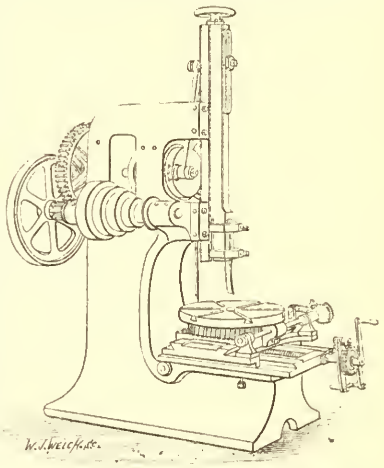


Fig. 12.—Slotting Machine.

For work of moderate size *shaping machines*, which are more of recent introduction than either slotting or planing machines, both of which they resemble in their action, are in some respects more convenient. The slide which carries the tool is in their case horizontal, and its short but variable strokes are in a direction transverse to the bed, along which it can travel, just as a slide-rest travels along a lathe bed. Curved surfaces, either convex or concave, as well as flat ones, can generally be worked up automatically in these machines, one of which is shown in fig. 13, but their details and arrangements vary considerably. For operating upon small surfaces, especially those of complicated outline, the plan of employing a revolving cutter, resembling a circular file, is now gaining favour. It is interesting to note that this is but a return to a system which is stated to have been devised by Dr Hooke in 1664, and which was certainly used in some of the early "engines" for cutting the teeth of wheels. One such cutter or *milling tool* is shown in fig. 14. Others are of a plain cylindrical form, or are varied in outline to any extent to suit the particular purpose for which they are intended, amongst which purposes may be mentioned that of cutting the teeth of other milling tools. When mounted on a compound slide and used in a *milling machine*, a tool of this kind is a labour-saving contrivance of a very efficient kind, and it should be observed that it may in some cases be employed for finishing metal surfaces possessing a double curvature, to which none of the foregoing planing or shaping machines could be applied.

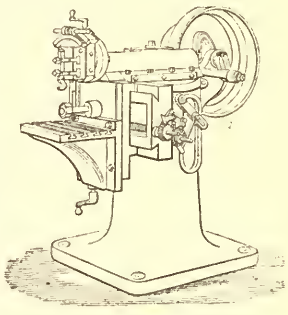


Fig. 13.—Shaping Machine.

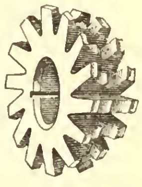


Fig. 14.—Milling Tool.

Profiling or *edge-milling machines* are a still more recent application of the milling-tool system. They enable the curved or complicated outline of a previously prepared templet to be reproduced with certainty any number of times in succession. They are in fact copying machines, acting in a similar manner to Jordan's carving machine or Blanchard's copying lathe, in both of which the form of the copy is derived from the original pattern by causing this pattern to control the movements of the revolving tool.

Another class of machine tools, which has sprung up of late years and is rapidly extending, is that of *emery grinders*. One thing which has given much impetus to these is the now not unfrequent necessity for turning or shaping steel in a more or less hard condition, for doing which these and natural grinding-stones are the only substances practically available on a large scale, while the rapid wear of the latter unfits them for many of the purposes to which the artificial preparations of emery can be applied with great advantage. Accordingly *emery wheels* are now mounted for use in a great many different ways,—either on slide-rests as turning tools, in *emery planers* and *emery shaping machines* (such as fig. 15), and various others in which they take the place of steel cutters, or as *tool grinders* either general or special, in which the rival material, so far from supplanting steel, does much towards increasing its efficiency, by enabling the process of grinding to be applied to many cutting tools which could previously be sharpened only with much greater labour and cost by other methods. Saws, grooved rimers and screw taps, and twist drills are familiar instances of this application. A high rate of speed is essential for obtaining the full effect of an emery wheel, half a mile a minute being by no means an unusual or excessive rate of travel for its cutting surface. A considerable amount of heat is consequently developed at the point of contact with the work, and the composition of the wheel must be such that it can endure this without injury. Some which could not fulfil this requirement have long been used by native workmen in India, but others which could fulfil it were patented in England in 1842, though for years after this they were but little known or used.

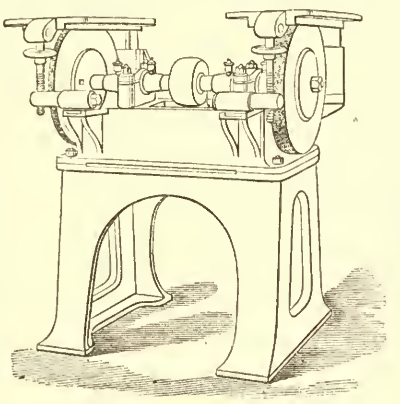


Fig. 15.—Emery Shaping Machine.

Punching and shearing machinery holds the same isolated position amongst machine tools that punches and shears occupy amongst cutting tools used by hand—if indeed either the one or the other can be regarded as cutting tools at all. Yet, for performing rapidly and in many cases without any waste of material, shears can often claim superiority to any other means available for accomplishing the same ends. The diagram (fig. 16) shows the old arrangement known as *cropping shears*, still in use at many iron-works, where early appliances seem to enjoy a remarkable vitality. An example of a self-contained *shearing and punching machine* is given in fig. 17. The apparent ease with which machines of this kind, acting with a slow quiet stroke, shear or perforate plates of iron, even when of considerable thickness, gives an altogether false impression of the amount of power which the operation requires. Arrangements for obviating the difficulty of placing the work exactly in the correct position for each one of a series of holes to be punched in it were devised by Maudslay ; his plan, which is the one now usually adopted, being to place a traversing table in front of the machine, from some part of which it is moved to a distance depending on the "pitch" of the holes after each stroke of the punch. Another system, by which the holes could be arranged in any required pattern, was subsequently invented by Roberts.

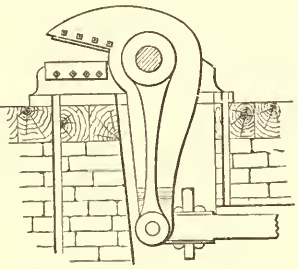


Fig. 16.—Cropping Shears.

The above examples of workshop tools have been confined to those to which the requisite power is transmitted from an independent steam-engine or some other prime mover—the usual mode of transmission being by lines of *shafting* carrying *pulleys* or *drums*. Belts pass from these to similar pulleys, which may be observed on many of the machines in the engravings. But this is not the invariable method. The prime mover may itself form part of the machine, as it does in the case of a steam-hammer. Or steam may be dispensed with and water confined under a high pressure substituted,—which constitutes the *hydraulic system* of distribution, now largely applied to the working of cranes and many other purposes, and to some extent also to machine tools. Punches and shears lend themselves readily to this system on account of their slow movements ; so, too, do *riveting machines*. The distribution of power by hydraulic means, and also by compressed air, was patented by Mr Bramah in 1796. Another formidable rival to steam also has now sprung up in the shape of *electricity*, and the results from it which are promised to us—and which indeed seem likely to be obtained—will go far towards revolutionizing all our present ideas as to the difficulty of transmitting power to a distance, and will work a complete transformation in the aspect of the machine tools of the future.

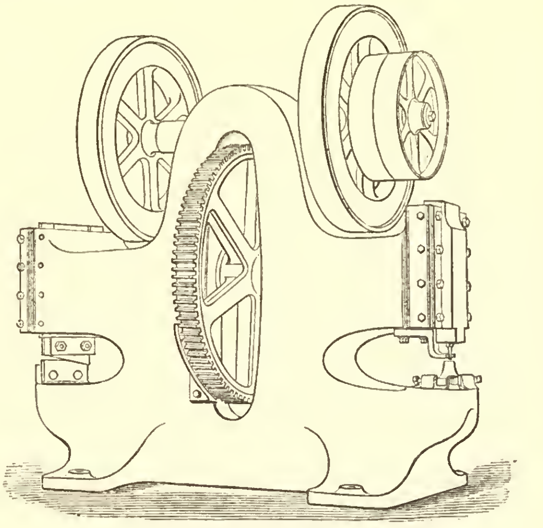


Fig. 17.—Punching and Shearing Machine.

One other class of machines must be mentioned before concluding, viz., *measuring machines*. The greatly increased accuracy of modern work has rendered necessary the recording of very minute dimensions, such as are quite beyond the measuring powers of ordinary rules and callipers. Difference engines, *i.e.*, machines which can measure minute differences between two articles—such as a standard gauge and an intended copy of it—have thus found a place in engineers' works. To their arrangement and manufacture, as well as to that of *standard measuring bars* and *gauges*, Sir J. Whitworth has paid great attention, and he has achieved such success that in his workshop measuring machines a difference of $\frac{1}{10000}$ part of an inch is readily appreciable. At the standards department of the Board of Trade there is one of these machines, used for the verification of standard gauges, which reads to the $\frac{1}{100000}$ of an inch ; and with his most sensitive machines—which, however, require great care and special precautions in their use—the $\frac{1}{1000000}$ part of an inch can be detected.

The social influence of machine tools we cannot discuss, though it is a subject upon which the diffusion of correct ideas is greatly needed. The days of mill-burning and implement-breaking mobs indeed are past, but the effect of the introduction of the machinery of which these tools are the parents is one which is still much misunderstood. More particularly is this the case amongst the hand-working classes in England, who see clearly the local and temporary hardships which its introduction occasionally causes, but are blind to the greatly preponderating advantages which they reap from it in an especial degree. (C. P. B. S.)

MACKENZIE, Sir Alexander (1755–1820), a Canadian explorer, was a native of Inverness. Having emigrated at an early age to Canada, he was for a number of years engaged in the fur trade at Fort Chipewyan, on the north side of the Lake of the Hills, and it was there that his schemes of travel were formed. His first journey (3d July to 27th September 1789)—for which he had prepared himself by a year's study in England of astronomy and navigation—was from Fort Chipewyan along the Great Slave Lake and down the river which now bears his name to the Frozen Ocean ; and his second (October 1792 to July 1793) from Fort Chipewyan up the Peace river across to the Columbia river, and thence westward to the coast of the Pacific at Cape Menzies, opposite Queen Charlotte Islands. The narrative of these expeditions (*Voyages through North America to the Frozen and Pacific Oceans*, London, 1801) is of considerable interest from the information it contains about the native tribes ; and it is prefaced by an historical dissertation on the Canadian fur trade. Mackenzie was rewarded for his discoveries by the honour of knighthood in 1801.

MACKENZIE, Sir George (1636–1691), of Rosehaugh, knight, a prominent Scottish lawyer, was the grandson of Kenneth, first Lord Mackenzie of Kintail, and the nephew of Colin and George, first and second earls of Seaforth; his mother was a daughter of Dr Andrew Bruce, principal of St Leonard's College, St Andrews. He was born at Dundee in 1636, and, having passed through the grammar school there, was sent at an early age to college at Aberdeen, and afterwards at St Andrews, graduating at sixteen. He then engaged for three years in the study of the civil law at Bourges; on his return to Scotland he was called to the bar in 1656, and before the Restoration had risen into considerable practice. Immediately after the Restoration he was appointed a "justice-depute," and it is recorded that he and his colleagues in that office were ordained by the parliament in 1661 "to repair, once in the week at least, to Musselburgh and Dalkeith, and to try and judge such persons as are there or thereabouts delate of witchcraft." In the same year he acted as counsel for the marquis of Argyll; soon afterwards he was knighted, and he represented the county of Ross during the four sessions of the parliament which was called in 1669. He succeeded Sir John Nisbet as king's advocate in August 1677, and in the discharge of this office became implicated in all the worst acts of the Scottish administration of Charles II., earning for himself an unenviable distinction as "the bloody Mackenzie." His refusal to concur in the measures for dispensing with the penal laws against Catholics led to his removal from office in 1686, but he was reinstated in February 1688. At the Revolution, being a member of convention, he was one of the minority of five in the division on the forfeiture of the crown. King William was urged to declare him incapacitated for holding any public office, but refused to accede to the proposal. When the death of Dundee (September 1689) had finally destroyed the hopes of his party in Scotland, Mackenzie betook himself to Oxford, where, admitted a student by a grace passed on June 2, 1690, he was allowed to spend the rest of his days in the enjoyment of the ample fortune he had acquired, and in the prosecution of his literary labours. One of his last acts before leaving Edinburgh had been to pronounce (March 15, 1689), as dean of the faculty of advocates, the inaugural oration at the foundation of the Advocates' Library. He died at Westminster on May 8, 1691, and was buried in Greyfriars churchyard, Edinburgh.

While still a young man Sir George Mackenzie appears to have aspired to eminence in the domain of pure literature, his earliest publication having been *Aretina, or a Serious Romance* (anon., 1660); it was followed, also anonymously, by *Religio Stoici, a Short Discourse upon several Divine and Moral Subjects* (1663), *A Moral Essay, preferring Solitude to Public Employment* (1665), and one or two other disquisitions of a similar nature. None of these earlier efforts are now read, if they ever were; and perhaps Mackenzie's strongest claim to be remembered at all in connexion with belles lettres is that which rests upon Dryden's grateful reminiscence of some stimulating conversation held with "that noble wit of Scotland, Sir George Mackenzie," about 1673. (See Dryden's "Discourse on the Origin and Progress of Satire," prefixed to his *Juvenal* in 1693.) His most important legal works are entitled *A Discourse upon the Laws and Customs of Scotland in Matters Criminal* (1678), *Observations upon the Laws and Customs of Nations as to Precedency, with the Science of Heraldry* (1680), *Institutions of the Law of Scotland* (1684), and *Observations upon the Acts of Parliament* (1686); of these the last-named is the most important, the *Institutions* being completely overshadowed by the similar work of his great contemporary Stair. In his *Jus Regium; or the Just and Solid Foundations of Monarchy in general, and more especially of the Monarchy of Scotland, maintained* (1684), Mackenzie appears as an uncompromising advocate of the highest doctrines of prerogative. His *Vindication of the Government of Scotland during the reign of Charles II.* is valuable as a piece of contemporary history. The collected *Works* were published at Edinburgh (2 vols. fol.) in 1716–22; and *Memoirs of the Affairs of Scotland from the Restoration of King Charles II.*, from previously unpublished MSS., in 1821. It may be well to add that the subject of this notice must not be confounded with Dr George Mackenzie, the author of *Lives and Characters of the Most Eminent Writers of the Scots Nation* (1708–22).

MACKENZIE, Henry (1745–1831), was born at Edinburgh in August 1745. His father was Dr Joshua or Josiah Mackenzie, a successful physician, who also cultivated letters in a small way. Mackenzie got the ordinary education of a youth in his position at the high school and university of Edinburgh, and was afterwards articled to Mr Inglis, who was then attorney for the crown in the management of exchequer affairs. To this comfortable post the author in due time succeeded, and perhaps knew as little as any of that tribe ever did about the struggles and sorrows of a literary career. For his work's sake it would have been better if he had travelled some of life's rougher paths, or else been content to write about what he had actually seen in the Scottish world of that day. There was plenty of material there if he had had the open eye to see it, as Walter Scott showed by and by; and it is a pity that Mackenzie did not try his hand at it, having been more in the heart of it than Scott could ever have been. As it is, his stories are clearly not the fruit of his experience, but rather the echo of his reading. He could write graceful enough sentences, somewhat artificial, yet smooth and pointed; but the men he describes are mere shadows, and the life altogether unreal. His first and best-known work, *The Man of Feeling*, was published anonymously when he was only twenty-six years of age, and soon became highly popular. It was a droughty season in Scottish literature, and therefore any little blossom, however sickly, was welcome for its rarity. Hume and Robertson and Smith had left the scene; Burns was just learning to think of the daisy he turned up with his ploughshare, and Fergusson had lately closed his brief and troubled career. Mackenzie had the field all to himself, and got the attention which is given to a solitary figure. He had read the *Sentimental Journey*, as one can see from expressions here and there, as well as from the affectation of writing his story in a fragmentary form; but he had not a gleam of Sterne's humour to relieve the sentimentality. He had read Richardson too, but he had none of that writer's subtle insight into character. Perhaps Goldsmith was his real model, but the likeness was as that between a firefly and a star. The "man of feeling" is a weak foolish creature, possessed with a futile benevolence, who goes up to London, where his friends should never have let him go, and meets a variety of sharpers, and comes out of their hands pretty much as Goldsmith makes the vicar's son do, only without the fun that clings to poor Moses. For this book is all in one key, sentimental and lachrymose, and the hero dies at last, from no particular cause, in a highly tragic fashion beside his fainting mistress. His next work, *The Man of the World*, is the picture of a born villain, a rogue in grain, who begins his rascality at school, perhaps earlier, and carries it through with entire consistency to the end. The man is unnaturally bad, and the incidents are badly unnatural; and such a book at present would only find a place in some third-rate penny paper, if even there. *Julia de Roubigné*, his only other novelette, was meant to depict the misfortunes of a number of quite blameless people—to be, in short, a tragedy without a villain, an *Othello* without an Iago. But, as it has no insight, and does not even try to have any insight, into the mystery of such calamities, the result is insipid and tedious. All these works had great popularity in their day; but that day is long past, and what life they now have is only a tradition.

Mackenzie also wrote several dramas, mostly of the tragic sort, for in that tone he had won his successes, such as they were. But one who had no conception of distinct character, of human individuality, was not likely to succeed in the drama, which depends more on that than on anything; and hence it was not our author's good fortune to deliver his country from the stigma of never having produced a genuine tragedy. Of *The Spanish Father*, *The Prince of Tunis*, and *The Shipwreck*, the second was brought on the stage, and managed to live for six nights; the other two were stillborn, and probably no man living has ever read them, unless for purely critical purposes.

But Mackenzie, if nowise a great writer, but quite otherwise essentially a small writer, with a knack of making sentences indeed, but having nothing particular of his own to say, was not therefore altogether a useless man in his day. That he did well for himself, and perhaps for the exchequer too, is quite likely, even though he toiled in the high-Tory service of Dundas, and wrote tracts meant to "broom" out of the country the tide of French Revolutionary notions. At any rate he became in his old age a kind of literary centre and social power in Edinburgh, when that was really needed and useful. He had known John Home and blind Dr Blacklock, and wrote lives of them; but, what is of more consequence, he was among the first to recognize the genius of Robert Burns, as editor of *The Lounger*, which he and a group of young men with some literary tastes wrote and printed for some years. Yet, though he once breakfasted with Johnson, and certainly met Burns more than once, he has told us nothing about either of them, though a page of Burns's talk would have been worth all *The Man of Feeling* twice told. It was so far good, however, that he hailed the peasant poet cordially, which we could hardly have hoped so artificial a writer would do, and even better that he noticed the dawn of German literature when Lessing and Schiller rose above the horizon, and not only wrote some account of them, taken from French sources, but boldly set to the study of German that he might really know them at first hand. How far he went in that study we do not know, only he set young Walter Scott on the scent, with results such as he himself could never have imagined. So he lived on, a kind of small king in the Edinburgh literary world, till 1831, dying in his eighty-sixth year, with a wonderful new world around him, which had not yet begun to criticize, but only to admire and honour him.

MACKEREL. Mackerels are pelagic fishes, belonging to a small family, *Scombridæ*, of which the tunny, bonito, albacore, sucking-fish (*Echeneis*), and a few other tropical genera are members (see ICHTHYOLOGY, vol. xii. p. 690). Although the species are fewer in number than in the majority of other families of fishes, they are widely spread and extremely abundant, peopling by countless schools the oceans of the tropical and temperate zones, and approaching the coasts only accidentally, occasionally, or periodically. The mackerels proper (genus *Scomber*) are readily recognized by their elegantly shaped, well-proportioned body, shining in iridescent colours. Small, thin, deciduous scales equally cover nearly the entire body. The dorsal fin extends over a great part of the back, and consists of several portions: the anterior, composed of feeble spines which can be laid backwards in a groove; the posterior, of rays only, of which the five or six hindmost are detached, forming isolated "finlets." The shape of the anal fin is similar to that of the rayed dorsal. The caudal fin is crescent-shaped, strengthened at the base by two short ridges on each side. The mouth is wide, armed above and below with a row of very small, fixed teeth.

No other fish shows finer proportions in the shape of its body. Every "line" of its build is designed and eminently adapted for rapid progression through the water; the muscles massed along the vertebral column are enormously developed, especially on the back and the sides of the tail, and impart to the body a certain rigidity which interferes with abruptly sideward motions of the fish. Therefore mackerel generally swim in a straightforward direction, deviating sidewards only when compelled, and rarely turning about in the same spot. They are in almost continuous motion, their power of endurance being equal to the rapidity of their motions. Mackerel, like all fishes of this family (with the exception, perhaps, of *Echeneis*, which has not yet been examined in this respect), have a firm flesh; that is, the muscles of the several segments are interlaced, and receive a greater supply of blood-vessels and nerves than in other fishes. Therefore the flesh, especially of the larger kinds, is of a red colour; and the energy of their muscular action causes the temperature of their blood to be several degrees higher than in other fishes.

All fishes of the mackerel family are strictly carnivorous; they unceasingly pursue their prey, which consists principally of other fish and pelagic crustaceans. The fry of clupeoids, which likewise swim in schools, are followed by the mackerel until they reach some shallow part of the coast, which their enemies dare not enter.

Mackerels are found in almost all tropical and temperate seas, with the exception of the Atlantic shores of temperate South America, where they have not hitherto been met with. The distinctive characters of the various species have not yet been fully investigated; and there is much confusion in the discrimination of the species. So much is certain that the European mackerel are of two kinds, of which one, the common mackerel, *Scomber scomber*, lacks, while the other possesses, an air-bladder. The best-known species of the latter kind is *Scomber colias*, the "Spanish" mackerel;[1] a third, *Scomber pneumatophorus*, is believed by some ichthyologists to be identical with *S. colias*. Be this as it may, we have strong evidence that the Mediterranean is inhabited by other species different from *S. scomber* and *S. colias*, and well characterized by their dentition and coloration. Also the species from St Helena is distinct. Of extra-Atlantic species the mackerel of the Japanese seas are the most nearly allied to the European, those of New Zealand and Australia, and still more those of the Indian Ocean, differing in many conspicuous points. Two of these species occur in the British seas: *Scomber scomber*, which is the most common there as well as in other parts of the North Atlantic, crossing the ocean to America, where it abounds; and the Spanish mackerel, *Scomber colias*, which is distinguished by a somewhat different pattern of coloration, the transverse black bands of the common mackerel being in this species narrower, more irregular or partly broken up into spots, while the scales of the pectoral region are larger, and the snout is longer and more pointed. The Spanish mackerel is, as the name implies, a native of the seas of southern Europe, but single individuals or small schools reach frequently the shores of Great Britain and of the United States.

The home of the common mackerel (to which the following remarks refer) is the North Atlantic, from the Canary Islands to the Orkneys, and from the Mediterranean and the Black Sea and the coasts of Norway to the United States.

Towards the spring large schools approach the coasts. Two causes have been assigned of this migration: first, the instinct of finding a suitable locality for propagating their species; and, secondly, the search and pursuit of food, which in the warmer season is more abundant in the neighbourhood of land than in the open sea. It is probable that the latter is the true and only cause, for the following reasons:—mackerel are known to increase much more rapidly in size while in the neighbourhood of land than in the months during which they lead a roving pelagic life in the open sea; and, further, one-year and two-year-old fishes, which have not yet attained maturity, and therefore do not travel land-

[1] The term "Spanish mackerel" is applied to a very different fish in America, viz., *Cybium maculatum*.

wards for the purpose of spawning, actually take the lead in the migration, and are followed later on by the older and mature fishes. Finally, according to the observations made by Sars, vicinity of land or shallow water are not necessary conditions for the oviposition of mackerel; they spawn at the spot which they happen to have reached during their wanderings at the time when the ova have attained their full development, independently of the distance of the land or of the depth of water below them, as the ova float and the embryo is developed on the surface of the water.

In the month of February, or in some years as early as the end of January, the first large schools appear at the entrance of the English Channel, and are met by the more adventurous of the drift-net fishers many miles west of the Scilly Islands. These early schools, which, as we mentioned above, consist chiefly of one-year and two-year-old fishes, yield sometimes enormous catches, whilst in other years they escape the drift-nets altogether, passing them, for some hitherto unexplained reason, at a greater depth than that to which the nets reach, viz., 20 feet. As the season advances, the schools penetrate farther northwards into St George's Channel or eastwards into the English Channel. The fishery then assumes proportions which render it next in importance to the herring and cod fisheries. In Plymouth alone a fleet of some two hundred boats assembles; and on the French side of the Channel no less capital and labour are invested in it, the vessels employed being, though less in number, larger in size than on the English side. Simultaneously with the drift-net the deep-sea-seine and shore-seine are used, which towards June almost entirely supersede the drift-net. Towards the end of May the old fish become heavy with spawn, and are in the highest condition for the table; and the latter half of June or beginning of July may be regarded as the time at which the greater part of mackerel spawn.

Mackerel are scarcely less abundant in the German Ocean; probably some of the schools never leave it, and this resident stock (if we are allowed to apply this term to a fish which is ever shifting its quarters) is increased by the schools coming from the Atlantic through the English Channel or round the north coast of Scotland. The schools approach the coasts of the German Ocean somewhat later in the season, partly owing to the greater severity of the weather, which detains the resident fishes in the open sea, and partly owing to the greater distance which the Atlantic shoals have to travel. On the Norwegian coast mackerel fishing does not begin before May, whilst on the English coasts large catches are frequently made in March. Large cargoes are now annually imported in ice from Norway to the English market.

After the spawning the schools break up into smaller companies which are much scattered, and offer for two or three months employment to the hand-line fishermen. They now begin to disappear from the coasts and return to the open sea. Single individuals or small companies are found, however, on the coast all the year round; they may have become detached from the main bodies, and be seeking for the larger schools which have long left on their return migration.

Although, on the whole, the course and time of the annual migration of mackerel are marked with great regularity, their appearance and abundance at certain localities are subject to great variations. They may pass a spot at such a depth as to evade the nets, and reappear at the surface some days after farther eastwards; they may deviate from their direct line of migration, and even temporarily return westwards. In some years between 1852 and 1867 the old mackerel disappeared off Guernsey from the surface, and were accidentally discovered feeding at the bottom. Many were taken at 10 fathoms and deeper with the line, and all were of exceptionally large size, several measuring 18 inches, and weighing nearly 3 lb; these are the largest mackerel on record.

The mackerel most esteemed as food is the common species, and individuals from 10 to 12 inches in length are considered the best flavoured. In more southern latitudes, however, this species seems to deteriorate, specimens from the coast of Portugal, and from the Mediterranean and Black Sea, being stated to be dry and resembling in flavour the Spanish mackerel (*S. colias*), which is not esteemed for the table. See also Fisheries. (A. C. G.)

MACKINTOSH, Sir James (1765–1832), publicist, historian, statesman, and philosopher, was born at Aldourie, 7 miles from Inverness, in 1765. He came of old Highland families both through his father and his mother. Of the former, who was an officer in the army, and was mostly on duty abroad, he saw but little, and he spent his early years under the care of his mother and her relatives. At a very early age young James bore the reputation of a prodigy for multifarious reading and learning. His schooling he received at Fortrose, whence he went in 1780 to college at Aberdeen. As a student in the arts faculty there his reading extended far beyond the bounds of the curriculum; but the influence that most powerfully formed his mind was the companionship of Robert Hall, afterwards so famous as a pulpit orator, with whom he ardently beat the usual round of vexed questions. In 1784 he proceeded for the study of medicine to Edinburgh, where he found a still more congenial field for his opening mind, at a time when Hume had been dead just eight years, while Adam Smith, Dr Black the father of chemistry, Dr Cullen, Robertson, Ferguson, and other eminent men, were resident there. Mackintosh participated to the full in the intellectual ferment, but did not quite neglect his medical studies, and took his degree, though with characteristic unpunctuality he kept the professors waiting for a considerable time on the examination morning.

In 1788 Mackintosh removed to London, then agitated by the trial of Hastings and the king's first lapse into insanity. He was much more interested in these and other political events than in his professional prospects; and his attention was specially directed to the events and tendencies which caused or preceded the Revolution in France. In the year of his removal to London his father died, and he succeeded to the family estate, which, being small and burdened, brought very little income; and, as he made no headway in his profession, his financial outlook was not very bright. It was under these circumstances that he wedded his first wife Catherine Stuart. Yet his marriage was a happy event for him. His wife's prudence was a corrective to his own unpractical temperament, and his efforts in journalism soon became fairly profitable. Mackintosh was soon absorbed in the question of the time; and in April 1791, after long meditation, he published his *Vindiciæ Gallicæ*, a reply to Burke's *Reflections on the French Revolution*. It was the only worthy answer to Burke that appeared. It placed the author in the front rank of European publicists at the age of twenty-five, and won him the friendship of some of the most distinguished men of the time, including Burke himself. About the same time he became honorary secretary of the association of the Friends of the People. The success of the *Vindiciæ* finally decided him to give up the medical for the legal profession. He was called to the bar in 1795, and gained a considerable reputation there as well as a tolerable practice. During this period his greatest public efforts were his lectures (1799) at Lincoln's Inn on the law of nature and nations, of which the introductory discourse was published, and his eloquent defence (1803) of Jean Peltier, a French refugee, tried at the instance of the French Government for a libel against the first consul. In 1804 he was created knight, and received the post of recorder at Bombay, where he spent the next seven years of his life. The spoilt child of London society was not at home in Bombay. He did seek to interest himself in India, and in imitation of Sir William Jones founded the Literary Society of Bombay; but the current literature of Europe was far more engrossing than the old Indian life, and the packet with the latest tidings from Europe and the newest development of the Napoleonic drama was infinitely more interesting than either. In spite of his scholarly and historic sympathies, his heart always was with the new era, and he was glad to return to England, where he arrived in 1812. True to his old faith, he courteously declined the offer of Perceval to resume political life under the auspices of the dominant Tory party, though tempting prospects of office in connexion with India were opened up. He entered parliament in the Whig interest as member for Nairn. He sat for that county, and afterwards for Knaresborough, till his death. In London society, and in Paris during his occasional visits, he was a recognized favourite for his genial wisdom and his great conversational power. On Madame de Staël's visit to London he was the only Englishman capable of representing his country in talk with that phenomenal woman. His parliamentary career was marked by the same wide and candid liberalism as his private life. He opposed the repressive and reactionary measures of the Tory Government, supported and afterwards succeeded Romilly in his efforts for reforming the criminal code, and took a leading part both in Catholic emancipation and in the Reform Bill. But he was too little of a partisan, too widely sympathetic and candid, as well as too elaborate, to be a telling speaker in parliament, and was consequently surpassed by more practical men whose powers were incomparably inferior. From 1818 to 1824 he was professor of law and general politics in the East India Company's College at Haileybury.

In the midst of the attractions of London society and of his parliamentary avocations Mackintosh felt that the real work of his life was being neglected. His great ambition was to write a history of England. His studies both in English and foreign speculation led him to cherish the design also of making some worthy contribution to philosophy. There is real pathos in the fact that it was not till 1828, when he was sixty-three years of age, and even then only at the instance of Macvey Napier, editor of the *Encyclopædia Britannica*, that he set about the first task of his literary ambition. This was the *Dissertation on the Progress of Ethical Philosophy*, prefixed to the seventh edition of the *Encyclopædia*. The dissertation, written mostly in ill-health and in snatches of time taken from his parliamentary engagements, was published in 1831. About the same time he wrote for the *Cabinet Cyclopædia* a "History of England from the Earliest Times to the Final Establishment of the Reformation." His more elaborate *History of the Revolution*, for which he had made great researches and collections, was not published till after his death. Already a privy councillor, Mackintosh was appointed commissioner for the affairs of India under the Whig administration of 1830. He died in 1832.

Mackintosh was undoubtedly one of the most cultured and catholic-minded men of his time. His studies and sympathies embraced almost every human interest, except pure science. But it was the width of his intellectual sympathies joined to a constitutional indecision and *vis inertiæ* that prevented him from doing more enduring work. Thus it was that his actual achievements came so far short both of his real power and of the promise given in his early efforts. The works of Mackintosh which have the best claim to permanent value are the *Vindiciæ Gallicæ*, the *Dissertation*, and the *History of the English Revolution*. Of the three the first is the greatest both in ability and historical significance. It is the verdict of a philosophic Liberal on the development of the French Revolution up to the spring of 1791, and is at the same time a sympathetic estimate of its causes, principles, and tendencies. While respectful to his great opponent, he is firm and manly in his assertion of the rights and interests of man so deeply concerned in the Revolution. Its excesses compelled him a few years after to express his entire agreement with the opinions of Burke; but few will now deny that his early judgment was the more correct. The *Dissertation* is a sketchy and fragmentary work, redeemed by catholic criticism and ingenious suggestion. It was a great undertaking, for which half a lifetime would hardly have been sufficient, attempted at a time when the study of the history of philosophy had hardly been begun. Yet his suggestions as to the formation of conscience are valuable. The *History of the Revolution in England in 1688*, which is only a posthumous fragment of a long meditated history of England beginning with the Revolution, is written in a style of calm and lofty impartiality. It is wanting in colouring, in movement, in the concrete and picturesque, and could never have been a popular history. It gives the history only of three years (1685–88), breaking off at the point where William of Orange is preparing to intervene in the affairs of England. The account of the early career of the prince is a noble and striking piece of work, showing that, if the author could have resisted the charms of society and applied himself resolutely to historical composition, he might have achieved something really great in that department.

See the *Memoirs of Sir James Mackintosh's Life*, edited by his son; also Macaulay's *Essay* on Sir J. Mackintosh.

MACLAURIN, Colin (1698–1746), one of the most eminent among the mathematicians and philosophers that Great Britain has produced, was the son of a clergyman, and born at Kilmodan, Argyllshire, in 1698. At the early age of eleven years he entered the university of Glasgow, where he graduated as master of arts in his sixteenth year. While at the university he exhibited a decided genius for mathematics, more especially for geometry; and it is said that before the end of his sixteenth year he had discovered many of the theorems afterwards published in his *Geometria Organica.*

In 1717 he was elected professor of mathematics in Marischal College, Aberdeen, as the result of a competitive examination. Two years later he was admitted a fellow of the Royal Society, and in a visit to London made the acquaintance of Newton, whose friendship and esteem he afterwards enjoyed. In 1719 he published his *Geometria Organica, sive descriptio linearum curvarum universalis.* This work was inspired by the beautiful discoveries of Newton on the organic description of conic sections. In it Maclaurin introduced the well-known method of generating conics which bears his name, and showed that many species of curves of the third and fourth degrees can be described by the intersection of two movable angles. In 1721 he wrote a supplement to the *Geometria Organica*, which he afterwards published, with extensions, in the *Philosophical Transactions* for 1735. This paper is principally based on the following general theorem, which is a remarkable extension of Pascal's hexagram:—"If a polygon move so that each of its sides passes through a fixed point, and if all its summits except one describe curves of the degrees m, n, p, &c., respectively, then the free summit moves on a curve of the degree $2mnp$ . . . . which reduces to mnp . . . when the fixed points all lie on a right line."

In 1722 Maclaurin travelled as tutor and companion to the eldest son of Lord Polwarth, and after a short stay in Paris resided for some time in Lorraine, where he wrote an essay on the percussion of bodies, which obtained the prize of the French Academy of Science for the year 1724. The following year he was elected professor of mathematics in the university of Edinburgh on the urgent recommendation of Newton. After the death of Newton in 1728, his nephew, Mr Conduitt, applied to Maclaurin for his assistance in publishing an account of Newton's life and discoveries. This Maclaurin gladly undertook, but before the account was written the death of Mr Conduitt put a stop to the project. It was not until many years afterwards, and subsequently to Maclaurin's death, that this account of Newton's philosophical discoveries was published (1748).

In 1740 Maclaurin obtained the high distinction of dividing with Euler and Daniel Bernoulli the prize offered by the French Academy of Science for an essay on the flux and reflux of the sea. This important memoir was subsequently revised by him, and inserted in his *Treatise on Fluxions*, which was published at Edinburgh in 1742, in two volumes. In the preface he states that the work was undertaken in consequence of the attack on the method of fluxions made by Berkeley in 1734, under the title of *The Analyst.* Maclaurin's object was to found the doctrine of fluxions on geometrical demonstration, after the manner of Archimedes and the ancient mathematicians, and thus to answer all objections to its method as being founded on false reasoning and full of mystery. He thus laid down the grounds of the fluxional method, regarding fluxions as velocities, after Newton. He proceeded to give an extensive application of the method to curves, surfaces, and the other subjects usually discussed in works on the differential and integral calculus, his treatment being almost exclusively geometrical; but the most valuable part of the work is that devoted to physical applications, in which he embodied his essay on the tides, as stated above.

In this he investigated the attraction of an ellipsoid of revolution, and showed that a homogeneous fluid mass revolving uniformly round an axis under the action of gravity ought to assume the form of an ellipsoid of revolution. The importance of this investigation in connexion with the theory of the tides, the figure of the earth, and other kindred questions has always caused it to be regarded as one of the great problems of mathematical physics. Thus Clairaut, D'Alembert, Lagrange, Legendre, Laplace, Gauss, Ivory, Poisson, Jacobi, Chasles, and other eminent mathematicians have successively attacked the problem, and in doing so have declared their obligations to Maclaurin as the creator of the theory of the attraction of ellipsoids. Lagrange's statement as to Maclaurin's discoveries deserves to be especially cited: after observing that the attraction of a spheroid of revolution is one of the problems in which the method of the ancients has advantages over that of modern analysis, he adds that Maclaurin's investigation is "un chef d'œuvre de géométrie qu'on peut comparer à tout ce qu' Archimède nous a laissé de plus beau et de plus ingénieux" (*Mém. de l'Acad. de Berlin*, 1773). It may be added that Maclaurin was the first to introduce into mechanics, in this discussion, the important conception of *surfaces of level*, namely, surfaces at each of whose points the total force acts in the normal direction. He also gave in his *Fluxions*, for the first time, the correct theory for distinguishing between maxima and minima in general, and pointed out the importance of the distinction in the theory of the multiple points of curves.

In 1745, when the rebels, having got between Edinburgh and the king's troops, were marching on that city, Maclaurin took a most prominent part in preparing trenches and barricades for its defence. This occupied him night and day, and the anxiety, fatigue, and cold to which he was thus exposed, affecting a constitution naturally weak, laid the foundation of the disease to which he afterwards succumbed. As soon as the rebel army got possession of Edinburgh, Maclaurin fled to England, to avoid making the submission to the Pretender which was demanded of all who had defended the town. He accepted the invitation of Dr Herring, then archbishop of York, with whom he remained until it was safe to return to Edinburgh. From that time his health was broken, and he died of dropsy on June 14, 1746, at Edinburgh, in his forty-eighth year. Maclaurin was married in 1733 to Anne, daughter of Walter Stewart, solicitor-general for Scotland. His eldest son, John, born in 1734, was distinguished as an advocate, and appointed one of the judges of the Scottish Court of Session, with the title of Lord Dreghorn. He inherited an attachment to scientific discovery, and was one of the founders of the Royal Society of Edinburgh, in 1782.

After Maclaurin's death his account of Newton's philosophical discoveries was published, and also his algebra in 1748. As an appendix to the latter appeared his work, *De linearum geometricarum proprietatibus generalibus tractatus*, a treatise of remarkable elegance. Of the more immediate successors of Newton in Great Britain Maclaurin is probably the only one who can be placed in competition with the great mathematicians of the Continent at the time, and his name will ever be held in remembrance in connexion with his important discoveries. Among his publications in the *Philosophical Transactions* the following should be noticed:—

(1) "Tractatus de curvarum constructione et mensura, ubi plurimæ series curvarum infinitæ vel rectis mensurantur, vel ad simpliores curvas reducantur," May 1718. The series of curves here treated are what are now styled "pedal" curves, which hold an important place in the modern discussion of curves. Maclaurin established many geometrical properties connecting a curve with its pedal. He investigated the properties of the successive pedals of a circle with respect to a point on its circumference, also those of the pedals of curves for which the perpendicular on the tangent varies as some power of the radius vector drawn to the point of contact. (2) "Nova methodus universalis curvas omnes cujuscunque ordinis mechanice describendi sola datorum angulorum et rectarum ope," January 1719. This and the preceding memoir were subsequently enlarged and incorporated by Maclaurin in his *Geometria Organica*. (3) "On Equations with Impossible Roots," May 1726. (4) On "Continuation of the Same," March 1729. In these papers he gave a proof of Newton's rule for the discovery of the number of imaginary roots of an equation. He added some general results on the limits to the roots, and gave the well-known method of finding equal roots by aid of the first derived equation. (5) "Observation of the Eclipse of the Sun of February 18, 1737," January 1738. (6) "On the Bases of the Cells where Bees Deposit their Honey," November 1743.

French translations of his *Treatise on Fluxions* and that on Newton's philosophical discoveries were published at Paris in 1749. His algebra was also translated into French, in 1753. (B. W.)

M'LENNAN, JOHN FERGUSON, LL.D. (1827-1881), one of the most original of modern inquirers into the constitution of early society, was born at Inverness 14th October 1827. He studied at King's College, Aberdeen, where he graduated with great distinction in 1849, and then proceeded to Cambridge, where he remained till 1855, but did not take his degree. After some years spent in literary work and legal studies in London and Edinburgh, he joined the Scottish bar (January 1857). In 1865 he published an epoch-making study on *Primitive Marriage*, in which, starting from the prevalence of the symbolical form of capture in marriage ceremonies, and combining with great argumentative power a variety of phenomena of primitive society previously quite obscure, he developed an intelligible picture of the growth of the marriage relation and of systems of kinship (see FAMILY) according to natural laws. Continuing his studies on allied topics, M'Lennan published in 1866 (*Fortnightly Review*, April and May 1866) an essay on "Kinship in Ancient Greece," in which he proposed to test by early Greek facts the theory of the history of kinship set forth in *Primitive Marriage*, and, three years later, a series of essays on "Totemism" (*Fortnightly Review*, 1869-70) (the germ of which had been contained in the paper just named), which mark the second great step in the systematic study of early society, to which the energies of his life were now devoted. A reprint of *Primitive Marriage*, with "Kinship in Ancient Greece" and some other essays not previously published, appeared in 1876 under the title of *Studies in Ancient History*. The new essays contained in this volume were mostly critical, but one of them, in which perhaps his guessing talent is seen at its best, on "The Divisions of the Irish Family," is an elaborate discussion of a problem which has long puzzled both Celtic scholars and jurists; and in another, "On the Classificatory System of Relationship," he propounded a new explanation of a series of facts which, he thought, might be made to throw a flood of light upon the early history of society, at the same time putting to the test of those facts the theories he had set forth in *Primitive Marriage*. Papers on "The Levirate and Polyandry," following up the line of his previous investigations, appeared in the following year (*Fortnightly Review*, 1877), and were the last work he was able to publish. From 1872 to 1875 his literary plans were much interrupted by his duties as parliamentary draftsman for Scotland, and when he retired from this office his health was broken; his last years were chiefly spent abroad, and in spite of the self-denying assistance of his second wife (his first wife, a daughter of M'Culloch the political economist, died in 1870, and he married again in 1875) the vast materials which he had accumulated for a comprehensive work on his favourite subjects were left only partially worked up, though the publication of his remains may still be looked for. He died 14th June 1881. In private life M'Lennan was distinguished by his remarkable powers of conversation, by an uncompromising sense of duty, especially of duty to truth, by a warm and affectionate disposition, and by his readiness to help all workers in science, especially young men of promise. Besides the works already cited, M'Lennan wrote *Life of Thomas Drummond* (Edinburgh, 1867). His later labours had for immediate object the solution of the origin of exogamy—that is, of laws prohibiting the marriage of relations (laws of incest); and in connexion with this he had prepared materials for a description of the social state of the less advanced races of men (keeping totemism in view as it bore on the history of society rather than the history of religion), which, he believed, would throw much light on the history of marriage and the family, of kinship, and laws of inheritance.

MACLEOD, Norman (1812-1872). There were three Norman Macleods, all ministers of the Church of Scotland, and all men of some note in their day. The first was settled in Morven, the "Highland parish," looking out on the Sound of Mull, of which his grandson has given us so many pleasant and sunny reminiscences. The second was minister of Campbeltown, afterwards of Campsie, and finally of St Columba's Gaelic Church in Glasgow, an able Celtic scholar and popular preacher, with a dash of dry humour in him, and general Highland "pawkiness." The third Norman was born in Campbeltown on June 3, 1812, and, like his father, he too could tell a good story, only his humour was not of the pawky kind, but verged on caricature, when it had not, as it mostly had, a vein of pathos in it; for he had received, probably from his mother, Agnes Maxwell, a richer blood and a larger life than we can trace in his more purely Celtic ancestry.

A sunny, light-hearted youth, full of jest and song, given to miscellaneous literature rather than to accurate scholarship or professional learning, would hardly seem to have been the kind of training to prepare for the life of an eloquent preacher and earnest pastor. Yet the broad human sympathies which were thus fostered were, after all, more serviceable for the work that lay before him than a knowledge of the Greek drama or of Dutch divinity; and, though he was never much of a scholar or a theologian, he was out and out a man, which is of more consequence in the long run. He had also moved about, and seen a good deal of the world in Highland Morven, in Glasgow, in Edinburgh, in England, and in Germany, when in 1838, on the recommendation of Dr Chalmers, he was presented by the dowager marchioness of Hastings to the parish of Loudoun, and began his ministry among a curious combination of Davie Deanses and Silas Marners—covenanting small farmers and Chartist hand-loom weavers. There, in the small rural parish, his work had the same characteristic features as in the larger sphere which afterwards opened up to him in the Barony church and in general literature. He carefully prepared for his pulpit, yet he was most eloquent when most spontaneous, for he was naturally more of a speaker than a writer. Courteous and chivalrous, yet also homely and ready-witted, he was as much liked by the radical weavers as he was honoured and trusted by the marchioness and her family. And if his natural gaiety of heart, which now and then amounted to rollicking animal spirits, gave him an occasional twinge of conscience which is duly recorded in his secret diary, that only shows that his genuine piety had not yet harmonized his whole nature, as it afterwards did, blending the grave and gay in one beautiful human service.

When he began his ministry, the troubles in the Scottish Church were already gathering to a head, and he found himself compelled to look around, and choose his ground. He wanted to get for the church all that Chalmers and his friends wanted. He felt that the best men, both lay and cleric, were with them, and against himself. He had no love for lay patronage, and he wished the church to be free to do its proper work. But more than all else he clung in those days to the idea of a national Established Church; and it was not without a sinking of heart that he saw the long array file out of the Assembly of 1843 after Drs Welsh and Chalmers. Yet he girded himself up for the task that had now to be done with courage and wisdom. It was a heavy job to fill four hundred and thirty pulpits with such materials as came to hand, mostly men who had already failed, and practically given up the profession. For years Macleod, and those who worked with him, toiled almost despairingly to inspire them with any living interest in the real business of the Christian Church. But in the long run his labours were crowned with a large measure of success, though his own brethren to the last hardly gave him the credit for it which was due almost to him alone—to him, at any rate, above all others. With his broad sympathies he flung himself upon the masses, and taught the working men to feel that the Church of Scotland was still as interested in their wellbeing as any denomination. Discerning also that the harder forms of Calvinism had no longer the hold on their minds that they once had, he made room for the thoughtful teachings of his cousin, Dr John Macleod Campbell, whom the Evangelical party had formerly cast out as a heretic, gaining by this means not a little influence with the young and inquiring intellects of the country. And finally, by his efforts to diffuse a wholesome religious literature through the land, he so identified his church with the growing spirit of the age that at length he lived to see it, not indeed the strong and united community which in his youth practically controlled the nation, but yet once more a great power, dear to the hearts of many of the people, and doing good Christian service to the land.

It may be doubted if the work which Norman Macleod did for Scotland could have been done in his day without the disruption of the church. For the Evangelical party, using that word in its technical sense, had not only gained the confidence of the people by much faithful service, but also had confirmed their power by somewhat sharp treatment of all who differed from them. It needed a different kind of church to tolerate the views of Macleod Campbell; but as these were now, more or less, identified with the living element in the kirk, with those who were most diligent in parochial work, and most zealous in mission enterprise, they gradually established their right to be preached in Calvinistic pulpits. Norman Macleod, of course, was not long left to expend his energies on the weavers of Loudoun. Removing first to Dalkeith, he was finally, in 1851, called to the Barony church, Glasgow, where the rest of his days were passed, in honour and influence, as the foremost of its citizens. There the more liberal theology rapidly made way among a people who judged it more by its fruits than its arguments. And, as they heard his eloquent voice pleading on behalf of churches and schools for the poor, penny savings banks, foreign missions, and every likely scheme for doing good to men, they learned to look without suspicion at opinions which yielded such Christian results.

Two other events also helped not a little to increase his influence. These were his position as editor of *Good Words*, and his relation to the queen and the royal family.

In 1860 a magazine was projected which was to deal with subjects common to all, only with a decidedly religious tone. It was not for Sunday only, nor was it for Christians only; but it was to be broadly human, and at the same time clearly pious. For the conducting of such a magazine Macleod was singularly well qualified. Not that he had yet attained any great literary position, or indeed was ever likely to do so. He had written some ecclesiastical pamphlets, amusing but not weighty. He had edited the *Edinburgh Christian Magazine*, without achieving any marked success. His best work as yet was the life of his friend and brother-in-law, John Mackintosh. But nothing human was foreign to him, and "good words," on things in general, were just the words that he could make quick and powerful. Very soon *Good Words* came to be by far the most popular magazine of the day. Nearly all his own literary work, by which he will be judged in other times, appeared in its pages,—sermons, stories, travels, novels, poems,—all of them honest "good words" which it was wholesome to read. But they hardly give him a name in literature,—at least, not such a name in the future as he had while he was still alive. They were too much the hurried productions of a life busy with many affairs. The short stories, like "Wee Davie" and "Billy Buttons," are those which are most likely to retain a place in letters, on account of their mingled humour and pathos. Of his more studied works "The Starling" is perhaps the best; but, while he could tell a brief tale admirably, he could not sustain a long narrative, with its play of varied character and incident; and, instead of leaving his art to read its own lesson, he preached a sermon by means of a story. Always, indeed, it is evident that he was more of an orator than a writer. The best of his poems is the hymn "Trust in God and do the right," though the "Curling" song has the right ring of the stones rattling over the ice. Altogether, his work was honest and good, not the highest in point of literary finish, but wholesomer than much that is more perfect in its form.

While *Good Words* made his name widely known, and helped the cause he had so deeply at heart, his relations with the queen and the royal family strengthened yet further his position in the country. Never since Principal Carstairs had any Scotch clergyman been on such terms with his sovereign; and their friendship was felt to be alike honourable to both, resting, on her part, on esteem for his work and character, and on his, on a loyal desire to serve his queen as a Christian minister may. All this helped not a little to increase his influence in the councils of the church, and to restore its prestige, which had for a time been nearly overthrown; and yet, while his popularity was in full swing, one unlucky piece of honesty made him for a time the man in all Scotland most profoundly distrusted.

Scotch Sabbatarian ideas had been a good deal disturbed by the running of Sunday trains and by other novelties, and in 1865 the presbytery of Glasgow issued a pastoral letter on the subject to be read from all the pulpits there. Macleod, of course, loved the day of rest as much as any of them, but he did not like the grounds on which they rested it, nor yet the spirit in which they would have it observed. Therefore he resolved to deliver his mind on the subject to his brethren. Like St Paul, he refused to let any man judge him concerning "new moons and Sabbaths." His speech was not at first well reported, those parts only being printed which were most likely to startle the religious public; and in consequence it was, for a while, greatly misunderstood. Old friends shrunk from him. His house seemed to be shunned as if plague-stricken. His brethren in the presbytery threatened a "libel" for heresy. And he needed all his courage to bear up against the outcry which assailed him on all hands. A more correct version of the speech was issued, however, and the good sense and Christian intelligence of the people soon learned to form a juster estimate of its real bearing. The threatened prosecution broke down. Truer ideas of Sabbath observance got a lodgment in men's minds. And, four years after, the church, which at one time seemed ready to cast him from her bosom, accorded him the highest honour in her power to give, by choosing him as moderator of her General Assembly.

Before that, however, he had already gained her confidence so far as to be sent, along with Dr Archibald Watson, to India to inquire into the state of her mission there. He had always taken a deep interest in the India mission, and had been for some time convener of the committee which took charge of its interests. When asked to undertake this duty, he was already labouring under the disease which afterwards shortened his days; his medical advisers were not without grave anxieties as to the effect of the climate on his constitution, and it was with clear consciousness of the risk he ran that, in 1867, he sailed for the East. He returned fully resolved to devote the rest of his days largely to the work of rousing the church to her duty in carrying out "the marching orders" of her Commander. But he was not destined to do much more for the cause that lay so near his heart than to make one or two stirring appeals to the conscience of the church. His health was now broken, and his old energy flagged. Always his habits of work had been somewhat irregular; properly, indeed, he had no fixed habits, but only tremendous fits of labour and periods of exhaustion. Now neither body nor brain could stand this strain, and with reluctance and pain he had to give up the charge of the India mission. His speech in doing so was the last and greatest he ever made. It was as if he had gathered up his failing powers for one final effort, and spent his life on it. Shortly after his return from the Assembly of May 1872, his disease showed some fresh symptoms that alarmed the doctors. And on Sunday the 16th of June, shortly after completing his sixtieth year, Norman Macleod peacefully fell asleep, the country hardly knowing how it had loved him till he was borne to his quiet resting-place in Campsie churchyard.

Memoir of Norman Macleod, D.D., by his brother, the Rev. Donald Macleod, 2 vols., appeared in 1876. (W. C. S.*)

MACLISE, DANIEL (1806 or 1811–1870), subject and history painter, was born at Cork, the son of a Highland soldier.[1] His education was of the plainest kind, but he was eager for culture, fond of reading, and anxious to become an artist. His father, however, placed him, in 1820, in Newenham's Bank, where he remained for two years, and then left to study in the Cork school of art. In 1825 it happened that Sir Walter Scott was travelling in Ireland, and young Maclise, having seen him in a bookseller's shop, made a surreptitious sketch of the great man, which he afterwards lithographed. It was exceedingly popular, and the artist became celebrated enough to receive many commissions for portraits, which he executed, in pencil, with very careful treatment of detail and accessory. Various influential friends perceived the genius and promise of the lad, and were anxious to furnish him with the means of studying in the metropolis; but with rare independence he refused all aid, and by careful economy saved a sufficient sum to enable him to leave for London. There he made a lucky hit by a sketch of the younger Kean, which, like his portrait of Scott, was lithographed and published. He entered the Academy schools in 1828, and carried off the highest prizes open to the students, including, in 1829, the gold medal for the best historical composition. In the same year he exhibited for the first time in the Royal Academy. Gradually he began to confine himself more exclusively to subject and historical pictures, varied occasionally by portraits of Campbell, Miss Landon, Dickens, and other of his celebrated literary

[1] The year of his birth is uncertain; he himself used to assert that the 25th of January 1811 was the correct date, but research in the register of the old Presbyterian church in Cork seems to prove that he was born on 2d February 1806.

friends. In 1833 he exhibited Snap Apple Night, or All Hallow Eve in Ireland, and Mokanna Unveiling his Features to Zelica, which greatly increased his reputation, and were followed in the succeeding year by the powerfully dramatic subject of the Installation of Captain Rock, and in 1835 by the Chivalric Vow of the Ladies and the Peacock, a work which procured his election as associate of the Academy, of which he became full member in 1840. The years that followed were occupied with a long series of figure pictures, deriving their subjects from history and tradition, and from the works of Shakespeare, Goldsmith, and Le Sage. He also designed illustrations for Moore's *Irish Melodies*, Lytton's *Pilgrims of the Rhine*, and several of Dickens's Christmas books, and for *The Story of the Norman Conquest* and Shakespeare's *Seven Ages*, published by the Art Union. Between the years 1830 and 1836 he contributed to *Fraser's Magazine*, under the *nom-de crayon* of Alfred Croquis, a very remarkable series of portraits of the literary and other celebrities of the time,—character studies, etched or lithographed in outline, and touched more or less with the emphasis of the caricaturist, which have been since reproduced and published in a volume. In 1858 Maclise commenced one of the two great monumental works of his life, the Meeting of Wellington and Blücher, on the walls of Westminster Palace, where he had previously painted his Spirit of Religion and his Spirit of Chivalry. It was begun in fresco, a process which proved unmanageable. The artist wished to resign the task; but, encouraged by Prince Albert, he studied in Berlin the new method of "water-glass" painting, and carried out the subject and its companion, the Death of Nelson, in that medium, completing the latter painting in 1864. The intense application which he gave to these great historic works, and the various depressing and discouraging circumstances connected with the commission, had a serious effect on the artist's health. He began to shun the company in which he formerly delighted; his old buoyancy of spirits was gone; and when, in 1865, the presidentship of the Academy was offered to him, he declined the honour. In 1868 he exhibited the Sleep of Duncan, and in 1869 his King Cophetua and the Beggar Maid. Having finished the Earls of Desmond and Ormond, he was attacked by acute pneumonia, which carried him off, after a brief illness, on the 25th April 1870.

The works of Maclise are distinguished by powerful intellectual and imaginative qualities, but most of them are marred by harsh and dull colouring, by metallic hardness of surface and texture, and by frequent touches of the theatrical in the action and attitudes of the figures. His fame rests most securely on his two greatest works at Westminster. A memoir of the artist by his friend W. J. O'Driscoll was published in 1871.

MACLURE, William (1763–1840), the pioneer of American geology, was born at Ayr in Scotland in 1763. After a brief visit to New York he began active life as a partner in the firm of Miller, Hart, & Co., London. Four years later (1796) business affairs brought him again to America, which he thereafter made his home. In 1803 he visited France as one of the commissioners appointed to settle the claims of American citizens on the French Government for spoliations committed during the Revolution; and during the few years then spent in Europe he applied himself with enthusiasm to the study of geology. On his return home he commenced the self-imposed task of making a geological survey of the United States. Almost every State in the Union from the St Lawrence to the Gulf of Mexico was traversed and mapped by him, the Alleghany mountains being crossed and recrossed some fifty times. The results of his unaided labours were submitted in a memoir to the American Philosophical Society (1809), and published in the Society's *Transactions* (vol. vi.), together with a geological map, which thus antedates William Smith's great geological map of England by six years. Subsequent survey has corroborated the general accuracy of Maclure's observations, so far at least as the Primary and Secondary formations are concerned. From 1817 to his death Maclure was president of the Academy of Natural Sciences of Philadelphia, and much of the prosperity of the institution was due to his devoted services. In 1819 he visited Spain, and attempted to establish an agricultural college near the city of Alicante; but with the overthrow of the short-lived Liberal constitution his plans became hopelessly deranged. Returning to America in 1824, he settled for some years at New Harmony, Indiana, endeavouring, but with small success, to develop his scheme of the agricultural college. Failing health ultimately constrained him to relinquish the attempt, and to seek (in 1827) a more congenial climate in Mexico. There, at San Angel, he died March 23, 1840.

His great geological memoir was issued separately, with some additional matter, in 1817; and in 1837 he published a collection of essays, in 2 vols., mainly on political economy, entitled *Opinions on Various Subjects*. His other original papers, including observations on the geology of the West Indies and of Mexico, and remarks on the origin and arrangement of rocks, were published in the *Journal of the Academy of Natural Sciences* (Philadelphia), in Silliman's *American Journal of Science and Arts*, and in the French *Journal de Physique*.

MACNEE, Sir Daniel (1806–1882), portrait painter, was born in 1806 at Fintry in Stirlingshire. He was educated in Glasgow, and at the age of thirteen apprenticed, along with Horatio Macculloch and Leitch the water-colour painter, to John Knox, a landscapist of some repute at the time. He afterwards worked for a year as a lithographer, was employed by the Messrs Smith of Cumnock to paint the ornamental lids of the planewood snuff-boxes for which their manufactory was celebrated, and, having studied in Edinburgh at the "Trustees' Academy," supporting himself meanwhile by designing and colouring book illustrations for Lizars the engraver, he established himself as an artist in Glasgow. At first he was occupied a good deal with figure pictures, but the increasing demands on his time as a fashionable portrait painter eventually left him little leisure for this branch of art. He was one of the twenty-four associates of the Royal Institution who, in 1829, were admitted members of the Royal Scottish Academy; and on the death of Sir George Harvey in 1876 he was elected president, and received the honour of knighthood, and the degree of LL.D. from the Glasgow University. From this period till his death, on the 18th of January 1882, he resided in Edinburgh, where his genial social qualities and his inimitable powers as a teller of humorous Scottish anecdote rendered him popular. Among his portraits may be mentioned those of Lord Brougham, Viscount Melville, Lord Inglis, and Mrs Bough. His Dr Wardlaw obtained a gold medal at the Paris International Exhibition of 1855.

MACNEILL, Hector (1746–1818), a minor Scottish poet, born near Roslin, October 22, 1746, died at Edinburgh, March 15, 1818. The son of an impoverished army captain, he spent several years of his boyhood on a farm which his father had taken on the banks of Loch Lomond, and was sent to Bristol at the age of fourteen to enter on a mercantile career. Soon afterwards he was despatched to the West Indies, where he remained many years without ever enjoying even a moderate prosperity. When about forty he returned to Scotland with the intention of devoting himself to a literary life, but his ill fortune still pursued him, and he was obliged to go back to Jamaica. The kindness of two friends enabled him soon to come home again to Scotland, and on the journey he finished *The Harp, a Legendary Tale*, published at Edinburgh in 1789. After six years spent at Edinburgh, rendered miserable by shattered health and depressed spirits, he retired to the house of a friend at Stirling, where he wrote most of his songs and his *Scotland's Skaith, or the History of Will and Jean*, a narrative poem intended to show the deteriorating influences of whisky and pot-house politics, which appeared in 1795, and at once made its author popular, having passed through fourteen editions within the year. A sequel, *The Ways of War*, appeared next year, and in 1799 *The Links of Forth, or a Parting Peep at the Carse of Stirling*, a somewhat feeble descriptive poem, intended as a parting tribute to his kind host before his own departure for Jamaica. Not long after his arrival an early friend settled on him an annuity of £100, which enabled the poet to return soon afterwards to Scotland, and so close his long struggle against adversity with fifteen years of comparative comfort at Edinburgh.

In 1800 he published *The Memoirs of Charles Macpherson, Esq.*, a novel understood to be a close narrative of his own hardships and adventures. His later works, which added little to his fame, were —*The Pastoral or Lyric Muse of Scotland*, 1809; two anonymous works in verse entitled *Town Fashions, or Modern Manners Delineated*, and *Bygone Times and Latecome Changes*, and *The Scottish Adventurers*, a novel. He left behind an autobiography still unpublished, but of which an abstract appeared in *Blackwood's Magazine* for December 1818. A complete edition of the poems he wished to own appeared in 1812, and it is on these that his fame will rest. His songs, "Mary of Castlecary," "Come under my plaidy," "My boy, Tammy," "O tell me how for to woo," "I lo'ed ne'er a lassie but ane," "The plaid amang the hether," and "Jeanie's black e'e," will live, spite of Allan Cunningham, for their sweetness and simplicity, while his *Will and Jean*, quite apart from its excellent intention and tendency, will maintain a place among the most characteristic productions of the Doric Muse in Scotland.

MACON, the capital of Saône-et-Loire, France, occupies a gently sloping site on the right bank of the Saône, 41 miles north of Lyons. It is connected by a bridge of twelve arches with the suburb of St Laurent on the opposite bank of the river. The site is sheltered and the climate mild, but the locality is subject to sudden changes of temperature. Of the public buildings of Macon the most prominent is the old church of St Pierre, reconstructed in 1866,—a three-naved basilica, 328 feet in length, with two fine spires. Of the old cathedral, destroyed at the Revolution, nothing remains but the façade, portions of the two towers, and a narthex of the 12th century, now used as a chapel. The old episcopal palace, which has been rebuilt, is now used as the prefecture. The hospital is from designs by Soufflot; the lyceum bears the name of Lamartine (a native of Macon, to whom there is a statue). The town house contains a library of 7000 volumes, and a museum. Macon is a railway centre of considerable importance, being the point at which the line from Paris to Marseilles is joined by that from Mont Cenis and Geneva, as well as by a branch from Digoin. The industries of the place include brass-founding, the manufacture of agricultural implements, weighing-machines, and the like, printing, dyeing, and the production of faience. The principal articles of commerce are wine, barrels and hoops, and grain. The population in 1876 was 17,570.

Macon (*Matisco*) was an important town of the Ædui, but under the Romans it was supplanted by Autun and Lyons. It suffered a succession of disasters at the hands of Germans, Burgundians, Vandals, Huns, Hungarians, and even of the Carlovingian kings. In 1228 it was sold to the king of France, but more than once afterwards passed into the possession of the dukes of Burgundy, until the ownership of the French crown was fixed in the time of Louis XI. In the 16th century Macon became a stronghold of the Huguenots, sided with the League, and did not yield to Henry IV. until 1594. The bishopric, created by King Childebert, was suppressed in 1790.

MACON, a city of the United States, the chief town of Bibb county, Georgia, is situated on rising ground in the midst of a beautifully wooded country on both sides of the Ocmulgee river, a navigable headwater of the Altamaha, about 80 miles south-east of Atlanta. It is well laid out with tree-bordered streets, often 180 feet wide, and possesses since 1870 a fine central park, on the formation of which $125,000 were expended. The principal institutions in the town are the State academy for the blind (1852), the Mercer university (a Baptist foundation, 1838), the Wesleyan Female College (1839), the Pio Nono (Roman Catholic) College, and the Southern Botanico-Medical Institute. As an important junction for the Georgia, the Georgia Central, and the South-Western Railways, and communicating with the coast by the direct line to Brunswick, Macon enjoys great facilities for trade; and, besides its extensive railway machine-shops, it has cotton factories, iron foundries, flour-mills, and sash and blind factories. The annual fair held in the Central Park is the great meeting-place of the Georgian planters. From 5720 in 1850 the population has steadily advanced to 8247 in 1860, 10,810 in 1870, and 12,748 in 1880. The foundation of the town dates only from 1823.

MACPHERSON, James (1738–1796), the "translator" of the Ossianic poems, was born at Ruthven, Inverness, Scotland, in 1738, was educated in his native village and at King's College, Aberdeen, and from 1756 taught the school of Ruthven for some time. In 1758 he published a poem entitled the *Highlander*, and about the same period contributed several minor pieces to the *Scots Magazine*. In 1759, while residing with a pupil at Moffat, he became accidentally known to Dr Carlyle of Inveresk and Mr Home, the author of *Douglas*, both of them already interested in the subject of ancient Highland poetry; some fragmentary "translations" from the Gaelic, which in the course of a few days he supplied to Home, were much appreciated in the literary circles of Edinburgh, and in 1760 a volume was published by Macpherson, entitled *Fragments of Ancient Poetry collected in the Highlands of Scotland, and translated from the Gaelic or Erse Language*, with a preface by Dr Blair. A sum of money was now subscribed by the faculty of advocates for the purpose of enabling Macpherson to go to the Scottish Highlands in search of other fragments, and the result of his labours was the publication at London in 1762 of *Fingal, an Epic Poem, in six books, with other lesser Poems*, dedicated to Lord Bute; this was followed in 1763 by *Temora*, in eight books, with several other poems. For the real character of these publications see Celtic Literature, vol. v. p. 313–4. At the time of their appearance they greatly advanced the translator both in fame and fortune; in 1764 he was appointed surveyor-general of the Floridas, and on his return to England two years afterwards he was permitted to retain for life the salary of the office. In 1771 he published *An Introduction to the History of Great Britain and Ireland*, and in 1775 *A History of Great Britain from the Restoration to the Accession of the House of Hanover* (2 vols. 4to) and *Original Papers containing the Secret History of Great Britain* for the same period (also in 2 vols. 4to). His translation of the *Iliad*, published in 1773, was greatly praised by Robertson and others in Scotland, but met with a severe reception in England, and has not stood the test of time. About 1779 he was appointed to the lucrative post of agent for the nabob of Arcot, and from 1780 onwards he sat in parliament for the borough of Camelford. He died at Belleville, an estate which he had recently purchased in Inverness, on February 17, 1796, and was buried in the Poets' Corner at Westminster Abbey. His will had provided for the publication of the Ossianic poems in the original Gaelic, which he is understood to have been preparing for the press at the time of his death; and the work accordingly appeared in 3 vols. 8vo, in 1807, with a literal translation into Latin, by Robert Macfarlane, and a dissertation on the authenticity of the poems, by Sir John Sinclair.

MACREADY, WILLIAM CHARLES (1793-1873), was born in London 3d March 1793, and educated at Rugby. His intention was to proceed to Oxford, but the embarrassed affairs of his father, the lessee of several provincial theatres, called him to share the responsibilities of theatrical management, in which he showed great prudence and address. In 1810 he made a successful debut as Romeo at Birmingham; and the fame which he had acquired in the provinces gave exceptional interest to his appearance in 1816 at Covent Garden, in the character of Orestes in the *Distressed Mother*. In London his choice of characters was at first confined chiefly to the romantic drama, but he showed his capacity for the highest tragic parts when he played Richard III. at Covent Garden in 1819, and in the following year his performance of Virginius, in the new play of Sheridan Knowles, assisted to give solidity to his reputation. Transferring his services to Drury Lane, he gradually rose in public favour, till, on the retirement of Kean and Young, he was regarded as the legitimate successor of these tragedians. In 1826 he completed a successful engagement in America, and in 1828 his performances met with a very flattering reception in Paris. Already he had done something to encourage the creation of a modern English drama through the interest awakened by his performances in *Virginius*, *Gaius Gracchus*, and *William Tell*, and after entering on the management of Covent Garden in 1837 he introduced, besides other new plays, Bulwer's *Lady of Lyons* and *Richelieu*, the principal characters of which were among his most effective parts. Both, however, in his management of Covent Garden, which he resigned in 1839, and of Drury Lane, which he held from 1841 to 1843, he found his designs for the elevation of the stage hampered and finally frustrated by the sordid aims of the proprietors and the absence of adequate public support. In 1843-44 he made a prosperous tour in the United States, but his last visit to that country, in 1849, was marred by a riot at the Astor Opera House, New York, arising from the jealousy of the actor Forrest, and resulting in the death of twenty-two persons, who were shot by the military called out to quell the disturbance. Macready retired from the stage in 1851; and the remainder of his life was occupied chiefly in superintending the education of his family, and in schemes for the welfare of the poorer classes. He died at Cheltenham 27th April 1873.

Macready's performances always displayed fine artistic perceptions developed to a high degree of perfection by very comprehensive culture, and even his least successful personations had the interest resulting from thorough intellectual study. He belonged to the school of Kean rather than of Kemble; but, if his tastes were better disciplined and in some respects more refined than those of Kean, his natural temperament did not permit him to give proper effect to the most characteristic features of the great tragic parts of Shakespeare, *King Lear* perhaps excepted, which in some degree afforded scope for his pathos and tenderness, the qualities in which he specially excelled. With the exception of a voice of good compass and capable of very varied expression, Macready was not in a special degree gifted physically for acting, but the defects of his face and figure cannot be said to have materially influenced his success. He created a considerable number of parts, which still retain their hold on the stage, and, although not by virtue of natural genius worthy of a place among tragedians of the first rank, he is almost entitled to this on account of the high degree of perfection to which he had cultivated his powers, and from the fact that there is no tragedian of the second rank who can be named his equal. See *Macready's Reminiscences*, edited by Sir Frederick Pollock, 2 vols., 1875.

MACROBIUS, AMBROSIUS THEODOSIUS, a Roman grammarian and philosopher, who wrote towards the beginning of the 5th century after Christ. He is described in the superscription of the best MSS. as *vir clarissimus et illustris*; hence it has been supposed that he is the Macrobius who was *præfectus prætorius Hispaniarum* in 399 A.D., proconsul of Africa in 410, and chamberlain (*præpositus sacri cubiculi*) in 422. But the tenure of high office at that date was limited to Christians, and there is no evidence in the writings of Macrobius that he was a Christian. On the contrary, he shows great interest in the deities of paganism; his friends seem to have belonged wholly to the pagan party; and his philosophical views are those of the Neo-Platonists. Hence the identification is more than doubtful. It is possible, but by no means certain, that he was the Theodosius to whom Avianus dedicates his fables. From the date of the persons who are mentioned by him as contemporaries, he appears to have flourished in the time of Honorius.

The most important of his works is the *Conviviorum Saturnaliorum Libri Septem*, containing an account of the discussions held at the house of Vettius Prætextatus during the holiday of the Saturnalia. The latter part of the second book and the beginning of the third, the second half of the fourth book, and the end of the seventh have been lost; otherwise the work is in fairly good preservation. It was written by the author for the benefit of his son Eustachius, and contains a great variety of curious historical, mythological, critical, and grammatical disquisitions, the value of which is much increased by the frequent quotations from earlier writers. The machinery is somewhat cumbrous; for, as in some of Plato's dialogues, the discussions are not directly reported, but a certain Postumianus reproduces, for his friend Decius, the account which he had received from a rhetorician Eusebius, who had been present at them. There is but little attempt to give any dramatic character to the dialogue; in each book some one of the personages takes the leading part, and the remarks of the others serve only as occasions for calling forth fresh displays of erudition. The first book is devoted to an inquiry as to the origin of the Saturnalia and the festivals of Janus, which leads to a history and discussion of the Roman calendar, and to an attempt to derive all forms of worship from that of the sun. The second book begins with a collection of *bons mots*, to which all present make their contributions, many of them being ascribed to Cicero and Augustus; it then appears to have passed into a discussion of various pleasures, especially of the senses; but almost the whole of this is lost. The third, fourth, fifth, and sixth books are devoted to Virgil, dwelling respectively on his learning in religious matters, his rhetorical skill, his debt to Homer (with a comparison of the art of the two) and to other Greek writers, and the nature and extent of his borrowings from the earlier Latin poets. The latter part of the third book is taken up with a dissertation upon luxury and the sumptuary laws intended to check it, which is probably a dislocated portion of the second book, being entirely out of place where it stands. The seventh book is of a more miscellaneous character, consisting largely of the discussion of various physiological questions. The value of the work consists solely in the facts and opinions quoted from earlier writers, for it is purely a compilation, and has little in its literary form to recommend it.

We have also two books of a commentary on the *Somnium Scipionis* narrated by Cicero in his *De Republica*. The nature of the dream, in which the elder Scipio appears to his (adopted) grandson, and describes the life of the good after death and the constitution of the universe from the Stoic point of view, gives occasion for Macrobius to discourse upon many points of physics in a series of essays interesting as showing the astronomical notions then current. The moral elevation of the fragment of Cicero thus preserved to us gave the work a popularity in the Middle Ages to which its own merits have little claim.

There is a good critical edition of Macrobius, with a commentary by L. van Jan (2 vols., Leipsic, 1848-52), and a convenient and excellent edition of the text by F. Eyssenhardt (Leipsic, 1868).

MADAGASCAR

Plate IV.

MADAGASCAR, an important island in the Indian Ocean, and the third largest island in the world, is about 300 miles from the south-east coast of the African continent, from which it is separated by the Mozambique Channel. It is 980 miles in length from north to south, the northern point, Cape Ambro, in 12° S. lat., inclining 16° to the east from the longitude of Cape St Mary, the southernmost point, in 25° 35′ S. lat., so that the main axis of the island runs from north-north-east to south-south-west. The broadest portion of Madagascar is near the centre, where it is nearly 350 miles across, and there it is only 230 miles distant from the African coast. From this part of the island its northern half forms a long irregular triangle, while south of it the average breadth is about 250 miles. Its total area is nearly 230,000 square miles, or not quite four times the extent of England and Wales.

Size and position.

Explora-tion.

Although known to Arab merchants for more than a thousand years past, and frequently visited by Europeans since the beginning of the 16th century, Madagascar is still but imperfectly explored. A careful survey of the coast was made in 1823–25 by Captain W. F. W. Owen, R.N., but all maps of the interior up to about ten years ago were constructed on the most insufficient data. But during the last decade many portions of the island previously unknown have been traversed by missionaries and naturalists, and maps, more or less detailed, have been prepared of a considerable portion of the interior. Conspicuous in this work have been the missionaries of the London Missionary Society and the Friends' Foreign Mission, especially the late Rev. Dr Mullens, whose large map, published in 1879, embodied all that was known up to that date, and also M. Alfred Grandidier, a French traveller and scientist, whose great work on the island is now in process of publication.

Bays.

Madagascar has a very regular and compact form, with but few indentations considering its great extent of shoreline. Along two-thirds of its eastern side the coast is almost a straight line, without any inlet, for Tamatàve and Foule Pointe, which are the most frequented ports on this side of the island, are only open roadsteads protected by coral reefs. North of this, however, is Antongil Bay, a deep and wide inlet running northwards for about 50 miles; farther north is Port Louquez, and at the extreme point of the island is Diego Suarez Bay, one of the finest harbours in the world. The north-western side of Madagascar is broken up by a number of spacious inlets, some of them landlocked and of considerable size. Going southward, these are the bays of Chimpaiky, Pàsandàva, Port Radàma, Narìnda, Majàmbo, Bémbatòka, and Ibòina, as well as the estuaries of some of the rivers. South of Cape St Andrew, the north-west angle of the island, there is nothing else in the shape of a gulf until we reach the estuary of the river Onilàhy, or St Augustine's Bay. Rounding the southern end of the island, we find no other inlet until we come to the small bay of Itapéra near Fort Dauphin, at the southern extremity of the straight line of coast already mentioned.

Islands.

The islands around Madagascar are few and unimportant. The largest are St Marie's, near the eastern coast, a narrow island about 30 miles long, and Nòsibé, larger and more compact in form, opposite Pàsandàva Bay on the north-west coast. Except the Minnow group, north of Nòsibé, the rest are merely rocky islets, chiefly of coral.

Moun-tains.

Much light has been thrown upon the physical geography of Madagascar by recent explorations. In most accounts, up to a very short time ago, a "central mountain chain" is described as running throughout the island as a sort of backbone from north to south; and most maps show this, with numerous branches extending in various directions. It is, however, now quite clear that instead of this supposed mountain chain there is an elevated mountainous region, from 3000 to 5000 feet in altitude, occupying from a third to two-fifths of the whole interior, but lying more towards the north and east. Around this upper region are extensive plains, at a much less elevation above the sea, and most developed on the western side of the island, and in its southern portion beyond 23° S. lat. But this lower region is not entirely level, as it is broken up towards the west by three prominent lines of hills running north and south. See Plate IV.

The shores of the greater portion of the southern half of the island are low and flat, but in the northern half much of the coast is bold and precipitous, the high land often approaching the sea. On the eastern side the plains vary from 10 to 50 miles in breadth, but on the western side they often exceed 100 miles across. From these coast plains the ground rises by successive ranges of hills to the high interior land. This elevated region is broken up in all directions by mountains, the highest in the island being centrally situated as regards its length, but more to the eastern side. These are the summits of the basaltic mass of Ankàratra, four of the peaks ranging in elevation from 8100 to 8950 feet above the sea, and from 3900 to 4700 feet above the general level of the surrounding country. The loftiest of these is named Tsi-àfa-jàvona, *i.e.*, "that which the mists cannot climb." Besides these highest points there are a considerable number of mountains in the central provinces, varying in height from 5000 to 7000 feet, the highest as yet measured being Iàvohàika ("the Lofty defying one"), 7100 feet high, about 30 miles west-south-west of Ankàratra, and the highest point of a remarkably rocky and rugged district named Vàvavàto ("Stonemouth"). There are also very many lofty and grand peaks in the Bétsiléo province, some, it is said, nearly 8000 feet high; and in the Bàra country the Isàlo mountains are compared by a recent traveller to the "Church Buttes" and other striking features of the scenery of Utah, on the line of the Pacific Railway. One of the grandest of all the Madagascar peaks is an isolated mountain near the northern point of the island, called Amber or Ambòhitra. This is said to be more than 6000 feet high, and, rising, not as do those before-mentioned, from an elevated plateau, but from plains little above the sea-level, is a remarkably majestic hill as observed from every direction, and is well seen far out to sea.

Valleys and hydro-graphy.

In the elevated region of Madagascar are many fertile plains and valleys. Among these are Bétsimitàtatra in Imérina, and Tsiénimparìhy in Bétsiléo, supplying a large proportion of the rice for the capitals of these two provinces. Still more extensive valleys are the plain of the Antsihànaka country, the valley east of Angàvo, and the Ankày district between the two eastern lines of forest (all of which are one step downwards towards the lower coast plains), and the valley east of the Bémaràha range in the Sàkalàva country. Sections across the central portions of Madagascar show that there is a somewhat saucer-like depression in the centre, the eastern and western edges rising higher than the enclosed space. The eastern ridge is the higher of the two, so that the watershed for a considerable distance is much nearer the eastern than the western side, averaging from 50 to 80 miles from the sea. The country is well watered, even in the highest ranges of the interior, the abundant rainfall giving a perennial supply to the innumerable springs and streams. There are, therefore, no extensive districts that can be called desert, except parts of the west and south-west provinces, where the rainfall is scanty. The extreme southern portion is also reported to be arid, but as yet little is accurately known of this part of the country.

Rivers.

As is necessarily the case from the physical conformation


MADAGASCAR
BY JAS. SIBREE, JR. F.R.G.S.
The Forest belt is shewn by Green tinting.
The approximate extent of upper Granitic region is shewn by pale Red colour.
Extinct Volcanoes shewn by Vermilion Dots; Lava Streams and Volcanic disturbance by vermilion Lines.
The Names in sloping Capitals are those of Tribes, as BÉTSILÉO; the upright capitals shew Districts, as MÉNABÉ.
COMORO ISLANDS
Great Comoro
Johanna
Mohilla
Mayotta
MOZAMBIQUE CHANNEL
INDIAN OCEAN
C. Ambro
C. St. Sebastian
Nosi-be
Volimàro
Sambàva
Mojanga
C. St. Andrew
Màrovoày
Màndritsàra
I.S. Marie
Fénoarivo
Tamatave
Antananarivo
IMERINA
HOVA
BÉTSILÉO
Fianarantsoa
Màhanòro
Ambàlavòntaka
Mahéla
MÉNABÉ
SAKÀLAVA
BÀRA
Unexplored
Tuléar
St. Augustines B.
Ambàlafàndrana
P. Itapéra
Ft. Dauphin
TANDRÒY
C. St. Mary
TANOSY
MAHAFALY
Jas. Sibree Jr. Del.
W. & A.K. Johnston, Edinburgh

of the interior, the chief rivers flow to the west and north-west sides of the island. The eastern streams are all less in size, except the Mangòro, which flows for some distance parallel with the coast. Few of them, therefore, are of much service for navigation, except for the light-draught native canoes, and almost all of them are more or less closed at their outlets by sand-bars. Commencing at the southern point and going northward, on the eastern side, the principal rivers are the Mànanàra, Mànambavà, Màtitànana, Mànanjàra, Onivé and Mangòro, Màningòry, and the Anjàhanàmbo at the head of Antongil Bay, besides numerous smaller streams. On the north-west coast, going southward, are the Sofia and Màhajàmba, falling into Majàmbo Bay, the Bétsibòka with the Ikiòpa,—the great drains of the northern central provinces, and forming unitedly the second largest river of the island and falling into Bémbatòka Bay,—the Mànjaray, Mànambòlo, Tsìribìhina or Onimàinty, the largest river of Madagascar, draining by its tributaries the Kitsàmby, Màhajìlo, and Manìa the central parts of the island, the Mòrondàva, Màharìvo, Mangòky, the third largest river, the Màhanòmby, Fiherénana, and Onilàhy.

Of these western rivers the Bétsibòka could be ascended by steamers of light draught for about 90 miles, and the Tsìribìhina is also navigable for a considerable distance. The former is about 300 miles long; the latter is somewhat less, but by its affluents spreads over a greater extent of country. It brings down so large a body of water that the sea is said to be fresh 3 miles from the land. But owing to the height of the interior of Madagascar there is no uninterrupted water-communication with it from the sea by any of the rivers, which are all crossed by rocky bars, and in some cases by grand waterfalls, as on the Manìa. The eastern rivers cut their way through the ramparts of the high land by magnificent gorges, amidst dense forest, and descend by a succession of rapids and cataracts. The Màtitànana, whose falls were first seen by the present writer in 1876, descends at one plunge some 400 or 500 feet.

Lagoons and lakes.

On the eastern side of Madagascar the contest between the fresh water of the rivers and the sea has caused the formation of a long chain of lagoons for nearly three hundred miles. In many parts these look like a river following the coast-line, but frequently they spread out into extensive sheets of water. So short is the distance between these that, by cutting about 30 miles of canal to connect them, a continuous water-way could be formed for 260 miles along the coast. This will doubtless be accomplished at some future time, with great benefit to the commerce of the country. Besides these lagoons, there are few lakes of any size in Madagascar, although there were probably some very extensive ones in a recent geological epoch. Of one of the largest of these the Alàotra Lake in the Antsihànaka plain is the relic; it is about 25 miles long. Next comes Itàsy, in western Imérina, about 8 miles long; and a large lake is reported by the natives to be formed by an expansion of the river Mangòky. Two salt lakes are said to exist near the south-west coast.

Volcanic belt.

Among the many new facts brought to light by recent research in Madagascar is the evidence of very widespread and powerful subterranean action throughout a great part of the island, apparently extending almost unbroken from the south-east to the north-west and extreme north. This volcanic belt is part of a line which has its northern extremity in the Comoro Islands, all of which are volcanic in origin, and where, in Great Comoro, there is a still active vent. There is now no active volcano in Madagascar, but a large number of extinct cones have been observed in various parts of the country. In the central province of Imérina, within an arc of about 90 miles round the mass of Ankàratra, Dr Mullens counted a hundred craters. Others are found farther north, in the Antsihànaka province and the Màndritsàra valley, and on the north-west coast and its islands, the great mountain Ambòhitra being an old volcano. Others have been observed towards the southern extremity of the higher region of the island, as well as columnar basalt, and beds of lava rock, pumice, and ash. Slight shocks of earthquake are felt every year in Madagascar, and other signs of subterranean action are evident in the hot springs which occur at several places in the central and eastern provinces. Several of these are sulphurous and medicinal, and have been found efficacious in skin diseases.

Geology.

The geology of Madagascar has as yet been very imperfectly investigated, for few travellers have possessed the special scientific knowledge requisite to give much value to their observations; and hardly anything has yet been done towards making collections of fossils, or in procuring specimens of rocks and minerals. There are, however, a few facts of a general character which are easily recognizable. In the first place, the upper region of the island already mentioned appears to consist chiefly of Primary and unstratified rocks—granite, gneiss, and basalt—which form the highest points of the hills, and present most varied and picturesque outlines, resembling titanic castles, cathedrals, domes, pyramids, and spires. The general face of the country consists of bare rolling moors, with a great amount of bright red and light brown clays, while the valleys have a rich vegetable soil of bluish-black alluvium. No stratified or fossiliferous rocks have yet been discovered in this upper part of the island, which appears to be very ancient land, and during portions of the Secondary and Tertiary periods probably formed the entire island, then about from a third to two-fifths of its present size, while the extensive southern and western plains were again and again submerged.

Fossils and minerals.

The lower portions of Madagascar do not, as far as is yet known, much exceed from 300 to 600 feet in height above the sea-level (except, of course, the three chains of hills in the south-west). They appear in several localities to consist of strata of the Secondary period, with fossils of the Neocomian age belonging to the genera *Nerinea*, *Turritella*, *Ammonites*, *Terebratula*, *Rhynconella*, *Neritina*, and Echinoderms, and also *Foraminifera* of the genera *Alveolina*, *Orbitoides*, *Triloculina*, &c. There are also beds of a much later age, containing fossils of recently extinct gigantic tortoises, hippopotami, and struthious birds. In addition to the rocks already mentioned as found in the higher portions of the island, there are also slate, mica schist, greywacke, chert, pink and white quartz, and an unstratified limestone deposited by hot springs. Iron exists in great abundance in the central parts of the country, and copper and silver are said to have been found in small quantities, but are not worked. Antimony seems to be plentiful in the north, and rock-salt, iron pyrites, plumbago, and various ochres and coloured earths are among the mineral products. On the north-west coast thin beds of lignite, suitable for steam coal, occur, but no true coal has yet been discovered.

Climate.

The climate varies very much in different parts of the country. In the high interior districts it resembles that of the temperate zones, with no intense heat, and is quite cold during the nights in winter. These parts of the island are therefore tolerably healthy for Europeans. But the coasts are much hotter, especially on the western side; and, from the large amount of marsh and lagoon, malarial fever is prevalent, and frequently fatal both to Europeans and to natives from the interior. The seasons are two—the hot and rainy season from November to April, and the cool and dry season during the rest of the year. Rain indeed falls almost all the year round on the eastern coast, which is exposed to the vapour-laden south-east trade

The Hòva[1] or commoners form the mass of the free population of Imérina. They are composed of a large number of tribes, who usually intermarry strictly among themselves, as indeed do families, so that property and land may be kept together. Hitherto they have also been divided into two great sections—the *bòrozàno* or civilians, and the *miàramìla* or military class; but this distinction does not follow tribal lines, members of the same family belonging to both classes; and the Andriana are also almost all members either of the civilian or the military orders.

The third great division of native society comprises the slave population. Until the year 1877 it was also again subdivided into three classes:—(*a*) the Zàza-hòva, that is, "offspring of the Hòva," or free people who have been reduced to slavery for debt or for political or criminal offences; (*b*) the Andèvo, or slaves proper, mostly the descendants of people of other Malagasy tribes who have been conquered by the Hòva, and thus have become their slaves; and (*c*) the Mozambiques or African slaves, whose ancestors or they themselves have been brought across from the African coast by the Arab slaving dhows. These last, however, were in 1877 formally set free, and will be henceforth mostly reckoned among the Hòva.

Royalty and chieftainship in Madagascar has many peculiar customs connected with it. It still retains a semi-sacred character, the chief being in heathen tribes, while living, the high priest for his people, and after death worshipped as a god; and in its modern development among the Hòva sovereigns it has gathered round it much state and ceremony. There are many curious examples of the *tabu* with regard to actions connected with royalty, and also in the words used which relate to Malagasy sovereigns and their surroundings. These are particularly seen in every thing having to do with the burial of a deceased king or queen.[2]

While the foregoing description of native society applies chiefly to the people of the central province of Imérina, it is more or less applicable, with local modifications, to most of the Malagasy tribes, amongst almost all of whom similar distinctions of rank are found. In modern times a kind of non-hereditary nobility has arisen, derived from military "honours"; and the tendency of recent changes in the native government is to depress the old feudal authority and influence, and to make it subservient to the army and its officers.

Agriculture.

The chief employment of the Malagasy is agriculture, a large portion of their time being spent in the cultivation of rice, their staple food. In this they show very great ingenuity, the *kètsa* grounds, where the rice is sown before transplanting, being formed either on the margins of the streams or in the hollows of the hills in a series of terraces, to which water is often conducted from a considerable distance. In this agricultural engineering no people surpass the Bétsiléo tribes. No plough is used, but all work is done by a long-handled spade; and oxen are only employed to tread out the soft mud preparatory to transplanting. The other processes are very primitive: the rice is threshed by being beaten in bundles on stones set upright on the threshing-floor; and when beaten out the grain is stored by the Hòva in rice-pits dug in the hard red clay, but by the coast tribes in small timber houses raised on posts to protect them from vermin. In preparing the rice for use it is pounded in a wooden mortar to remove the husk, this work being always done by the women. The manioc root is also largely consumed, together with several other roots and many vegetables; but little animal food (save fish and freshwater *Crustacea*) is taken by the mass of the people except at festival times. Rice is used less by the western tribes than by those of the central and eastern provinces, and the former people are more nomadic in their habits than are the others. Large herds of fine humped cattle are kept almost all over the island.

Handicrafts.

The central and eastern peoples have a considerable amount of manual dexterity. The women spin and weave, and with the rudest appliances manufacture a variety of strong and durable cloths of silk, cotton, and hemp, and of ròfia palm, aloe, and banana fibre, of elegant patterns, and often with much taste in colour. They also make from straw and papyrus peel strong and beautiful mats and baskets in great variety, some of much fineness and delicacy, and also hats resembling those of Panama. The people of the south and south-east make large use of soft rush matting for covering, and they also prepare a rough cloth of bark. Their non-employment of skins for clothing is a marked distinction between the Malagasy and the South African races, and their use of vegetable fibres an equally strong link between them and the Polynesian peoples. The ordinary native dress is a loin-cloth or *salàka* for the men, and a *kitàmby* or apron folded round the body from waist to heel for the women; both sexes use over this the *làmba*, a large square of cloth folded round the body something like the Roman *toga*. The Malagasy are skilful in metal working; with a few rude-looking tools they manufacture silver chains of great fineness, and filagree ornaments both of gold and silver. Their iron-work is of excellent quality, and in copper and brass they can produce copies of anything made by Europeans. They display considerable inventive power, and they are exceedingly quick to adopt new ideas from Europeans.

Houses and villages.

There is a considerable variety in the houses of the different Malagasy tribes. The majority of Hòva houses are built of layers of the hard red clay of the country, with high-pitched roofs thatched with grass or rush. The chiefs and wealthy people have houses of framed timber, with massive upright planking, and lofty roofs covered with shingles or tiles. The forest and coast tribes make their dwellings chiefly of wood framing, filled in with the leaf-stalks of the traveller's-tree, with the leaves themselves forming the roof covering. The houses of the Bétsiléo and Sàkalàva are very small and dirty, but those of the coast peoples are more cleanly and roomy. Among the Hòva and Bétsiléo the old villages were always built for security on the summits of lofty hills, around which were dug several deep fosses, one within the other. In other districts the villages and homesteads are enclosed within formidable defences of prickly pear or thorny mimosas.

Commerce.

The country is very deficient in means of communication. There are no roads or wheeled vehicles, so that all goods are carried either by canoes, where practicable, or on the shoulders of bearers along the rough paths which traverse the country, and which have only been formed by the feet of the travellers. Intercourse between distant portions of the island is therefore very limited, but a large quantity of European goods is brought up to the capital city and its neighbourhood, and a good deal of native produce is taken down to the coast. Commerce is gradually increasing, as shown by the consular returns, the chief articles of export being bullocks, rice, hides, ròfia palm cloths (*rabànnas*) and fibre, and also gum-copal and india-rubber, although the yield of these products has latterly much diminished. Coffee is being planted to some extent by creole traders, and is likely to become a staple article of export, and from the natural fertility of the soil almost

[1] This is, of course, a special and restricted use of the word, Hòva in its widest sense being a tribal name, and including all ranks of people in Imérina—royalty, nobles, commoners, and slaves alike.

[2] See Sibree, *The Great African Island*, pp. 185–90, 226, 227, &c.

unlimited quantities of most tropical produce could be obtained—sugar, coffee, rice, cotton, tobacco, indigo, spices, &c. The chief imports are European and American calicoes and prints, hardware, and spirits.[1] On the west coast a sea-going canoe with outrigger is employed, but in the south-east an ingeniously constructed boat, with all the timbers tied together, is used for going through the heavy surf. A considerable number of European traders are scattered along the coasts, especially at Tamatàve and other eastern seaports, and there is a large Arab and Indian community in the north-western ports. There is no native coinage, but the French five-franc piece or dollar is the standard, and all sums under that amount are obtained by cutting up these coins into all shapes and sizes, which are weighed with small weights and scales into halves, quarters, eighths, twelfths, and twenty-fourths of a dollar, and are even reckoned down to the seven-hundred-and-twentieth fraction of the same amount.

Morals. Apart from the modern influence of religious teaching, the people are very immoral and untruthful, disregardful of human life and suffering, and cruel in war. Until lately polygamy has been common among all the Malagasy tribes, and divorce effected in an absurdly easy fashion. At the same time the position of woman is much higher in Madagascar than in most heathen countries; and, since for more than fifty years past there have been (with a few months' exception) only female sovereigns, this has helped to give women considerable influence in native society. Among some of the tribes, as, for instance, the Bàra, there is often a shameless indecency of speech and gesture. The southern and western peoples still practice infanticide as regards children born on several unlucky days in each month. This was formerly the general practice all over the island. The old laws among the Hòva were very barbarous in their punishments, and death in various cruel forms was inflicted for very trifling offences. Drunkenness is very prevalent in many parts of the island (except in Imérina, where it is much restrained by the laws); and it can hardly be said of many of the Malagasy that they are very industrious. But, on the other hand, they are courageous and loyal to their chiefs and tribe, and for short periods are capable of much strenuous exertion. They are affectionate and firm in their friendships, kind to their children and their aged and infirm relatives, very respectful to old age, most courteous and polite, and very hospitable to strangers. Although slavery has existed among them from time immemorial, it bears quite a patriarchal and family character, and is seldom exercised in a cruel or oppressive way. In 1877 all the African slaves who had been brought into the island were formally set free; the other slaves are still retained in servitude, but probably with the advance of Christianity slavery will eventually pass away.

Religion. In their religious notions and practices the Malagasy seem to occupy a middle position among heathen peoples. On the one hand, they have never had any organized religious system or forms of worship; there are no temples, images, or stated seasons of devotion, nor is there a priesthood, properly so called. On the other hand, they have never been without some distinct recognition of a Supreme Being, whom they call *Andriamànitra*, "The Fragrant One," and *Zànahàry*, "The Creator,"—words which are recognized all over the island. They have also retained in their public and oratorical forms of speech many ancient sayings, proverbial in their style, which enforce many of the truths of natural religion as to the attributes of God. With all this, however, there has long existed a kind of idolatry, which in its origin is simply fetichism, the belief in charms—worthless objects of almost any kind—as having power to procure various benefits and protect from certain evils. Among the Hòva in modern times some four or five of these charms had acquired special sanctity and renown, and were each honoured as a kind of national deity, being called god, and brought out on all public occasions to sanctify the proceedings. Together with this idolatry there is also a firm belief in the power of witchcraft and sorcery, in divination, in lucky and unlucky days and times, in ancestor worship, especially that of the sovereign's predecessors, and in several curious ordeals for the detection of crime. The chief of these was the celebrated tangéna poison ordeal, in which there was implicit belief as a test of guilt or innocence, and by which, until its prohibition by an article in the Anglo-Malagasy treaty of 1865, thousands of persons, mostly innocent, perished every year. Sacrifices of fowls and sheep are made at many places at sacred stones and altars, both in thanksgiving at times of harvest, &c., and as propitiatory offerings. Blood and fat are used to anoint many of these stones, as well as the tombs of ancestors, and especially those of the Vazìmba, the supposed aboriginal inhabitants of the central provinces. In some of the southern districts it is said that human sacrifices were occasionally offered. The chief festival among the Hòva, and almost confined to them, is that of the New Year, at which time a kind of sacrificial killing of oxen takes place, and a ceremonial bathing, from which the festival takes its name of *Fandròana* (the Bath). Another and more general feast is at circumcision times. This rite is observed by royal command at intervals of a few years; these are occasions of great rejoicing, but also of much drunkenness and licentiousness. Funerals are also times of much feasting, and at the death of people of rank and wealth numbers of bullocks are killed. Although, as already observed, there was no proper priesthood, the idol keepers, the diviners, the day-declarers, and some others formed a class of people closely connected with heathen customs and interested in their continued observance.

Early political divisions. HISTORY.—From the earliest accounts given of the people of Madagascar by European travellers, as well as from what may be inferred from their present condition over a large portion of the island, they seem for many centuries to have been divided into a number of tribes, each occupying its own territory, and often divided from the others by a wide extent of uninhabited country. Each of these was under its own chief, and was often at war with its neighbours. No one tribe seems to have gained any great ascendency over the rest until about two hundred and thirty years ago, when a small but warlike people

[1] The following tables will give some idea of the imports and exports in English vessels from Tamatàve, the chief eastern port of Madagascar, to Mauritius during the last few years, since the country has been reopened to European trade :—

	Exports.	Imports.
1862	£70,707	£57,714
1865	66,873	40,082
1870	57,922	63,047
1872	154,659	145,258
1875	113,961	113,598
1877	54,882	59,680

The great diminution in the eastern trade during the last four or five years was due to a fearful epidemic of small-pox, which desolated the coast provinces and is said to have carried off 40 per cent. of the population. Of these figures, in the exports, cattle form the largest item, amounting from three-fourths in early years to one-third more recently of the total value; and next to this comes india-rubber, which, in 1872, was exported to the value of £65,000. These figures, however, by no means represent the whole trade of the country, as they do not include French, American, and German commerce, nor do they show what is the trade on the western side of the island. Mr Samuel Procter, the consul for Madagascar in England, says that the west coast has developed very much during the last five or six years, and his opinion is "that the entire foreign trade with Madagascar, import and export, does not fall far short, if at all, of a million pounds sterling." When it is remembered that it is less than thirty years since almost all foreign commerce was excluded, it will be seen that Madagascar trade has developed somewhat rapidly since the reopening of the country.

called Sàkalàva, in the south-west of Madagascar, advanced northward, conquered all the inhabitants of the western half of the island, as well as some northern and central tribes, and eventually founded two kingdoms which retained their supremacy until the close of last century. About that time, however, the Hòva in the central province of Imérina began to assert their own position under two warlike and energetic chieftains, Andrianimpòina and his son Radàma; they threw off the Sàkalàva authority, and after several wars obtained a nominal allegiance from them; they also conquered the surrounding tribes, and so made themselves virtual kings of Madagascar. Since that time the Hòva authority has been retained over the central and eastern provinces, but is only nominal over much of the western side of the island, while in the south-west the people are quite independent, and are still under their own petty kings or chiefs.

Arab intercourse and influence.

While European intercourse with Madagascar is comparatively recent, the connexion of the Arabs with the island dates from a very remote epoch; and in very early times settlements were formed both on the north-west and south-east coasts. In the latter locality there are still traces of their influence in the knowledge of Arabic possessed by a few of the people; and it is asserted that the ruling clans of the Tanàla and other tribes in that district are all of Arab descent. But in these provinces they have almost lost all separate existence, and have become merged in the general mass of the people. It is different, however, in the north-west of the island. Here are several large Arab colonies, occupying the ports of Amòrontsànga, Mòjangà, Màrovoày, and Mòrondàva, and retaining their distinct nationality, together with their own dress, habits, houses, worship, and language. There is also in these districts a Hindu element in the population, for intercourse has also been maintained for some centuries between India and northern Madagascar, and in some towns the Banyan Indian element is as prominent as the Arab one, and Hindu dress, ornament, music, food, and speech are marked features in the social life of these places. In the early times of their intercourse with Madagascar, the Arabs had a very powerful and marked influence upon the Malagasy. This is seen in the number of words derived from the Arabic which are found in the native language. Among these are the names of the months and the days of the week, those used in astrology and divination, some forms of salutation, words for dress and bedding, money, musical instruments, books and writing, together with a number of miscellaneous terms. These form enduring memorials of the influence the Arabs have exerted upon Malagasy civilization, and also on their superstition.

European intercourse and attempted colonization.

The island is mentioned by several of the early Arabic writers and geographers, but mediæval maps show curious ignorance of its size and position. Marco Polo has a chapter upon it, and terms it Madeigascar, but his accounts are evidently confused with those of the mainland of Africa. The first European voyager who saw Madagascar appears to have been a Portuguese captain named Fernando Soares, in command of a squadron of eight ships from the fleet of Don Francisco de Almeida. On his way home from India he sighted the island on the 1st of February 1506. The Portuguese gave names to most of the capes, but made no persistent attempts at colonization. After them the Dutch endeavoured, but with little success, to form colonies; and in the time of Charles I. proposals were made to form an English "plantation," but these were never carried into effect, although for a short time there was a settlement formed on the south-west coast. In the latter part of the 17th and during most of the 18th century the French attempted to establish military positions at various places on the east coast, but with little permanent result. For some time they held the extreme south-east point of the island at Fort Dauphin; but several of their commandants were so incapable and tyrannical that they were frequently involved in war with the people, and more than once their stations were destroyed and the French were massacred. Early in the present century all their positions on the mainland were relinquished, and they now retain nothing but the islands of St Marie on the east coast and Nòsibé on the north-west. No foreign power now holds any portion of Madagascar, for the native Government has jealously reserved all territorial rights to itself, and will suffer no purchase of land by foreigners, allowing it only to be held on short leases.

Radàma I.

The political history of Madagascar as a whole may be said to date from the reign of Radàma I. (1810–28). The ancestors of that king had been merely chiefs of the central provinces, but he was the first to claim by right of conquest to be supreme ruler of the whole island, although actually exercising authority over less than two-thirds of its surface. Radàma was a man much in advance of his age,—shrewd, enterprising, and undeterred by difficulty,—a kind of Peter the Great of his time. He saw that it was necessary for his people to be educated and civilized if the country was to progress; and making a treaty with the governor of Mauritius to abolish the export of slaves, he received every year in compensation a subsidy of arms, ammunition, and uniforms, as well as English training for his troops. He was thus enabled to establish his authority over a large portion of the island, and, although this was often effected with much cruelty, the ultimate results were beneficial to the country as a whole. A number of native youths were sent to Mauritius, and others to England, for education and instruction in some of the arts of civilization, as well as in seamanship. For some years a British agent, Mr Hastie, resided at Radàma's court, and exercised a powerful influence over the king, doing very much for the material advance of the country.

Introduction of Christianity.

At the same period (1820) Christian teaching was commenced in the capital by the London Missionary Society, and by the efforts of its missionaries the language was for the first time reduced to a systematic written form, and the art of printing introduced; books were prepared, the Scriptures were translated, numerous schools were formed, and several Christian congregations were gathered together. The knowledge of many of the useful arts was also imparted, and many valuable natural productions were discovered, and their preparation and manufacture taught to the people. At the same time the power of superstition was greatly broken, a result partly due to the keen good sense of the king, but chiefly to the spread of knowledge and religious teaching.

Rànavàlona I.

The bright prospects thus opening up for the country were clouded by the death of Radàma at the early age of thirty-six, and the seizure of the royal authority by one of his wives, the Princess Rànavàlona. Superstitious and despotic in temper, the new sovereign looked with much suspicion upon the ideas then gaining power among many of her people, and after a few years of temporizing she at length determined to strike a decisive blow at the new teaching. In 1835 the profession of the Christian religion was declared illegal; all worship was to cease, and all religious books were ordered to be given up. By the middle of the following year all the English missionaries were obliged to leave the island, and for twenty-five years the most strenuous efforts were made by the queen and her Government to suppress all opposition to her commands. This, however, only served to show in a very remarkable manner the courage and faith of the Christian Malagasy, of whom about two hundred suffered death in various cruel forms, while many hundreds were punished more or less severely by fine, degradation, imprisonment, and slavery. During the queen's reign the political condition of the country was deplorable; there were frequent rebellions owing to the oppressive nature of the government; many of the distant provinces were desolated by barbarous wars; and for some years all Europeans were excluded, and foreign commerce almost ceased. This last circumstance was partly owing to an ill-managed attack upon Tamatàve in 1846 by a combined English and French force, made to redress the wrongs inflicted upon the foreign traders of that port. But for the leaven of Christianity and education which had been introduced into the country it would have quite reverted to a state of barbarism.

Radàma II.

This reign of terror was brought to a close in 1861 by the death of the queen and the accession of her son Radàma II. The island was reopened to European trade, and missionary efforts were recommenced. A determined attempt was made by some enterprising Frenchmen to gain for their country an overwhelming influence by means of a treaty which they induced the king to sign. But this act, as well as the vices and insane follies into which he was led by worthless foreign and native favourites, soon brought his reign and his life to an end. He was put to death in his palace (1863) after having reigned for less than two years, and his wife was placed on the throne. The new sovereign and her Government refused to ratify the agreement which had been illegally obtained, choosing rather to pay a million francs as compensation to the French company.

Rasohérina.

During the five years' reign of Queen Rasohérina, quiet and steady advances were made in civilization and education, and treaties were concluded with the English, French, and American Governments.

Rànavàlona II.

At the death of Rasohérina in 1868, she was succeeded by her cousin, the present (1882) sovereign, Rànavàlona II. One of the first acts of the new queen was the public recognition of Christianity; and very soon afterwards she and her husband, the prime minister, were baptized, and the erection of a chapel royal was commenced in the palace yard. These acts were followed in the succeeding year by the burning of the royal idols, and immediately afterwards by the destruction of the idols throughout the central provinces, the people generally putting themselves under Christian instruction. Since that time education and enlightenment have made great progress, chiefly through the labours of the London Missionary Society's missionaries, with whom are also associated several agents of the Friends' Foreign Mission Association. About 1200 congregations have been formed, and about 900 schools, in which nearly 50,000 children receive instruction; and there are also normal schools and colleges where teachers, pastors, evangelists, and the sons of the upper classes are well educated. A considerable amount of literature has been prepared, and several printing presses are constantly at work. Very marked advance has been made as regards the morality of the people by the suppression of the grosser and more open forms of vice, the abolition of polygamy, and the restrictions placed upon arbitrary divorce. All the barbarous punishments of the old laws have been done away with; and the only war carried on during the present reign was conducted with such humanity as well as sagacity that peace was speedily restored.

Although these changes have as yet only affected about a fourth part of the whole population, there is reason to believe that the influences at work in the centre of the island will eventually affect all the different tribes. Missionary work is also carried on by English Episcopalians (S. P. G.), Norwegian Lutherans, and French Roman Catholics.

Government. The government of Madagascar during the present century has been and still is monarchical theoretically despotic, but practically limited in various ways. Radàma I. and Rànavàlona I. were much more absolute sovereigns than those before or after them, but even they were largely restrained by public opinion. New laws are announced at large assemblies of the people, whose consent is asked, and always given through the headmen of the different divisions of native society; and this custom is no doubt a "survival" from a time when the popular assent was not a merely formal act, as it has now almost entirely become. The large disciplined army formed by Radàma I. aided much in changing what was formerly a somewhat limited monarchy into an absolute one. The Hòva queen's authority is maintained over the central and eastern portions of Madagascar, and at almost all the ports, by governors appointed by the queen, and supported by small garrisons of Hòva troops. At the same time the chiefs of the various tribes are left in possession of a good deal of their former honours and influence, so long as they acknowledge the suzerainty of the Hòva sovereign, and perform a certain amount of Government service. The present queen and her predecessor have both been married to the prime minister, a man of great ability and sagacity, who, by his position as husband and chief adviser of the sovereign, is the virtual ruler of the country. Chiefly owing to his influence, the last five or six years have been marked by the introduction of several measures tending to modify the government of the country and improve the administration. The purpose of these new laws is to weaken the old oppressive feudal system; to remodel the army; to appoint a kind of local magistracy and registrars; to encourage education; and to form a responsible ministry, with departments of justice, war, education, agriculture, commerce, revenue, &c.

Owing to the conservative habits of the people, considerable time will probably elapse before all these measures are carried into effect, but their mere enactment is a proof of the progress of enlightened ideas. **Army.** Until lately the military service has been very oppressive upon certain classes, being for life, and without any pay; but it is now to be made compulsory upon all, and for short periods only. The Hòva army has been variously estimated at from 30,000 to 40,000 men, although it is popularly termed *ny Fòlo-àlin-dàhy*, *i.e.*, "the Ten ten-thousand men." Military rank is reckoned by numbers, from one "honour," that of a private, to sixteen "honours," the rank of the highest officer; but several of the English words for different ranks are employed, as a sergeant, captain, general, marshal, &c. **Justice.** Justice has hitherto been administered by a number of unpaid judges appointed by the sovereign, and they generally sit in the open air. There appears to be a somewhat small amount of crimes of violence; but cattle-stealing raids made by one tribe upon another are a frequent cause of petty wars away from the Hòva authority. **Revenue.** The revenue of the Government is derived from customs duties, first fruits, fines and confiscation of offenders' property, and a money offering called *hàsina*, presented on a great variety of occasions both to the sovereign in person and to her representatives; and these are supplemented by "benevolences" (in the mediæval sense of the word) levied upon the people for occasional state necessities. Besides these, the Government claims the unpaid service of all classes of the community for all kinds of public work. **Foreign relations.** Consuls appointed by the English, French, and American Governments are accredited to the Malagasy sovereign, and the queen has a consul in England, and a consular agent at Mauritius. During the late Lord Clarendon's tenure of office as foreign secretary an understanding was come to between the English and French Governments by which it was agreed that each power should respect the independence of Madagascar; and, although the intrigues of Jesuit priests have more than once fomented difficulties between the native Government and the French, it may be hoped that the home authorities in France will still refuse to interfere, and will allow the Malagasy—undisturbed by fear of foreign invasion—quietly to advance in that path of progress which they have for some years been following with such happy results. The best prospects for the future of the country would appear to be bound up in the gradual consolidation of the central Hòva authority over the whole island, bringing to every part of it those civilizing and enlightening influences which have already worked such changes in the central provinces.

The capital. Antanànarivo, the capital of Madagascar, is by far the largest city in the island. It has about 100,000 inhabitants, and has been almost rebuilt during the last twelve years, the old timber and rush houses being nearly all replaced by much larger and more substantial ones of sun-dried brick and stone, constructed in European fashion. A group of royal palaces, with lofty roofs and stone-arched verandahs, crowns the summit of the ridge on and around which the city is built, and hardly less conspicuous is the grand new residence of the prime minister. Four handsome stone memorial churches, with spires or towers, mark the spots where the Christian martyrs suffered; and other prominent buildings are the Chapel Royal, the Norwegian and the Roman Catholic churches, the London Missionary College, the London Missionary Society and the Friends' normal schools, mission hospitals, the court of justice, and numerous large Congregational churches of sun-dried brick.

Other towns. Next to the capital in size are the port of Mojangà, on the north-west coast, with about 14,000 inhabitants; Tamatàve, the chief eastern port, and Fianàrantsòa, the chief town of the Bétsiléo, each with about 6000 people; and Ambòhimànga, the old capital of Imérina, with about 5000. There are very few places besides these with as many as 5000 people, and the majority of native towns are small. **Population.** The population is dense in two or three districts only, and the entire island is variously estimated to contain from four to five millions of inhabitants.

Literature.—A considerable number of books have been written upon Madagascar, both in the English and French languages, but many of the latter are of little value. And during the last twenty years a great many papers upon the exploration, natural resources, animal and vegetable life, and political and religious condition of the country have appeared in various periodicals and in the *Proceedings* of the different learned societies, both English and French. In the following lists no attempt is made at completeness, but only to select the most important of each class. As regards the scientific aspects of the country, almost everything worth preserving in previous books and papers will be included in the magnificent work now in course of publication in twenty-eight 4to vols. by M. Alfred Grandidier, entitled, *Histoire Naturelle, Physique, et Politique de Madagascar*. Of this *magnum opus* four volumes are already issued.

Of books treating of the country generally, the following are the most noteworthy:—Hamond, *Madagascar, the Richest and most Frritfull Island in the World*, London, 1643; Boothby, *A Breife Discovery or Description of the most famous Island of Madagascar or St Laurence*, London. 1664; Flacourt, *Histoire de la grande Isle de Madagascar*, Paris, 1658; *Madagascar, or Robert Drury's Journal during Fifteen Years' Captivity on that Island*, London, 1729; *Voyages et Mémoires de Maurice Auguste comte de Benyowski*, Paris, 1791; Rochon, *Voyages à Madagascar*, &c., Paris, an x.; Froberville, *Histoire de Madagascar*, Isle de France, 1809; Copland, *A History of the Island of Madagascar*, London, 1822; Ellis, *History of Madagascar*, London, 1838; Leguevel de Lacombe, *Voyage à Madagascar et aux îles Comores*, Paris, 1840; Guillain, *Documents sur . . . la partie occidentale de Madagascar*, Paris, 1845; Macé Descartes, *Histoire et Géographie de Madagascar*, Paris, 1846; Ellis, *Three Visits to Madagascar*, London, 1859; Oliver, *Madagascar and the Malagasy*, London, 1863; Sibree, *Madagascar and its People*, London. 1870; articles in *Revue des Deux Mondes*, 1872; *Tantara ny Andriana eto Madagascar: Histoire des Rois d'Imérina d'après les manuscrits Malgaches*, Antanànarìvo, 1875; Mullens, *Twelve Months in Madagascar*, London, 1875; Blanchard, *L'Île de Madagascar*, Paris, 1875; Dahle, *Madagaskar og dets Beboere*, Christiania, 1876–78; *The Antanànarìvo Annual*, Nos. i.–v., 1875–81; and Sibree, *The Great African Island*, London, 1880, and "The Arts and Commerce of Madagascar," *Jour. Soc. Arts*, June 4, 1880.

Philology.—Houtman, *Spraak ende woord boek in de Maleische ende Madagaskarsche talen*, Amsterdam, 1603; *Voyage de C. van Heemskerk; vocabulaire de la langue parlée dans l'île Saint-Laurent*, Amsterdam, 1603; Megiser, *Beschreibung der Mechtigen und Weitberhümbten Insul Madagascar*, with dictionary and dialogues, Altenburg, 1609; Arthus, *Colloquia Latino-Maleyica et Madagascarica*, Frankfort, 1613; Challand, *Vocabulaire français-malgache et malgache-français*, Île de France, 1773; Froberville, *Dictionnaire français-madecasse*, 3 vols., Île de France, 1809; Dumont D'Urville, *Voyage de la Corvette l'Astrolabe*, volume on "Philologie," Paris, 1833; Freeman and Johns, *Dictionary of the Malagasy Language* (*Eng.-Mal. and Mal.-Eng.*), Antanànarìvo, 1835; Dalmond, *Vocabulaire et Grammaire pour les langues Malgaches, Sàkalàva et Bétsimisàra*, Bourbon, 1842; R. C. Missionaries' *Dictionnaire Français-Malgache*, Réunion, 1853, and *Dictionnaire Malgache-Français*, Réunion, 1855; Van der Tuuk, "Outlines of a Grammar of the Malagasy Language," *Jour. Roy. Asiat. Soc.*, 1860; Ailloud, *Grammaire Malgache-Hòva*, Antanànarìvo, 1872; W. E. Cousins, *Concise Introduction to the Study of the Malagasy Language as spoken in Imérina*, Antan., 1873; Sewell, *Diksionary Eng. sy Mal.*, Antan., 1875; Marre de Marin, *Grammaire Malgache*, Paris, 1876; Id., *Essai sur le Malgache, ou Étude comparée des langues Javanaise, Malgache, et Malayse*, Paris, 1876; Id., *Le Jardin des Racines Océaniennes*, Paris, 1876; Dahle, *Specimens of Malagasy Folk-lore*, Antan., 1877; and W. E. Cousins, "The Malagasy Language," in *Trans Phil. Soc.*, 1878. Besides these there are several valuable papers by Dahle in the yearly numbers of *The Antanànarìvo Annual* (*ante*), and a number of short vocabularies of coast and other dialects of Malagasy in the notes of various exploratory journeys published at Antanànarivo, noticed below.

Scientific: General and Exploratory.—Vinson, *Voyage à Madagascar*, Paris, 1865; Coignet, "Excursion sur la Côte Nord-est de l'Île de Madagascar," *Bull. Soc. Géog.*, Sept. et Oct., 1867; Grandidier, "Madagascar," *Bull. Soc. Géog.*, August 1871; Id., "Excursion chez les Antanosses émigrés," *Bull. Soc. Géog.*, Feb. 1872; Id., "Madagascar," *Bull. Soc. Géog.*, April 1872; Mullens, "Central Provinces of Madagascar," *Proc. Roy. Geog. Soc.*, January 1875; Sibree, *South-east Madagascar*, Antan., 1876; Houlder, *North-east Madagascar*, Antan., 1877; Richardson, *Lights and Shadows* [South-west Madagascar], Antan., 1877; chap. xi., vol. i., of Wallace's *Geographical Distribution of Animals*, London, 1876; Sibree, "Observations on the Physical Geography and Geology of Madagascar," *Nature*, August 14, 1879; Id., "History of our Geographical Knowledge of Madagascar," *Proc. Roy. Geog. Soc.*, October 1879; chap. xix. in Wallace's *Island Life*, London, 1880; Cowan, *The Bàra Land*, Antan., 1881; Id., "Explorations in South Madagascar," *Proc. Roy. Geog. Soc.*, Sept. 1882. The best general map of Madagascar is that published by Rev. Dr Mullens in 1879, which is to a large scale (12¼ miles to the inch), and includes almost every journey made up to that date, but is somewhat deficient as regards the delineation of the physical geography.

Zoology.—Klug, "Insekten von Madagaskar," in *Kön. Ak. der Wissenschaften*, Berlin, 1832; Boisduval, *Faune Entomologique de Madagascar*, &c., Paris, 1833; Owen, *Monograph on the Aye-aye*, London, 1863; Vinson, *Araneides des Iles Réunion, Madagascar*, &c., Paris, 1863; Bates, "Natural History of Madagascar," *Proc. Zool. Soc.*, 1863; Sclater, "Mammals of Madagascar," *Quart. Jour. Sci.*, April 1864; Pollen and Van Dam, *Recherches sur la Faune de Madagascar et ses Dépendances*, 5 vols., Leyden, 1867 *sq.*; Hartlaub, *Die Vögel Madagascars und der benachbarten Inselgruppen*, Halle, 1877; "Reliquiæ Rutenbergianæ—Zoologie," in the Bremen *Naturwissenschaftliche Verein*, April 1881; also very numerous articles on Madagascar animals, birds, &c., in *Proc. Zool. Soc.*, 1863–81, and in *Ann. and Mag. of Nat. Hist.*, 1863–81.

Botany.—Du Petit Thouars, *Histoire des Végétaux recueillés sur les isles de . . . Madagascar*, Paris, 1804; "Floræ Madagascariensis fragmenta," in *Annales des Sciences Naturelles*, 4 ser., vols. vi., viii., ix.; Davidson, "Account, Historical and Physiological, of the Madagascar Poison Ordeal

(*Tanghinia Veneniflua*)," *Jour. of Anat. and Phys.*, vol. viii.; articles on ferns and flowering plants, in *Linn. Soc. Jour.—Bot.*, for 1864, 1876, 1877, 1880; "Reliquiæ Rutenbergianæ," in the Bremen *Naturwissenschaftliche Verein*, November 1880; Baker on "The Plants of Madagascar," *Nature*, December 9, 1880, and on "Botany of Madagascar," *Proc. of Brit. Assoc.*, 1881.

Anthropology.—Oliver, "The Hovas and other Characteristic Tribes of Madagascar," *Jour. Anthrop. Inst.*, 1868; Wake, "The Race Elements of the Madecasses," *Ibid.*, 1869; Mullens, "On the Origin and Progress of the People of Madagascar," *Ibid.*, 1875; Wake, "Notes on the Origin of the Malagasy," *Ibid.*, 1881; Sibree, "Malagasy Folk-Lore and Popular Superstitions," *Folk-Lore Soc. Record*, 1880; Id., *The Oratory, Songs, Legends, and Folk-Tales of the Malagasy*, 1882.

Religious History.—Freeman and Johns, *Narrative of the Persecutions of the Christians in Madagascar*, London, 1840; Prout, *Madagascar, its Missions and its Martyrs*, London, 1863; Ellis, *Madagascar Revisited*, London, 1867; Id., *The Martyr Church*, London, 1869; "Religion in Madagascar," *Ch. Quart. Rev.*, July 1878; and *Ten Years' Review of Mission Work in Connexion with the London Missionary Society*, 1870-80, Antan., 1880. (J. S., jr.)

MADDALONI, a city of Italy, in the province of Caserta (Terra di Lavoro), about 3½ miles south-east of Caserta, with a station both on the railway from Caserta to Benevento and on that from Caserta to Avellino. It is prettily situated at the base of one of the Tiffata hills, the towers of its mediæval castle and the church of San Michele crowning the heights above. The fine old palace of the Caraffas, once dukes of Maddaloni, the old college now named after Giordano Bruno, and the institute for the sons of soldiers (dating from 1859, and accommodating 500 pupils) are the chief points of interest. In 1871 the population was 18,767. About 2½ miles to the east, at Valle di Maddaloni, the Caroline aqueduct (so called after Charles IV. of Naples), conveying the water of the Tiburno to Caserta (a distance of 19 miles), is carried across the valley between Monte Longano and Monte Gargano by a threefold series of noble arches rising to a height of 178 feet. The work was designed by Lodovico Vanvitelli, and constructed between 1753 and 1759.

Maddaloni (in mediæval documents *Matalonum*, *Madalonum*, and *Magdalonum*) lies on the Appian Way, and is doubtfully identified with Sessucla. Its castle and walls are probably of Lombard origin. The first count of Maddaloni was invested with the fief in 1465, the first duke in 1558. In 1860 General Bixio's volunteers beat the royal Neapolitan forces at Maddaloni. See A. de Reumont, *The Carafas of Maddaloni*, Bohn's series, 1854.

MADDEN, SIR FREDERIC (1801-1873), one of the first palæographers and antiquaries of his time, and for nearly forty years assistant keeper and keeper of manuscripts at the British Museum, was born at Portsmouth on February 16, 1801, the son of an officer of Irish extraction. From his earliest years he displayed a strong bent to linguistic and antiquarian studies. In 1825 he was engaged in collating the text of Cædmon for the university of Oxford, and assisting Dr Bliss in editing Blore's *Monumental Remains*; in the following year he joined Mr Roscoe in preparing a catalogue of the earl of Leicester's MSS. at Holkham, which was completed in eight volumes folio, but remains unpublished. In the same year he was engaged by the British Museum to assist in the preparation of the classed catalogue of printed books at that time contemplated, and in 1828 he became assistant keeper of manuscripts. In 1833 he was knighted, and in 1837 succeeded the Rev. Josiah Forshall as keeper of manuscripts, which office he continued to hold until his retirement in 1866. Notwithstanding his indefatigable attention to his official duties, he found time for a great amount of exceedingly valuable literary work. Between 1828 and 1838 he edited for the Roxburghe Club the old English romances of *Havelok the Dane* (discovered by himself among the Laudian MSS. in the Bodleian) and *William and the Werwolf*, and the old English versions of the *Gesta Romanorum*. In 1839 he edited the ancient metrical romances of *Syr Gawayne* for the Bannatyne Club, and in 1847 Layamon's *Brut*, with a prose translation, for the Society of Antiquaries. In 1850 the magnificent edition of Wickliffe's translations of the Scriptures from the original MSS., upon which he and his coadjutor, Mr Forshall, had been engaged for twenty years, was published by the university of Oxford. In 1866-69 he edited the *Historia Minor* of Matthew Paris for the Rolls series. In 1833 he prepared the literary part of Mr Shaw's work on *Illuminated Ornaments*; and in 1850 he edited the English translation of Silvestre's *Universal Palæography*. He had projected a history of chess in the Middle Ages; ill-health, however, and other causes, prevented the completion of the work. He died on March 8, 1873, bequeathing his journals and other private papers to the Bodleian Library, where they are to remain unopened until 1920.

Sir Frederic Madden's attainments were great, and his services to literature highly distinguished. He was perhaps the first palæographer of his day, and as keeper of manuscripts was most zealous and industrious, imposing a large amount of manual as well as intellectual labour upon himself, and continually, although too often unsuccessfully, exerting himself to enrich the collections committed to his care. He was an acute as well as a laborious antiquary, but rather qualified for critical than for original research, and his unacquaintance with German prevented his ranking high as a philologer, although he paid much attention to the early dialectical forms of French and English. His judgment was shown in the substantial value of the works edited by him. Wickliffe's Bible is the first English version; Layamon's *Brut*, a semi-Saxon paraphrase of the Norman *Brut* of Robert Wace, unites two ages of English poetry, is an inestimable monument of the language at the period of its composition, and possesses no small poetical merit; while *Havelok* is hardly less important in a philological and a metrical point of view. The first volume of his edition of Matthew Paris contains a valuable critical introduction, and the third a biography of the historian, with an estimate of his place in literature. Sir Frederic's minor contributions to antiquarian research were exceedingly numerous: the best known, perhaps, is his dissertation on the orthography of Shakespeare's name, which, mainly on the strength of the Florio autograph, he contends should be "Shakspere." This mode of spelling has been adopted by the New Shakspere Society. It is not generally known that Sir Frederic was the first to discover the "Perkins" forgeries in the duke of Devonshire folio *Shakespeare*, although private considerations induced him to leave the further elucidation of the matter to others. He also promptly detected the fabrications of the Greek Simonides, which had imposed upon some of the first scholars in Germany.

MADDER, or DYER'S MADDER, is the root of *Rubia tinctorum*, L., and perhaps of *R. peregrina*, L., as well, both being European; but *R. cordifolia*, L., and perhaps *Mungista*, Roxb., a native of the mountains of Nepal, Bengal, Japan, &c., supply the Indian madder or *manjit* (see Pickering, *Chron. Hist. of Pl.*, 421; Drury, *Useful Plants of India*, 541). Rubia is a genus of about thirty species of the tribe *Galieæ* of the order *Rubiaceæ*, and much resembles the familiar *Galiums*, *e.g.*, the lady's bedstraw and cleaver of English hedges having similarly whorled leaves, but the parts of the flowers are in fives and not fours, while the fruit is somewhat fleshy. The sole British species is *Rubia peregrina*, L. The use of madder appears to have been known from the earliest times, as cloth dyed with it has been found on the Egyptian mummies. It was the ἐρευθέδανον used for dyeing the cloaks of the Libyan women in the days of Herodotus (Herod., iv. 189). It is the ἐρυθρόδανον of Dioscorides, who speaks of its cultivation in Caria (iii. 160), and of Hippocrates (*De Morb. Mul.*, i.), and the *Rubia* of Pliny (xix. 17), (see Pickering, p. 275). *Rubia tinctorum*, L., a native of western Europe, &c., has been extensively cultivated in South Europe, France, where it is called *garance*, and Holland, and to a small extent in the United States. Large quantities have been imported into England from Smyrna, Trieste, Leghorn, &c. The cultivation, however, is decreasing since alizarin, the red colouring principle of madder, has been made artificially (see ALIZARIN). Madder was employed medicinally by the ancients and in the Middle Ages. Gerard, in 1597, speaks of it as having been cultivated in many gardens in his day, and describes its supposed many virtues (*Herball*, p. 960); but the influence of madder over the system is now believed to be exceedingly slight. Its most remarkable physiological effect is that of colouring red the bones of animals fed upon it, as also the claws and beaks of birds. This appears to be due to the chemical affinity of phosphate of lime for the colouring matter (Pereira, *Mat. Med.*, vol. ii. pt. ii. p. 52). *Rubia chilensis*, Mol., has been used for dyeing red from time immemorial (Pickering, p. 661). The chay-root, which furnishes a red dye in Coromandel and other parts of India, is obtained from *Hedyotis umbellata*, Lam., of the same family as madder (Drury, p. 366).

e III. MADEIRA. The Madeiras, a group of islands in the North Atlantic Ocean belonging to Portugal, consist of two inhabited islands named Madeira and Porto Santo, and three uninhabited rocks named collectively the Desertas. Funchal, the capital of Madeira, is on the south coast of the principal island, in 32° 37′ 45″ N. lat., 16° 55′ 20″ W. long. It is about 360 miles from the coast of Africa, 535 miles from Lisbon, 1215 from Plymouth, 240 from Teneriffe, and 480 from Santa Maria, the nearest of the Azores. Funchal is connected by the Brazilian submarine telegraph, which belongs to a British company, with Lisbon on the one hand, and on the other with Brazil.

Madeira, the largest island of the group, has a length of 30 geographical miles, an extreme breadth of 13 miles, and a coast-line of 80 or 90 miles. Its longer axis lies east and west, in which direction it is traversed by a mountain chain, the backbone of the island, having a mean altitude of 4000 feet, up to which many deep ravines penetrate from both coasts, rendering travelling by land from place to place a very tedious and fatiguing labour. Pico Ruivo, the highest summit, stands in the centre of the island, and has a height of 6100 feet, but some of the adjacent summits are very little lower. The depth and narrowness of the ravines, the loftiness of the rugged peaks that tower above them, the bold precipices of the coast, and the proximity of the sea afford many scenes of picturesque beauty or striking grandeur which are continually changing in character as the traveller advances on his way. The greater part of the interior is uninhabited, for the towns, villages, and scattered huts lie either at the mouths of ravines or upon the lower slopes that extend from the mountains to the coast. The ridges between the ravines usually terminate in lofty headlands, one of which has the height of 1920 feet, and much of the coast is bound by precipices of dark basalt. The north coast, having been more exposed to the erosion of the sea, is on the whole more precipitous than the south coast, and presents everywhere a wilder aspect. On the south there is left very little of the indigenous forest which once clothed the whole island and gave it the name it bears (Madeira, from *materia*, wood), but on the north some of the valleys still contain native trees of fine growth. A long, narrow, and comparatively low rocky promontory forms the eastern extremity of the island, and here is to be seen a tract of calcareous sand, known as the Fossil Bed, containing land shells and numerous bodies resembling the roots of trees, probably produced by infiltration. Upon an islet off this promontory stands the only lighthouse of the group. It has a flashing light visible at the distance of 25 miles in clear weather.

History.—It has been conjectured, but on insufficient evidence, that the Phœnicians discovered Madeira at a very early period. Pliny mentions certain Purple or Mauretanian Islands, the position of which with reference to the Fortunate Islands or Canaries might seem to indicate the Madeiras. There is a romantic story, of doubtful truth, to the effect that two lovers, Robert Machim and Anna d'Arfet, fleeing from England to France in 1346, were driven out of their course by a violent storm, and cast on the coast of Madeira at the place subsequently named Machico, in memory of one of them. On the evidence of a portulano dated 1351, preserved at Florence, it would appear that Madeira had been discovered long previous to that date by Portuguese vessels under Genoese captains. In 1419 two of the captains of Prince Henry of Portugal were driven by a storm to the island called by them Porto Santo, or Holy Port, in gratitude for their rescue from shipwreck. The next year an expedition was sent out to colonize the island, and, Madeira being descried, they made for it, and took possession on behalf of the Portuguese crown. The islands were then uninhabited. For the sixty years intervening between 1580 and 1640, Madeira, with Portugal itself, was under Spanish rule. In 1801 British troops occupied the island for a few months, commanded by General Beresford, and it was again under the British flag from 1807 to 1814. Madeira is now a province and an integral part of the Portuguese kingdom, entitled to send deputies to the Cortes assembling at Lisbon.

Inhabitants.—The inhabitants are of Portuguese descent, with probably some intermixture of Moorish and Negro blood amongst the lower classes. The dress of the peasantry, without being picturesque, is peculiar. Both men and women in the outlying country districts wear the *carapuça*, a small cap made of blue cloth, in shape something like a funnel, with the pipe standing upwards. The men have trousers of linen, drawn tight, and terminating at the knees; a coarse shirt enveloping the upper part of their person, covered by a short jacket, completes their attire, with the exception of a pair of rough yellow boots. The women's outer garments consist of a gaudily coloured gown, made from island material, with a small cape of coarse scarlet or blue woollen cloth. At the end of 1881 the inhabitants of Madeira numbered 131,906 persons, the females exceeding the males by 7060. The population increases, notwithstanding the emigration to Demerara and the Hawaiian Islands that occasionally takes place. There is strong reason for thinking that the islands are too densely peopled, considering the small proportion which cultivable ground bears to the whole, and the general want of capital.

Government.—The administration of affairs is in the hands of a civil governor appointed by the crown, under whom is a military officer in command of the troops, which consist of a battalion of infantry, a detachment of artillery, and some militia. The law of Portugal is administered by four chief judges, each of whom has a separate division (*comarca*) of the island in his jurisdiction, within which he tries both civil and criminal cases with the assistance of a jury. Magistrates elected by the people decide minor cases. For municipal purposes the island is divided into nine districts, called *concelhos* (Porto Santo forming a tenth), each of which has its popularly elected municipal chamber, whose duty it is to repair the roads, light and cleanse the towns and villages, &c. The chief police magistrate of each district is the *administrador*, who is appointed by the central Government. A bishop is at the head of the clergy, his cathedral being at Funchal. There are forty-eight parishes, each with its church and resident priest. Roman Catholicism is the established form of religion, but others are now tolerated.

Education.—By law all children of a certain age should be sent to school, but this regulation is not strictly enforced, and only a small fraction of the total number actually receive instruction. The chief educational establishment is the Lyceo at Funchal, where there are seven professors paid by Government. In 1881 the pupils at this establishment were two hundred and fifty in number. There is a seminary for young priests, and a number of public primary schools are scattered over the island.

Agriculture.—Until recently a considerable portion of the land was strictly entailed in the families of the landlords (*morgados*), but entails have been abolished by the legislature, and the land is now absolutely free. Owing to the irremediable difficulties of the surface, the roads are bad, except in the neighbourhood of the capital. A deficient supply of water is another great obstacle to the proper cultivation of the land, and the rocky nature or steep inclination of the upper parts of the islands is an effectual bar to all tillage. An incredible amount of labour has been expended upon the soil, partly in the erection of walls intended to prevent its being washed away by the rains, and to build up the plots of ground in the form of terraces, so as to lessen their slope. Water-courses, too, have been constructed for purposes of irrigation, without which at regular intervals the island would not produce a hundredth part of its present yield. These water-courses originate high up in the ravines, are built of masonry or driven through the rock, and wind about for miles until they reach the cultivated land. Some of them are brought by tunnels from the north side of the island through the central crest of hill. The water thus conveyed is carefully dealt out according to the rights of each occupier, who takes his turn at the running stream for so many hours in the day or night at a time notified to him beforehand. In this climate flowing water has a saleable value as well as land, for the latter is useless without a supply of the former. The agricultural implements employed are of the rudest kind, and the system of cultivation is extremely primitive. Very few of the occupiers are the owners of the land they cultivate; but they are almost invariably the owners of the walls, cottages, and trees standing thereon, the bare land alone belonging to the landlord. The tenant can sell his share of the property without the consent of the landlord, and if he does not so dispose of it that share passes to his heirs. In this way the tenant practically enjoys fixity of tenure, for the landlord is seldom in a position to pay the price at which the tenant's share is valued. Money rents are rare, the métayer system regulating almost universally the relations between landlord and tenant; that is, the tenant pays to the owner a certain portion of the produce, usually one half or one third. The holdings are usually very small, rarely larger than one man can cultivate with a little occasional assistance. Meadows and pastures are seldom to be met with, the cattle being stall-fed when not feeding on the mountains. Horses are never employed for draught, all labour of that kind being done by oxen, of which there is an ample supply.

The two staple productions of the soil are wine and sugar. The vine was introduced from Cyprus or Crete soon after the discovery of the island by the Portuguese, but it was not actively cultivated until the early part of the 16th century. The vines, after having been totally destroyed by the oidium disease, which made its first appearance in the island in 1852, were replanted, and in a few years wine was again made. The disease is now kept in check by the application of sulphur, which has the effect of increasing the quantity of fruit, whilst it shortens the life of the plant. The phylloxera has also made its way to the island, and every vineyard in Madeira is more or less affected by it. The wine usually termed Madeira, and known in the trade as "London particular," is made from a mixture of black and white grapes, which are also made separately into wines called Tinta and Verdelho, after the names of the grapes. Other high-class wines, known as Bual, Sercial, and Malmsey, are made from varieties of grapes bearing the same names. The exported Madeira is a strong-bodied wine of fine bouquet and excellent quality, but of late years it has gone out of fashion in England, the lighter wines of France and Germany having to a certain extent supplanted it. Taking the four years 1878–1881, the average quantity annually exported was 3045 pipes, each of 92 imperial gallons. It is not usual for the merchant to possess vineyards of his own. The vines are cultivated by the peasants in their small patches of land, and the general rule is for the merchant or wine manufacturer to buy the must from them, and to have it conveyed as it comes from the press direct to his store, where the process of fermentation and the subsequent treatment are carried on from first to last under his own eye.

The sugar cane is said to have been brought from Sicily about 1452, and in course of time its produce became the sole staple of the island. The cultivation languished, however, as the more abundant produce of tropical countries came into the European market, and sugar had long ceased to be made when the destruction of the vines compelled the peasants to turn their attention to other things. Its cultivation was resumed, and sugar machinery imported. In 1881 about 6515 cwts. of sugar, valued at £14,452, were exported. A considerable quantity of spirit is made by the distillation of the juice, or of the molasses left after extracting the sugar, and this is consumed on the island,—not an unmixed benefit to the people, for intemperate habits have greatly increased since they have been subjected to the temptation of cheap spirits. The cane does not flourish here as luxuriantly as within the tropics; still in localities below 1000 feet, where there is a good supply of water, it pays the cultivator well.

The grain produced on the island (principally wheat, barley, and Indian corn) is not sufficient for the consumption of the people. The common potato, sweet potato, and gourds of various kinds are extensively grown, as well as the *Colocasia esculenta*, the *kalo* of the Pacific islanders, the root of which yields an insipid food. Most of the common table vegetables of Europe—cabbages, carrots, onions, beans, pease, &c.—are plentiful. Besides apples, pears, and peaches, all of poor quality, oranges, lemons, guavas, mangos, loquats, custard-apples, figs, bananas, and pine-apples are produced, the last two forming articles of export to the London market. The date palm is occasionally seen, but its fruit is scarcely edible. On the hills large quantities of the Spanish chestnut afford an item in the food of the common people. A little tobacco is grown, and is made up into cigars of inferior quality.

Trade and Commerce.—Excepting sugar and tobacco, the manufactures are insignificant. Coarse linen and woollen articles and boots and shoes are made for island use. A good deal of needlework embroidery is made by the women in and about Funchal for exportation. Baskets, chairs, &c., of wicker work are also exported. According to official returns the total value of exports in 1881 was £134,000, whilst the imports from foreign countries amounted to £175,000 (including £128,500 from the United Kingdom), and the imports from Portugal and the Azores to £112,800. The principal imports were textile fabrics, hardware, grain, salt fish, salt, tea and coffee, tobacco, cask staves, timber, and petroleum (the last three articles coming from America). The duties levied at the custom-house amounted in the same year to about £41,000. In the course of the year 710 merchant vessels entered the port, but more than half of these were English steamers calling on their passage to and from the west coast of Africa, the Cape of Good Hope, or Brazil. The number of Portuguese vessels was only 113.

There is a local bank at Funchal, and also a branch of the Bank of Portugal. The English merchants act as bankers for visitors, and bills or cheques can be negotiated through them. Accounts are made out in reis, an imaginary coin, 4500 of which are equal to the pound sterling, and 1000 form the *mil-rei* or dollar, equal to 4s. 5⅓d. The coins in circulation are of British gold and Portuguese silver, the latter in pieces of 50, 100, 200, and 500 reis, the coinage being decimal. The French decimal system has been established here as in Portugal. Madeira, as a province of Portugal, has the benefit of the regulations of the International Postal Union. Consuls from Great Britain and other European states, as well as from the United States and Brazil, reside at Funchal. Lines of steamers from Liverpool to the British colonies on the west coast of Africa, and from London and Plymouth to the Cape of Good Hope, touch at Madeira, both on their outward and homeward voyages. There is steam communication with Lisbon, and also with Brazil, the Cape Verds, the Canaries, and the Azores (St Michael's), as well as with Antwerp. A large coal depôt for supplying the steamers has been established at Funchal by a firm of British merchants.

Funchal, the capital of the archipelago, lies on the south coast of Madeira, and has a population of about 18,000 persons, the immediate neighbourhood being inhabited by nearly as many more. It is seen to great advantage from the bay, lying on its curving shore, and backed by an amphitheatre of lofty mountains, some of them 4000 feet in height. Numerous country houses (*quintas*) with terraced gardens, and surrounded by vineyards and patches of sugar cane, adorn the slopes and give an air of cheerfulness to the landscape. A small fort on an insulated rock close to the shore commands the bay with its cannon, and there is a much larger fortress on an eminence behind the city. There are no facilities for landing either passengers or goods, nor is there any dock for vessels, which are obliged to remain in the open roadstead, where, however, the anchorage is good. Vessels are protected from all winds except that from the south, which, when blowing with violence, occasionally drives those on shore that do not slip their cables in good time, and take to the open sea. The principal edifices in the city are the cathedral and the churches, none of which deserve much notice, the governor's residence, a semi-castellated building, and the substantial custom-house. The streets are for the most part narrow, but fairly clean, paved with small stones, without side walks, and lighted at night by petroleum lamps. There are two public walks planted with trees, and a garden of small extent, but rendered gay with flowering plants which would need protection in England. There are also fountains of good water, a large hospital, a poor-house, and an unsightly ill-managed jail. The late empress of Brazil built a spacious and handsome hospital close to the town for the reception of twenty-four consumptive patients of Portuguese or Brazilian birth. The entrances of some of the larger houses are through great gates into a paved vestibule, from which a double flight of stairs ascends to the principal rooms. The shops are poor and without display. The windows on the ground floor of the dwelling houses are filled with stout iron bars, which give a prison-like air to the streets. Three streams come down from the hills and run across the town at the bottom of deep channels, which in summer are dry, because the water is diverted higher up for irrigation purposes. Convenient market places have been constructed for the sale of meat, vegetables, and fish. Vegetables and fruit are abundant, but not of the first quality. Fish is plentiful and cheap when fishing is possible, and fresh fish forms with salted cod and herrings an important item in the food of the islanders. Butcher meat is fairly good, with the exception of the mutton, which is very inferior.

The affairs of the city are managed by a municipal chamber of seven persons with a president. Their revenue is derived from imposts on grain and salt imported, and from duties on fresh meat and fish sold in the open market, on wine exported, on houses, and on persons carrying on trade or business. It is expended principally on the lighting and repairing of the streets, and the maintenance of markets and public gardens.

Wheel carriages are not in use; and all heavy articles are transported either on the backs of mules or upon rude wooden sledges drawn by bullocks. When horses are not employed, locomotion is effected either by means of hammocks, or by bullock cars. The hammock is a piece of stout canvas gathered up and secured at each end to a long pole carried by a couple of bearers. In place of cabs, curtained cars on sledges, made to hold four persons, and drawn by a pair of bullocks, are employed. They are convenient enough, but the rate of progress is very slow. The common people carry heavy burdens on the head and shoulders. Such aids as wheelbarrows and trucks are entirely rejected.

A few daily and weekly newspapers are published at Funchal, but they are small sheets, and their circulation is very limited. In a room of the building occupied by the municipal chamber there is a collection of books, numbering about 2800 volumes, accessible to the public. The Portuguese have a club, which has a large house containing a ball room, card rooms, and a billiard room, but no library.

The wine trade attracted several British merchants in the last century to take up their residence at Funchal, where, notwithstanding the decrease of that trade, there was in 1881 a resident British population of 208 persons. A church has been built where a resident chaplain conducts the services of the English Established Church, and the Presbyterians of the Free Church of Scotland have also erected a place of worship. The British community have formed a cemetery, which is kept in admirable order. The English Club, to which strangers can subscribe, has a library of 5000 volumes and a billiard table.

Climate and Meteorology.—The following results have been derived from observations made for a series of eight years at the Government observatory, Funchal, which has a height of 80 feet above the sea. The mean annual barometrical pressure was 30·14 inches. The mean annual temperature was 65°·84 Fahr., the highest point during the eight years having been 90°·3 Fahr. and the lowest 46°·22 Fahr. The two hottest months are August and September, when the mean temperature was 72°·58 Fahr. The three coldest months are January, February, and March, their mean temperature being 60°·6 Fahr. The mean temperature of the six months November to April was 61°·8 Fahr. The mean temperature of winter (December to February) was 61°; of spring (March to May) 62°·64; of summer (June to August) 70°·8; of autumn (September to November) 68°·9. The mean number of days in the year on which rain fell was 80½. The distribution of rain through the months from October to May varies a good deal, but the wettest months are usually November, December, January, and March. Taking a series of twelve years' observations, the mean annual rainfall was 30½ inches, the extremes being 16 and 49·15 inches. The mean daily range of the thermometer from 8 A.M. to 6 P.M. during the six months November to April is about 6°·1 Fahr., but taking the twenty-four hours the mean daily range is about 10°.

The remarkable mildness both in summer and winter of the climate of Madeira, though it lies only 10° north of the Tropic of Cancer, is owing to its being surrounded by a great ocean, from which the atmosphere obtains a large supply of watery vapour. The mean humidity of the air is about 75 (saturation = 100). The prevalent winds are those that blow from the north or from a few points east or west of north, but these winds are much mitigated on the south coast by the central range of mountains. The west wind usually brings rain. That from the east is a dry wind. A hot and dry wind, the *leste* of the natives, occasionally blows from the east-south-east, the direction of the Great Sahara, and causes the hill region to be hotter than below, but even on the coast the thermometer under its influence sometimes indicates 93°. As the thermometer has never been known to fall as low as 46° at Funchal, frost and snow are there wholly unknown, but snow falls on the mountains once or twice during the winter, very seldom, however, below the altitude of 2000 feet. Thunderstorms are rare, and scarcely ever violent.

Madeira has long had a high reputation as a sanatory resort for persons suffering from diseases of the chest. "When we take into consideration," said Sir James Clark in his work on *Climate*, "the mildness of the winter and the coolness of the summer, together with the remarkable equality of the temperature during the day and night, as well as throughout the year, we may safely conclude that the climate of Madeira is the finest in the northern hemisphere." Notwithstanding the ever-increasing competition of other winter resorts, a considerable number of invalids, both English and

German, continue to spend the winter at Funchal, where there are numerous well-conducted hotels and boarding-houses, as well as furnished houses, with gardens, for hire in the neighbourhood, and where English and German physicians practise their profession. The island possesses one great advantage over most other places frequented by invalids in affording cool and comfortable summer quarters on the hills, so that they have no need to make a long journey for the purpose of escaping from the heat.

Zoology.—No species of land mammal is indigenous to the Madeiras. Some of the early voyagers indeed speak of wild goats and swine, but these animals must have escaped from confinement. The rabbit, and those pests the black rat, brown rat, and mouse, have been introduced. The first comers encountered seals, and this amphibious mammal (*Monachus albiventer*) still lingers at the Desertas, but its early extinction is threatened, from the same cause that has brought about its extinction at the Canaries, the persistent attacks of man. Amongst the thirty species of birds which breed in these islands are the kestrel, buzzard, and barn owl, the blackbird, redbreast, wagtail, goldfinch, ring sparrow, linnet, two swifts, three pigeons, the quail, red-legged partridge, woodcock, tern, herring gull, two petrels, and three puffins. Only one species is endemic, and that is a wren (*Regulus madeirensis*), but five other species are known elsewhere only at the Canaries. These are the green canary (*Fringilla butyracea*, the parent of the domesticated yellow variety), a chaffinch (*Fringilla tintillon*), a swift (*Cypselus unicolor*), a wood pigeon (*Columba trocaz*), and a petrel (*Thalassidroma bulwerii*). There is also a local variety of the black cap, distinguishable from the common kind by the extension in the male of the cap to the shoulder. About seventy other species have been seen from time to time in Madeira, chiefly stragglers from the African coast, many of them coming with the *leste* wind.

The only land reptile is a small lizard (*Lacerta dugesii*), which is abundant and is very destructive to the grape crop. The loggerhead turtle (*Caouana caretta*, Gray) is frequently captured, and is cooked for the table, but the soup is much inferior to that made from the green turtle of the West Indies. The only batrachian is a frog (*Rana esculenta*) which has been introduced and has made its way from ravine to ravine.

About 250 species of marine fishes taken at Madeira have been scientifically determined, the largest families being *Scombridæ* with 35 species, the sharks with 24, the *Sparidæ* with 15, the rays with 14, the *Labridæ* with 13, the *Gadidæ* with 12, the eels with 12, the *Percidæ* with 11, and the *Carangidæ* with 10. Many kinds, such as the mackerel, horse mackerel, groper, mullet, braise, &c., are caught in abundance, and afford a cheap article of diet to the people. Several species of tunny are taken plentifully in spring and summer, one of them sometimes attaining the weight of 300 lb. The only freshwater fish is the common eel, which is found in one or two of the streams. (See lists and memoirs by R. T. Lowe and J. Y. Johnson, published by the Zoological Society of London.)

According to the latest writer on the land mollusca of the Madeiras (T. V. Wollaston, *Testacea Atlantica*, 1878), there have been found 158 species on the land, 6 inhabiting fresh water, and 7 littoral species, making a total of 171. A large majority of the land shells are considered to be peculiar, but naturalists do not agree as to the distinctness of the so-called species. Many of the species are variable in form or colour, and some have an extraordinary number of varieties. Of the land mollusca 91 species are assigned to the genus *Helix*, 31 to the genus *Pupa*, and 15 to the genus *Achatina* (or *Lovea*). About 43 species are found both living and fossil in superficial deposits of calcareous sand in Madeira or Porto Santo. These deposits were assigned by Lyell to the Newer Pliocene period. Some 12 or 13 species have not been hitherto discovered alive. As to the marine testaceous mollusca it may be stated that between 300 and 400 species have been collected, but they have been only partially examined, and a large number of forms await identification. Few of them are remarkable for size or colour, and a considerable number are very small. More than 100 species of *Polyzoa* (*Bryozoa*) have been collected, and amongst them are some highly interesting forms.

The only order of insects which has been thoroughly examined is that of the *Coleoptera*. By the persevering researches of the late T. V. Wollaston the astonishing number of 695 species of beetles has been brought to light at the Madeiras (*Insecta Maderensia*, *Cat. of Madeiran Col.*, &c.). The proportion of endemic kinds is very large, and it is remarkable that 200 of them are either wingless or their wings are so poorly developed that they cannot fly, whilst 23 of the endemic genera have all their species in this condition. This fact, Mr Darwin thinks, may be mainly due to the action of natural selection combined with disuse, since those beetles which were much on the wing would incur the risk of being blown out into the sea, whilst those with less-developed wings had the best chance of surviving. With regard to the *Lepidoptera*, 11 or 12 species of butterflies have been seen, all of which belong to European genera. Some of the species are interesting as being geographical varieties of well-known types. Upwards of 100 moths have been collected, the majority of them being of a European stamp, but probably a fourth of the total number are peculiar to the Madeiran group. Thirty-seven species of *Neuroptera* have been observed in Madeira, 12 of them being so far as is known peculiar.

The bristle-footed worms of the coast have been studied by Professor P. Langerhans, who has met with about 200 species, of which a large number were new to science. There are no modern coral reefs at these islands, but several species of stony and flexible corals have been collected, though none are of commercial value. There is, however, a white stony coral allied to the red coral of the Mediterranean which would be valuable as an article of trade if it could be obtained in sufficient quantity. Specimens of a rare and handsome red *Paragorgia* are to be seen in the British Museum and Liverpool Museum.

Botany.—The vegetation of these islands is strongly impressed with a South-European character. Many of the plants in the lower region have undoubtedly been introduced and naturalized since the Portuguese colonization. A large number of the remainder are found at the Canaries and the Azores, or in one of these groups, but nowhere else. Lastly, there are about a hundred plants which are peculiarly Madeiran, either as distinct species or as strongly marked varieties. The late Mr Lowe undertook a description of the vegetation in his *Manual Flora of Madeira*, but unfortunately this valuable work has been left unfinished. The flowering plants found truly wild belong to about 363 genera and 717 species,—the monocotyledons numbering 70 genera and 128 species, the dicotyledons 293 genera and 589 species. The three largest orders are the *Compositæ*, *Leguminosæ*, and *Gramineæ*. Forty-one species of ferns grow in Madeira, three of which are endemic species and six others belong to the peculiar flora of the North Atlantic islands. About 100 species of moss have been collected, and 47 species of *Hepaticæ*. A connexion between the flora of Madeira and that of the West Indies and tropical America has been inferred by the presence in the former of six ferns found nowhere in Europe or North Africa, but existing on the islands of the east coast of America or on the Isthmus of Panama. A further relationship to that continent is to be traced by the presence in Madeira of the beautiful ericaceous tree *Clethra arborea*, belonging to a genus which is otherwise wholly American, and of a *Persea*, a tree laurel, also an American genus. The dragon tree (*Dracæna Draco*) is almost extinct. Amongst the trees most worthy of note are four of the laurel order belonging to separate genera, an *Ardisia*, *Pittosporum*, *Sideroxylon*, *Notelæa*, *Rhamnus*, and *Myrica*,—a strange mixture of genera to be found on a small Atlantic island. Two heaths of arborescent growth and a whortleberry cover large tracts on the mountains. In some parts there is a belt of the Spanish chestnut about the height of 1500 feet. There is no indigenous pine tree as at the Canaries; but large tracts on the hills have been planted with *Pinus pinaster*, from which the fuel of the inhabitants is mainly derived. A European juniper (*J. Oxycedrus*), growing to the height of 40 or 50 feet, was formerly abundant, but has been almost exterminated, as its scented wood is prized by the cabinet-maker. Indeed the flora has been recklessly defaced by the unsparing hand of man. Several of the native trees and shrubs now grow only in situations which are nearly inaccessible, and some of the indigenous plants are of the greatest rarity. There are few remains of the noble forests that once clothed the island, and these are daily becoming less. On the other hand, some plants of foreign origin have spread in a remarkable manner. Amongst these is the common cactus or prickly pear (*Opuntia Tuna*), which in many spots on the coast is sufficiently abundant to give a character to the landscape. As to *Algæ*, the coast is too rocky and the sea too unquiet for a luxuriant marine vegetation, consequently the species are few and poor.

Geology.—The hypothesis that the Madeiras during or since the middle part of the Tertiary epoch formed part of a large tract of land connecting the Canaries in the south and the Azores in the west with south-western Europe and northern Africa has been completely discredited by the discovery of the great depth of the surrounding ocean. The origin of its existing fauna and flora, both of which must have been very different if such a connexion had ever been a fact, is now attributed to the chance arrival from Europe or Africa at distant intervals of the ancestors of the present species, the winds and waves, birds and insects, having been the means of transport. This immigration must have commenced at an early date if the aboriginal flora is partly traceable, as is asserted, to the Miocene flora of Europe, which has been found to contain genera now represented by species only living in the Atlantic islands and in America.

In one of the northern ravines of Madeira some masses of hypersthenite are exposed to view, and these are believed to belong to a diabase formation (better displayed in some of the Canary Islands than in Madeira) of much older date than the beds of basalt, tuff, &c., constituting the rest of the island. It is therefore supposed that there existed at an ancient but unknown epoch an island or the foundation of an island composed of diabase rocks, which, after being subjected to denudation, were overlaid by the materials thrown out by volcanoes of Miocene or later times.

All the islands of the group are of volcanic origin, and recent soundings show that they are the summits of very lofty mountains which have their bases in an abyssal ocean. The greater part of what is now visible in Madeira is of subaerial formation, consisting of an accumulation of basaltic and trachytic lavas, beds of tuff and other ejectamenta, the result of a long and complicated series of eruptions from innumerable vents. Besides this operation of building up by the emission of matter from craters and clefts there is evidence that a certain amount of upheaval in mass has taken place, for at a spot about 1200 feet above the sea in the northern valley of St Vicente, and again at about the same height on Pico Juliana in Porto Santo, there have been found fragments of limestone accompanied by tuffs containing marine shells and echinoderms of the Miocene Tertiary epoch. We have here proof that during or since that epoch portions at least of these islands have been bodily uplifted more than 1000 feet. The fossils are sufficiently well preserved to admit of their genera and in many instances even their species being made out.

That there were pauses of considerable duration whilst the island of Madeira was being increased in height is proved by several facts. The leaf bed and the accompanying carbonaceous matter, frequently termed lignite, although it displays no trace of structure, which lie under 1200 feet of lavas in the valley of St Jorge, afford proof that there had been sufficient time for the growth of a vegetation of high order, many of the leaf impressions having been identified as belonging to species of trees and shrubs which still exist on the island. It is evident, moreover, that great alterations and dislocations had taken place in the rocks of various localities before other lavas and tuffs had been thrown upon them.

There are no data for determining when volcanic action commenced in this locality, but looking at the enormous depth of the surrounding sea it is clear that a vast period of time must have elapsed to allow of a great mountain reaching the surface and then rising several thousand feet into the air. Again, considering the comparatively feeble agents for effecting the work of denudation (neither glaciers nor thick accumulations of alpine snow being found here), and then the enormous erosion that has actually taken place, the inference is inevitable that a very great lapse of time was required to excavate the deep and wide ravines that everywhere intersect the island. Nor is anything known as to the period of the cessation of volcanic action. At the present day there are no live craters, or smoking crevices, as at the Canaries and Cape Verds, nor any hot springs, as at the Azores. On the slopes which descend from the central ridge to the sea, especially in the neigbourhood of Funchal, there are many hills with conical shapes of more or less regularity, which seem to have been formed at a comparatively modern epoch. Volcanic cinders and slag are lying upon several of them, which look as if they had been thrown out of a furnace yesterday. Yet round the base of others there may be traced streams of lava flowing from a higher source, and showing that, subsequent to the construction of these lateral cones, modern as they look, molten matter issued from higher vents, which assumed, on cooling, the character of ordinary compact basalt.

If we examine the general configuration of Madeira, we shall see a mountain chain, about 30 miles in length, running east and west, and throwing off lateral ridges, that give it an extreme breadth of about 12 miles. Peaks rise about the middle to a height of more than 6000 feet; and deep ravines, lying between the lateral ridges, strike for the most part north and south from the central ridge to the sea. In the sections afforded by the ravines, the nucleus of the island is seen to consist of a confused mass of more or less stratified rock, upon which rest beds of tuff, scoriæ, and lava, in the shape of basalt, trap, and trachyte, the whole traversed by dykes. These beds are thinnest near the central axis; as they approach the coast they become thicker and less intersected by dykes. At the centre of the island there are several summits of nearly the same altitude, and these are in some places connected by narrow walls and ridges, which are frequently quite impassable, whilst at others they are separated by ravines of great depth. On all sides are seen vertical dykes, projecting like turrets above the weathered surface of the softer beds.

In various parts of the island may be seen elevated tracts of comparatively level ground. These are supposed to have been formed by the meeting of numerous streams of lava flowing from cones and points of eruption in close proximity, various ejectamenta assisting at the same time to fill up inequalities. Deep down in some of the lateral ravines may be seen ancient cones of eruption which have been overwhelmed by streams of melted matter issuing from the central region, and afterwards exposed to view by the same causes that excavated the ravines. These ravines may be regarded as having been formed at first by subterranean movements, both gradual and violent, which dislocated the rocks, and cut clefts through which streams flowed to the sea. In course of time the waters, periodically swollen by melted snows and the copious rains of winter, would cut deeper and deeper into the heart of the mountains, and would undermine the lateral cliffs, until the valleys became as large as we now find them. Even the Curral, which, from its rounded shape and its position in the centre of the island, has been usually deemed the ruins of a crater, is thought to be nothing more than a valley scooped out in the way described. The rarity of crateriform cavities in Madeira is very remarkable. There exists, however, to the east of Funchal, on a tract 2000 feet high, the Lagoa, a small but perfect crater, 500 feet in diameter, and with a depth of 150 feet; and there is another, which is a double one, in the district known as Fanal, in the north-west of Madeira, nearly 5000 feet above the sea. The basalt of which much of the outer part of the island is composed is of a dark colour and a tough texture, with small disseminated crystals of olivine and augite. It is sometimes full of vesicular cavities, formed by the expansion of imprisoned gases. A rudely columnar structure is very often seen in the basalt, but there is nothing so perfect as the columns of Staffa or the Giant's Causeway. The trachytic rocks are small in quantity compared with those of the basaltic class. The tufa is soft and friable, and generally of a yellow colour; but where it has been overflowed by a hot stream of lava it has assumed a red colour. Black ashes and fragments of pumice are sometimes found in the tufaceous strata.

The mineral contents of the rocks of Madeira are unimportant. There are no metallic ores, nor has any sulphur been found; but a little iron pyrites and specular iron are occasionally met with. The basalt yields an excellent building-stone, various qualities of which are quarried near Cama dos Lobos, 5 or 6 miles west of Funchal.

At Porto Santo the trachytic rocks bear a much greater proportion to the basaltic than in Madeira. An adjacent islet is formed of tuffs and calcareous rock, indicating a submarine origin, upon which supramarine lavas have been poured. The older series contains corals and shells (also of the Miocene Tertiary epoch), with water-worn pebbles, cemented together by carbonate of lime, the whole appearing to have been a coral reef near an ancient beach. The calcareous rock is taken in large quantities to Funchal, to be burnt into lime for building purposes.

Porto Santo.—This forms a single concelho and parish, about 25 geographical miles north-east of Madeira. It has a length of 6½ geographical miles and a width of 3. A stationary population of about 1750 persons inhabits 435 houses, chiefly collected at one spot known as the Villa, where a lieutenant-governor resides. The island is very unproductive, water being scarce and wood wholly absent. Around the little town there is a considerable tract of pretty level ground covered by calcareous sand containing fossil land shells. At each end of the island there are hills, of which Pico do Facho, the highest, reaches the altitude of 1600 feet. Barley, but little else, is grown here, the limited requirements of the inhabitants being supplied from Funchal by means of small sailing vessels.

The Desertas.—These are three uninhabited rocks lying about 11 miles south-east of Madeira. They are not easily accessible, as they present lofty precipices to the sea on all sides. Rabbits and goats abound on them. The archil weed grows on the rocks, and is gathered for exportation. The largest islet is 6½ miles long, and attains the height of 2000 feet. These rocks are conspicuous objects in the sea-views from Funchal. (J. Y. J.)

MADISON, a city of the United States, the county seat of Jefferson county, Indiana, is situated on the north bank of the Ohio, 90 miles below Cincinnati, and 44 above Louisville, with which it has daily steamboat communication. As the terminus of one of the divisions of the Jeffersonville, Madison, and Indianapolis Railroad, Madison commands extensive means of traffic; and its provision trade especially has attained important dimensions. Pork-packing is also carried on, and brass and iron foundries, tanneries, and flour-mills appear among the industrial establishments. The population was 8012 in 1850, 8130 in 1860, 10,709 in 1870, and 8945 in 1880.

MADISON, a city of the United States, the capital of Wisconsin, and seat of justice of Dane county, lies towards the south of the State, in 43° 4′ N. lat. and 89° 21′ W. long., 75 miles west of Milwaukee. In the beauty of its situation it has few rivals, occupying as it does the undulating isthmus between Mendota and Menona, two of the lakes which give name to the Four Lake Region, connected with the Mississippi by Yahara or Catfish river and Rock river; and the cool summer climate, which it owes to the fact that it stands 788 feet above the level of the sea, and 210 feet above Lake Michigan, renders it a health resort of some value, especially for consumptive patients. The State capitol, situated in the midst of a finely wooded park of 13 acres, is a rather imposing but hybrid edifice of white limestone crowned by a central dome rising 200 feet above the level of the basement; it was originally built in room of an earlier capitol in 1860, at a cost of $400,000, and has since been greatly enlarged. About a mile to the west of the capitol stand, on the high grounds known as College hill, the buildings of the Wisconsin university, an institution dating from 1850, and attended by about eight hundred students. Other buildings of note are the United States post-office and court-house, the soldiers' orphans' home, and at some distance from the city the State lunatic asylum. The Wisconsin Historical Society has a library of 58,000 volumes. Various lines belonging to the Chicago and North-Western Railway and to the Chicago, Milwaukee, and St Paul Railway meet at Madison; and the city has not only a good general trade, but manufactures ploughs and other agricultural implements, waggons, woollen goods, and flour. The population, which was only 1525 in 1850, appears in the three later censuses as 6611, 9176, and 10,325. When the site was selected (1836) for the capital of the territory of Wisconsin it was altogether unoccupied.

MADISON, JAMES (1751–1836), fourth president of the United States, was born in King George county, Virginia, on the 16th of March 1751, during a temporary visit of his mother to her relatives. His father was the owner of large landed estates in Orange county, Virginia, and was a man of distinction in the county. In 1769 Madison entered Princeton College in New Jersey, and graduated as B.A. in 1771; but he remained another year at Princeton studying under the direction of President Witherspoon. His close application to study had seriously impaired his health, which continued delicate for many years. Returning to Virginia in 1772, he pursued his reading and studies, however, with the same zeal as before, the subjects chosen being particularly those of philosophy, theology, and law.

Madison had as yet taken no active part in the exciting politics of the time. In 1775, however, he was chairman of the committee of public safety for Orange county, and in the spring of 1776 he was chosen a delegate to the new Virginia convention, which formed a constitution for the State. Failing to be re-elected in 1777, he was chosen in that year a member of the council of State, in which he took a prominent part until the end of 1779, at which time he was elected a delegate to the Continental Congress, later the Congress of the Confederation. It was in this assembly that Madison first displayed those powers which ultimately made him the founder of the constitution of the United States. He was in Congress during the final stages of the revolutionary war, and one year after the establishment of peace, at a time when the confederation was in a chronic state of collapse, occasioned by the neglect or the refusal of the States to respond to the requisitions of Congress for supplies for the federal treasury, Madison was among the first to advocate the granting of additional powers to Congress. In 1781 he favoured the amendment of the articles of confederation, giving to Congress the power to enforce its requisitions; and in 1783 he zealously advocated the proposed plan by which the States should grant to Congress for a period of twenty-five years the authority to levy an impost duty. Accompanying this plan was an address to the States drawn up by Madison. This address is one of the ablest of his state papers, and with others of this period placed him in the front rank of American statesmen.

In November 1783, the constitutional limit of his term as deputy having expired, Madison returned to Virginia, and the next year he again took a seat in the legislature of that State. As chairman of the judiciary committee, he was particularly instrumental in revising the statute laws of the State. He opposed the further issue of paper money by the State, and tried to induce the legislature to repeal the law confiscating British debts.

As a member of the legislature of Virginia, Madison did not lose sight of the interests of the confederacy. He looked beyond mere local interests, believing that the highest good of the State would best be advanced through a respected central Government. Virginia and Maryland possessing a common jurisdiction over the waters of the Potomac river and the Chesapeak Bay, it became necessary to come to some agreement between them as to the commerce and navigation upon those waters. On Madison's proposal, commissioners of the two States met at Mount Vernon in March 1785. Maryland having proposed to invite the States of Pennsylvania and Delaware to join in the arrangement, Madison saw an opportunity for a more extended and general concert in regard to commerce and trade, and proposed that all the States should be invited to send commissioners to take into consideration the trade of the United States. This resolution was adopted by the legislature of Virginia; and thus was inaugurated the movement which led to the meeting at Annapolis in 1786, and later to the convention at Philadelphia in 1787. The palpable defects in the government of the confederation had led Madison to make an extended study of confederacies, ancient and modern. Among his papers was found one bearing the title *Notes on Confederacies*, but he gave the results of these researches more at length in Nos. 17, 18, and 19 of *The Federalist*. His conclusion was that no confederacy could be long successful which acted upon States only, and not directly upon individuals.

As the time for the meeting of the convention approached, he drew up an outline of a new system of government to take the place of the articles of confederation.

As expressed in a letter to General Washington of the 16th of April 1787, it was in substance that the individual sovereignty of the States is totally irreconcilable with the aggregate sovereignty, and that a consolidation of the whole into one simple republic would be as inexpedient as it was unattainable. He sought therefore some middle ground, which might at once support a due supremacy of the national authority and not exclude the local authorities whenever they might be subordinately useful. He proposed, to this end, to change the basis of representation in Congress from States to the population.

The national government should have authority in all cases requiring uniformity. In addition to this positive power, the national government should have a negative on all State laws "as heretofore exercised by the kingly prerogative." This negative, he thought, would best be vested in the senate, which should be a comparatively permanent body.

The national supremacy should extend to the judiciary department and to the militia. The legislature should be composed of two branches—one, the more numerous, elected for a short term, the other, few in number, for a longer term. A national executive should be provided for, and the States should be guaranteed against both internal and external dangers. The right of coercion should be expressly declared. "But the difficulty and awkwardness of operating by force on the collective will of a State rendered it desirable that the necessity of it should be precluded." He thought the negative on State laws might answer the purpose. This was a weak point in Madison's theory of government. He thought, with Jefferson, that there could be found some means of governing without resorting to force. Lastly, "to give the new system its proper validity and energy, a ratification must be obtained from the people, and not merely from the legislatures."

These ideas, somewhat modified and extended in details, formed the Virginia plan of government, presented in the convention by Edmund Randolph; and this plan, again, became the basis of the extended deliberations in the convention which resulted in the constitution adopted in that body on the 17th of September 1787. In the convention, as a delegate from Virginia, Madison took a leading part in the debates, of which he kept notes which were afterwards published by order of Congress. It was his influence which largely shaped the form of the final draft of the constitution. But the labour was not finished with this draft; the constitution was yet to be accepted by the people; that it was accepted was due in an eminent degree to the efforts of Madison. In order to place the new constitution before the people in its true light, and to meet objections brought against it, he joined Hamilton and Jay in the publication of a series of essays, which were published in a collected form in 1788 under the name of *The Federalist*, and which are still worthy of careful study.

In the Virginia convention for ratifying the constitution he was again called upon to defend that instrument, and against such staunch patriots as Patrick Henry and George Mason. Madison here appeared at his best. He answered every objection in detail, calmly, yet with an eloquence and zeal that carried conviction to his audience. The result was a victory against an adverse public opinion, as well as against the eloquence of his opponents.

Although he remained in the public service for nearly twenty-five years longer, his greatest work was finished with the adoption of the constitution. He had gained the well-earned title of "father of the constitution." The part he had taken, however, alienated from him the support of a majority of the people of his State. He was defeated as a candidate for United States senate, though he was chosen in his own district as representative to Congress. Taking his seat in the Lower House in April 1789, he assumed a leading part in the legislation necessary to the organization of the new government. To Hamilton's measures, however, for the funding of the debt, the assumption of the State debts, and the establishment of a national bank, he was opposed. On other questions, too, he sided with the Anti-Federalists, and gradually assumed the leadership of the opposition in the House of Representatives.

One would have expected to find him advocating with Washington, Hamilton, Marshall, Jay, and others those measures which would strengthen still more the federal government. On the contrary, we find him labouring to confine the powers of the national government within the narrowest possible limits.

Much has been said in regard to Madison's change of principles at this time. It has been intimated that he was influenced, perhaps unconsciously, by the decided attitude of his State, but especially by the dominating mind of his most intimate friend, Jefferson. Probably there is something of truth in this charge, yet it must be said that Madison had shown on many previous occasions an aversion to a liberal construction of granted powers. Timid by nature, he was frightened at the bold and comprehensive measures of the secretary of the treasury. He thought he saw in them a constructive latitude of interpretation and a centralization of interests dangerous to republican principles.

Madison opposed also the foreign policy of the administration in 1793–96, in its attempts to maintain a neutral position between Great Britain and France, then at war with each other. And under the signature of "Helvidius" he published in the public journals five papers of great power and acuteness, criticizing the "monarchical prerogative of the executive" as exercised in the proclamation of neutrality of 1793, and the right of the recognition by the president of foreign states. So far as the question of international law was concerned, Madison was essentially right, but in regard to the authority of the executive, and the question of the expediency of Washington's neutral policy, the subsequent practice of the Government and the general verdict of history condemn his view. In 1794 Madison introduced in the House of Representatives resolutions based upon Jefferson's report on commerce, advising retaliatory measures against Great Britain and a discrimination in commercial and navigation laws in favour of France. Again, in 1796 he strenuously opposed the appropriation of money for the purpose of carrying into effect the treaty of 1794 with Great Britain. He scouted the idea as visionary that Great Britain would go to war on a refusal to carry the treaty into effect. It was not conceivable, he thought, that she would "make war upon a country which was the best market she had for her manufactures." It had been a favourite theory with Madison, as with Jefferson, that foreign nations could be coerced through their commercial interests. The fallacy of this doctrine was well exemplified by its utter inefficiency when put in practice by them in 1807–12.

In 1797 Madison withdrew to private life, though not to a life of inactivity. In 1798 he was induced by Jefferson to join in a movement in opposition to the Alien and Sedition Laws passed by the Federalists in that year, and was himself the author of the Virginia resolutions, which declared—

"That the constitution of the United States was a compact, to which the States were parties, granting limited powers of government; that in case of a deliberate, palpable, and dangerous exercise of other powers, not granted by the compact, the States had the right, and were in duty bound, to *interpose* for arresting the progress of the evils and for maintaining within their respective limits, the authorities, rights, and liberties pertaining to them; that the Alien and Sedition Laws were such infractions of the compact; . . . . and finally that the State of Virginia declared those laws unconstitutional and not law, but utterly null, void, and of no effect, and invited the other States to join her in this action."

These resolutions, with those of Kentucky drawn by Jefferson, met with decided objections from the other States. Upon these objections Madison made a report to the legislature of Virginia, consisting of an elaborate and carefully considered argument sustaining in every point the resolutions of 1798. Thirty years later these arguments were freely made use of by Calhoun and his school of nullifiers as the basis of their doctrine. But Madison, in 1830, repudiated the idea that the resolutions of 1798 involved the principles of nullification. He wrote at that time many letters to public men, and especially one to Edward Everett, in August 1830, to prove this position. The nullifiers were not convinced, however, by this reasoning, and continued to use his arguments in favour of their doctrine, till it became a source of great annoyance to him.

With the rise of the republican party to power in 1801, Madison became secretary of state in Jefferson's cabinet,—a position for which he was well fitted both by his temperament and his training, well versed as he was in constitutional and international law, and practising a calmness and fairness in discussion which are essential qualities of the diplomatist. In defending the neutral rights of the United States against the encroachments of European belligerents (1801–9), there was almost constant need of the use of all those qualities. The most important of his papers during this period was *An Examination of the British Doctrine which subjects to capture a neutral trade not open in time of peace*, that is, the so-called "rule of the war of 1756," as extended by Great Britain in 1793 and 1803. This treatise, published in 1806, was an argument against the British doctrine, drawn from a careful investigation of authorities on international law, and was a valuable contribution to the discussion of a question which, for various reasons, has now lost its importance.

In 1809 Madison was elected president to succeed Jefferson, whose peace policy—a policy of commercial restrictions to coerce Great Britain and France—he continued to follow until, in 1812, he was forced by his party to change it for a policy of war. He had been, under the lead of Jefferson, a great lieutenant; he had for the most part furnished the arguments in support of the republican policy since 1790; but he did not possess the qualities of a leader. His cabinet was in part forced upon him in 1809 by a senatorial clique, and his administration lacked vigour, particularly during the war of 1812–15. He had never been a partisan in politics, and was averse to forcing his views upon others, except in so far as he could do so by impartial arguments. In argument, he was not satisfied with generalities; his reasoning went to the foundation of principles—to the minutest details, sometimes almost painfully so. His analysis of the arguments was powerful and searching. In this he resembled Hamilton; but his conclusions were reached through a laborious process of induction, whilst those of Hamilton seemed more the result of intuition. Madison, moreover, lacked Hamilton's boldness of conception and courage in assuming the responsibility of his theories. The difference between them was the difference between great talent and genius.

Madison served two terms as president, and in 1817 retired to Montpellier, his country seat in Virginia. For nearly twenty years thereafter he was engaged in agricultural pursuits, but was ever interested in literature and politics. To the time of his death he continued to be consulted by statesmen as an oracle on all constitutional questions.

In character he was mild and conciliatory; and, whether in power or in opposition, he never lost the friendship or confidence of his political opponents. His death occurred on the 28th of June 1836.

His *Letters and Writings*, in 4 vols., were published by order of Congress in 1865. *The Madison Papers*, a report of debates during the Congress of the Confederation, and reports of debates in the Federal Convention, were also published by order of Congress. *The History of the Life and Times of Madison*, by William C. Rives, in 3 vols., comes down only to 1794.

MADRAS, a presidency of British India, occupying, with its dependencies, the entire south of the Indian peninsula, and washed on the east by the Bay of Bengal and on the west by the Indian Ocean. The north boundary is extremely irregular. On the extreme north-east is the Bengal province of Orissa; then the wild highlands of the Central Provinces; next the dominions of the nizám of Hyderabad; and lastly, on the north-west, the Bombay districts of Dhárwár and North Kánara. The extreme length from north-east to south-west is about 950 miles, and the breadth 450 miles; the area of the British districts (1879) is 138,856 square miles, and the population in 1871 was 31,672,613. The five native states attached to Madras—Travancore, Cochin, Puducottah, Banganapalli, and Sandúr—have an additional area of 9818 square miles, and a population of 3,289,392, making a grand total area of 148,674 square miles, with a population of 34,962,005.

General Aspect.—From a physical point of view, the Madras presidency may be roughly divided into three tracts —(1) the long and broad east coast, (2) the shorter and narrower west coast, and (3) the high interior table-land. These divisions are determined by the great mountain ranges of the Eastern and Western Gháts. The Eastern Gháts form a continuation of the confused hill system of Chutiá Nágpur. They run in a south-west direction through almost the entire length of Madras until they lose themselves in the Nílgiris, and there join the Western Gháts. Their average height is only 1500 feet, and for the most part they leave a broad expanse of low land between their base and the sea; their line is pierced by three great rivers—the Godávari, Kistna, and Káveri (Cauvery). The Western Gháts stretch continuously along the shore of the Indian Ocean. Rising steeply at a distance of from 30 to 50 miles from the coast, they catch almost the whole rainfall of the monsoon; and within Madras territory not a single stream breaks through their barrier. Some of the peaks attain an elevation of more than 5000 feet. Between these two ranges lies the central table-land, with an elevation of from 1000 to 3000 feet, which includes the whole of Mysore, and extends over about half a dozen districts of Madras. The three principal rivers above-mentioned, each having a large tributary system, all rise in the Western Gháts, and run across the peninsula in a south-east direction into the Bay of Bengal. In the upper parts of their course they drain rather than water the country through which they flow, and are comparatively valueless either for navigation or for irrigation; but before reaching the sea they spread over alluvial deltas. Other but smaller rivers of the same character are the North and South Pennár or Ponniyár, Palar, Váigai, Vellar, and Tambraparni. The two main hill systems have been already described (see Gháts, vol. x. p. 559). The Nílgiris, which join these, culminate in Dodabetta (8640 feet), the loftiest peak in southern India. There are, besides, many outlying spurs and tangled masses of hills, of which the Shevaroys, Anamalais, and the Palnis are the most important. The principal lake in the presidency is that of Pulicat on the east coast, which is 33 miles from north to south, and forms an important means of communication between Madras city and the north districts. On the west coast are a remarkable series of backwaters or lagoons, fringing the seaboard of Kánara, Malabar, and Travancore. The largest is the backwater of Cochin, which extends for a distance of 120 miles from north to south.

The mineral wealth of the province is as yet undeveloped. Iron of excellent quality has been smelted by native smiths in many localities from time immemorial; but attempts to work the beds after European methods have hitherto proved unsuccessful. Carboniferous sandstone extends across the Godávari valley as far as Ellore, but the coal has been found to be of inferior quality. Scientific researches have proved the existence of gold in the Nílgiris, in sufficient quantity to render outlay on it profitable; and several companies, representing a large amount of capital, have been formed for working the mines. Among other minerals may be mentioned manganese in the Nílgiris and Bellary; copper and lead ores in many parts of the Eastern Gháts; antimony and silver; and corundum in the valley of the Káveri. Garnets are abundant in the sandstone of the Northern Circars, and diamonds of moderate value are found in the same region. Stone and gravel quarries are very numerous.

The Forest Department of Madras was first organized in 1856, and it is estimated that forests cover a total area of more than 5000 square miles, the whole of which is under conservancy rules. For supplying fuel to the railways an area of about 160,000 acres is strictly conserved. In the remaining forests, after supplying local wants, timber is either sold direct by the department, or licences are granted to wood-cutters. The more valuable timber-trees comprise teak, ebony, rosewood, sandal-wood, and redwood. The Government plantations cover an area of 9000 acres. The trees thus artificially reared are teak, sandal-wood, *Casuarina*, and *Eucalyptus*. The finest teak plantation (over 3000 acres) is near Beypur in Malabar. At Mudumalli there are plantations of both teak and sandal-wood; and the *Eucalyptus* or Australian gum-tree now grows on the Nílgiris in magnificent clumps. The total value of timber and wood exported was £95,801 in 1875–76, and £122,413 in 1880–81.

The wild animals are those for the most part common to the rest of India. Those deserving mention are the elephant, bison, sambur, and ibex of the Western Gháts and the Nílgiris. Bison are also found in the hill tracts of the Northern Circars. In Travancore state the black variety of leopard is not uncommon. In 1880–81 182 persons and 11,628 cattle were returned as killed by wild beasts. The number of persons killed by snake-bites in 1880 was 928. The elephant is now protected by law from indiscriminate destruction. The agricultural returns for 1880–81 report the number of buffaloes as

1,324,435, bullocks 3,228,907, cows 2,873,979, goats 2,803,407, sheep 4,082,411, horses 8986, and elephants 532. The cattle are small, but in Nellore and along the Mysore frontier a superior breed is carefully kept up by the wealthier farmers. The best buffaloes are imported from the Bombay district of Dhárwár. Experiments in sheep breeding have been made at the Saidápet model farm, with fair success.

Population.—The first census, in 1822, returned the population as 13,476,923, and an enumeration in 1866-67 gave 26,539,052. The census of November 1871, however, was the first conducted in regular form. The following table gives the results for the British districts of the presidency. According to the preliminary return the total population at the census in 1871 was 30,839,181 (15,242,122 males and 15,597,059 females). This would seem to show that the loss caused by the famine of 1876–78 has been nearly made up.

Area, Population, &c., of Madras Presidency in 1871.

Name of District.	Sq. Miles.	Villages.	Houses.	Population.	Inhab. per Sq. Mile.
Ganjám	8,313	4,562	341,404	1,520,088	182·9
Vizagapatam	18,344	8,581	489.419	2,159,199	117·7
Godávari	6,224	2,202	389,712	1,592,939	253·9
Kistna	8,036	2,140	282,358	1,452,374	180·7
Nellore	8,462	2,174	263,820	1,376,811	162·7
Cuddapah	8,367	1,337	339,063	1,351,194	161·5
Bellary	11,007	2,568	351,943	1,668,006	151·5
Karnúl	7,358	787	205,884	959,640	130·4
Chengalpat	2,753	2,362	141.434	938,184	340·7
North Arcot	7,139	5,292	329,844	2,015,278	282·3
South Arcot	4,873	3,198	228,761	1,755,817	360·3
Tanjore	3,654	3,935	369,984	1,973,731	540·1
Trichinopoli	3,515	1,641	210,690	1,200,408	311·5
Madura	9,502	5,459	443.513	2,266,615	238·5
Tinnevelli	5,176	1,824	403,803	1,693,959	327·3
Coimbatore	7,432	1,575	361,109	1,763,274	237·3
Nílgiris	749	17	13,922	49,501	66·0
Salem	7,483	4,021	391,519	1,966,995	262·9
South Kánara	3,902	1,288	184,569	918,362	235·4
Malabar	6,002	432	435,462	2,261,250	376·7
Madras city	27	23	51,741	397,552	14,724·1
Total	138,318	55,421	6,229,954	31,281,177	226·2

Hindus numbered 28,863,978 ; Mohammedans, 1,857,857; Christians, 533,760 ; Jains, 21,254 ; and "others," 4328. The Hindus (92·3 per cent. of the whole) are subdivided into 16,159,610 Sivaites, 11,657,311 Vishnuvites, 154,989 Lingáyats, and 892,068 "others," including hill tribes. The Sivaites are most numerous in the extreme south and on the west coast, while the Vishnuvites are chiefly found in the northern districts. The Lingáyats may be described as a sect of Sivaite puritans, who derive their name from their practice of carrying about on their persons the *lingá* or emblem of Siva. Of Hindu castes, Bráhmans number 1,094,455. They follow various pursuits, and many of them are said to be recent immigrants, who came south in the train of the Mahratta armies. A peculiar caste of Bráhmans, called Namburi, is found in Malabar, who are said to be descended from fishermen. The Kshattriyas, or warrior caste of the ancient Hindu organization, number only 190,415. The three trading castes of Chettis, Beri Chettis, and Komatis number 714,712, and except in Kánara district still retain in their hands nearly all the commerce of the country. Agricultural castes number 7,826,127 ; the highest classes among them do not cultivate with their own hands, and many of them formerly held their lands on a military tenure. The pastoral castes number 1,730,681, but a large proportion of them have now abandoned their hereditary occupation. Artisans number 785,085, of whom nearly one-half are workers in metal. Weavers number 1,017,781, but their industry is now decayed owing to Manchester competition. The labouring castes are returned at 3,944,463. Fishing and hunting castes number 971,837, but many have now betaken themselves to agriculture. The palm cultivators and toddy makers amount to 1,664,862. Out-castes (Pariahs) number 4,761,503 ; in the country round Madras they form about one-quarter of the total population. Up to the close of the last century they lived in a state of slavery to the superior castes ; and they are still compelled by custom to live in separate hovels outside the boundary of the village, and to perform all menial services. They are described as a laborious, frugal, pleasure-loving people, omnivorous in diet, and capable of performing much hard work. Unclassified Hindus (2,666,890) consist of aboriginal hill races and wandering tribes. Numerically the most important are the Kandhs and Sauras, two cognate races who inhabit the mountainous tracts of the Eastern Gháts attached to several of the large *zamindáris* of Ganjám and Vizagapatam. On the Nílgiris, the aboriginal tribe best known to Europeans is the Todas, a stalwart, haughty race, who domineer over the more timid jungle folk, and confine themselves to the pasturing of buffaloes. It is believed that the Todas are now dying out, for in 1871 they numbered only 693. The principal wandering tribes are the Brinjaris and Lambadis, who are to be found in all parts of the country as carriers of grain and salt.

The Mohammedans are thus subdivided:—Sunnis, 1,654,529 ; Shias, 69,302 ; Wahhábis, 3954 ; unspecified, 130,072. A more familiar division is a race one :—Labbay, Mopla, Arab, Shaikh, Sayyid, Pathán, and Mughal. The Labbays (312,088) are the descendants of Hindu converts, and are traders by hereditary occupation, although many now employ themselves as sailors and fishermen. The Moplas (612,789) are the descendants of Malayalam converts to Islám,—the head of the tribe, the rájá of Kananúr, being descended from a fisher family in Malabar. They are a hard-working, frugal people, but quite uneducated and very fanatical, and under the influence of religious excitement have often disturbed the public peace. The Shaikhs number 511,112, the Sayyids 89,219, the Patháns 70,943, and the Mughals 12,407.

Christians are more numerous in Madras than in any other part of India. They number in the British districts 533,760, of whom 40,879 are Europeans or Eurasians, and the remainder native converts ; Roman Catholics number 397,071, and Protestants 93,228. In Travancore and Cochin states the native Christians are still more numerous, constituting as much as one-fourth of the population. The Roman Catholics, whose number throughout southern India is estimated at upwards of 650,000, owe their origin to St Francis Xavier, and the famous Jesuit mission of Madura ; they are partly under the authority of the archbishop of Goa, and partly under twelve Jesuit vicariates. Protestant missions date from the beginning of the last century. The Danes were the pioneers ; but their work was taken up by the Society for Promoting Christian Knowledge, under whom laboured the great Lutherans of the last century—Schultz, Sartorius, Fabricius, and Schwartz. The Church Missionary Society entered the field in 1814 ; and subsequently an American mission joined in the work. The total number of Protestant native Christians in southern India (British and native) in 1878 was 296,408.

Urban life may be said to be more highly developed in Madras than in Bengal or Bombay. Populous cities, indeed, are not numerous, but there is an unusual proportion of towns with from 2000 to 20,000 inhabitants. The six cities with a population of more than 50,000 are—Madras city (1871), 397,552 ; Trichinopoli, 76,530 ; Tanjore, 52,175 ; Madura, 51,987 ; Bellary, 51,766; Salem, 50,012.

Agriculture.—Over the greater part of the area of Madras artificial irrigation is impossible, and cultivation is dependent upon the local rainfall, which rarely exceeds 40 inches a year, and is liable to fall irregularly. The Malabar coast is the only part where the rainfall brought by the south-west monsoon may be trusted both for its amount and regularity. Other districts, such as Bellary, are also dependent upon this monsoon, but in their case the rain clouds have spent themselves in passing over the Western Gháts, and cultivation becomes a matter of hazard. Over the greater part of the presidency the rainy season is caused by the south-east monsoon, which breaks about the end of September. The deltas of the Godávari, Kistna, and Káveri rivers are the only spots on the east coast which artificial irrigation is able to save from risk of occasional scarcity. Of the total cultivated area about 80 per cent. is returned as "dry" land, or that which is solely dependent upon local rainfall ; 15 per cent. as "wet" land, irrigated from river channels ; 2 per cent. as garden land irrigated from wells ; and about 3 per cent. fallow and pasture. The principal food staples are rice, *cholam*, *kambu*, *ragi*, and *varagu*. The most common oil-seed is gingelly. Garden crops comprise tobacco, sugar-cane, chillies, betel-leaf, and plantains. The fruit trees are cocoa-nut, areca-nut, date and palmyra palm, jack, tamarind, and mango. Special crops include cotton, indigo, coffee, tea, cinchona. The principal coffee tract stretches along the slopes of the Western Gháts from the north of Mysore almost down to Cape Comorin. The larger portion of this area lies within Mysore, Coorg, and Travancore states, but Wainád and the Nílgiri hills are within Madras. The first coffee plantation was opened in the Wainád in 1840. Many of the early clearings proved unprofitable, and the enterprise made little progress till about 1855, in which year the total exports were 32,000 cwts. Coffee, which is much cultivated on the Nílgiris, now covers in the whole presidency 131,348 acres. The tea plant was also introduced into the Nílgiri hills about 1840, but was not taken up as a commercial speculation till 1865. The area under tea is over 4000 acres, and the exports in 1880–81 were 263,940 lb. The cinchona plant was successfully introduced into the Nílgiri hills by Government in 1860. In 1880–81 847 acres were under cultivation ; 1,087,637 plants were raised ; and the receipts of sales were £39,618, the amount in 1875–76 being only £4989. Tobacco is extensively grown in Godávari and Kistna districts. The greater part of the soil in Madras is held by the cultivators direct from Government under the tenure known as *ráyatwari*. The average rate of Government assessment is about 2s. 3d. per acre on unirrigated and 9s. 6d. on irrigated land. In 1880–81 the total revenue from this source amounted to £4,170,052. Besides these lands in the hands of the Government, there are also proprietary or *zamindári* estates in all parts of the country. These estates are either the remains of ancient principalities, which the holder cannot sell or encumber beyond his own life interest, or they are creations of British rule and subject to the usual Hindu custom of partition. The total area of the *zamindári* estates is about 21 million acres, or one-fourth of the whole presidency. The *peshkash* or tribute payable to Government in perpetuity amounts to about £500,000 a year. *Ináms*, revenue-free or quit-rent grants of lands made for religious endowments or for services rendered to the state, occupy an aggregate area of a little over 1,500,000 acres.

Manufactures.—Madras possesses few staple manufactures. The preparation of the coffee berry for export constitutes the one great business carried on by means of European capital and under European supervision. Indigo is manufactured in considerable quantities, but of inferior quality. The more important of the large manufactories are three cotton mills in Madras, a weaving establishment maintained by the Basel mission in South Kánara, sugar works in Ganjám and South Arcot, and a jute factory at Vizagapatam. Up to the close of the last century cotton goods constituted the main article of export. Masulipatam, where the first English factory on the Coromandel coast was established in 1620, enjoyed a special reputation for its chintzes, which were valued for the freshness and permanency of their dyes. There is still a small demand for these articles in Burmah, the Straits, and the Persian Gulf; but Manchester goods have nearly beaten the Indian exporter out of the field. Native looms, however, still hold their own in the local market, in face of strenuous opposition. After weaving, working in metals appears to be the most widespread native industry. Among local specialities which have attracted European curiosity may be mentioned the jewellery of Trichinopoli, ornaments of ivory and horn worked at Vizagapatam, and sandal-wood carving at Kánara. The manufacture and sale of salt is a Government monopoly, carried on under close supervision. The process employed is solar evaporation, and the entire eastern coast-line from Orissa to Cape Comorin affords natural facilities for the industry. The preparation of arrack and toddy spirit is also a Government monopoly. On the Nílgiri hills and at Bellary country beer is manufactured by European firms subject to an excise duty of 6d. per gallon.

Railways.—Two guaranteed railway companies, the Madras and the South Indian, have their lines almost entirely within the presidency. The Madras Railway, which connects at Ráichur with the Great Indian Peninsular system, runs south-east to Madras, and then west across the peninsula to Beypur, with branches to Bellary and Bangalore. The total length open in 1881 was 858 miles; the capital expended, £10,441,699; the net profits £177,433, giving a dividend of 1·7 per cent. on the capital expended. The South Indian Railway (narrow guage) runs north from Tuticorin to Madras. In 1881 the total length was 658 miles; the capital expended, £4,291,311; and the net profits yielded a dividend of 2·9 per cent.

Commerce and Trade.—The continuous seaboard of the Madras presidency, without any natural harbours of the first rank, has tended to create a widely diffused trade. Madras city conducts nearly one-half of the total sea-borne commerce; next comes Malabar, containing the western railway terminus near Calicut; then Godávari, with its cluster of ports along the fringe of the delta; Tinnevelli, with the new harbour at Tuticorin, which has opened large dealings with Ceylon; Tanjore, South Kánara, Ganjám, and Vizagapatam in the order given. The total foreign trade in 1880–81 was as follows. The imports amounted to £6,518,783, of which cotton piece goods and twist made up £2,908,379, grain £158,144, and apparel £147,691. The exports amounted to £9,271,345, the chief items being—coffee, £1,393,090; raw cotton, £939,127; hides and skins, £1,261,182; rice, £996,314; seeds, £708,390; indigo, £693,103; spices, £379,282; oils, £372,119; sugar, £301,670. The total number of vessels engaged in foreign trade that cleared and entered Madras ports in 1880–81 was 6247, with a tonnage of 1,177,337; the coasting trade was conducted by 11,316 vessels, with 3,748,474 tons, for ports outside Madras presidency, and 24,057 vessels, with 3,092,286 tons, for ports within the presidency. The importance of this active coasting trade may be gathered from the fact that in 1876–77 (the first year of the late famine) the imports of grain suddenly rose to 652,850 tons, by far the greater part consisting of rice from Bengal.

Administration.—The supreme executive authority is vested in the governor, with a council of three members, of whom one is the commander-in-chief; the others belong to the covenanted civil service. For legislative purposes this council is increased by the presence of the advocate-general and from four to eight other members nominated by the governor, of whom not less than one-half must be non-officials. The local administration is organized with the district or *zilá* as its unit. Of these districts there are twenty-one in all, including the Nílgiris and Madras city, both of which occupy an exceptional position. Each of the remaining districts is under the jurisdiction of a collector-magistrate and a sessions judge. Beneath the collector-magistrate come deputy collectors, sub-collectors, and assistants. Each district is subdivided into *táluks*, numbering one hundred and fifty-six in all, under the charge of a *tahsildár*. Each *táluk* comprises from fifty to one hundred villages, which constitute the ultimate units for fiscal and administrative purposes. The hereditary village officials, to be found in almost every Hindu village, are employed to perform minor public offices, revenue and judicial, and are inadequately remunerated either by fees in grain and other cesses levied from the villagers, or by a reduction in their land assessment. The heads of villages and village accountants (*karnam*) collect and account for all revenue, rates, and taxes within their respective villages or townships.

Local and municipal administration, including roads and communications, schools and primary education, public health and local endowments, together with special taxation levied for any of these purposes, is provided for by special legislation passed in 1871. Entire districts or, where these are of unmanageable size, parts of districts have been constituted local fund circles, each under the management of a board of commissioners, of which the collector is *ex officio* president, and the district engineer, medical officer, and one or more civil officers are official members. With them are associated at least an equal number of native non-official gentlemen, appointed by Government. To these boards is entrusted the entire management of the local interests above named, subject to the submission of an annual budget for the sanction of Government, and of a report of the board's transactions at the close of each year. The twenty-one districts of the presidency comprise thirty-five such local fund circles. The sources of income at the disposal of these boards are a grant from provincial funds, a special land rate not exceeding one *anna* in the rupee of the Government assessment, tolls, school fees, local endowments, and other minor special funds. Municipal administration of the larger towns is provided for by boards of town commissioners, constituted similarly to the local boards as regards official and non-official members, except that, with the consent of Government, the latter may be elected by the ratepayers. Besides the above-named local interests, the commissioners manage the local sanitation and hospitals of the towns, registration of births and deaths, lighting, and police. About fifty towns, including Madras city, with an aggregate population of 1,500,000, are provided with municipal administration, and the number is steadily increasing. The funds at the disposal of the commissioners consist of rates on houses and lands, a tax on professions and trades, a wheel and animal tax, tolls and ferries, school and market fees, &c. Under the administration of these local and municipal boards great impulse has been given to the development of roads, education, and hospitals and dispensaries.

Revenue and Expenditure.—Down to 1871 every branch of revenue and expenditure throughout India was managed in all details by the Government of India. Under the decentralization scheme of that year the financial administration of the jail, police, and educational services, together with certain branches of the medical, sanitary, and other minor services, were transferred to the Government of Madras, and a grant of a single fixed sum from the imperial funds was assigned for their maintenance. The local fund boards, described above, were constituted in the same year, and the municipal administration improved. The provincial expenditure is almost entirely met by a grant from imperial funds; and the local receipts benefit in a similar way by a subsidy from the imperial budget. The following figures show the revenue and expenditure under each head of finance for the year 1880–81, exclusive of the charges under the heads of army, interest, and imperial public works. (1) Imperial: total revenue, £8,526,451, of which about one-half, £4,284,335, is derived from the land revenue, and £1,433,974 from salt; expenditure, £3,478,655. (2) Provincial: total revenue, £955,162, of which £781,990 forms the allotment from the imperial funds; expenditure, £971,011,—the main items being police, £376,356; law and justice, £105,962; public works, £142,187; education, £90,875. (3) Unfettered local funds: receipts, £24,768; charges, £19,628. (4) Fettered local funds: income, £748,315; expenditure, £729,746. (5) Municipal: total revenue, £137,364; expenditure, £129,525. The gross revenue of the presidency was £9,030,152, and the expenditure £6,893,960.

Army.—The Madras army garrisons, besides the whole of Madras proper, the adjoining state of Mysore, the Nizám's Dominions, the Central Provinces, and British Burmah; a regiment is also usually stationed at Dorunda in the Chutia Nágpur division of Bengal, and another at Cuttack in Orissa. The entire force consists of 1 regiment of European cavalry, 19 batteries of European artillery, and 8 regiments of European infantry, with 1 company of native sappers and miners, 4 regiments of native cavalry, and 40 regiments of native infantry. In 1880–81 the European force numbered 10,229, and the native army 30,958 of all ranks. The military expenditure charged against Madras in 1880–81 was £2,722,105. The principal cantonments are Kámpti, Secunderábád, Bangalore, Bellary, and Rangoon. St Thomas's Mount near Madras city is an important station for artillery. The two military sanatariums are Ramandrug near Bellary, and Jakatála or Wellington in the Nílgiri hills.

Administrative Statistics.—An early task of the English administration was the repression of the system of black mail levied by bands of Kavílgárs, which was not fully extinguished for many years. By a Government regulation in 1866 the village police was placed under the head of the village, and became practically the most useful (although a somewhat dishonest) agency of the magistrate in the police administration. The Madras police force was organized in its present form in 1860. In March 1881 it consisted of a total strength of 26,415 officers and men, maintained at a cost of £364,233. In 1880 the total number of prisoners passing through the jails in the presidency was 27,708,—considerably less than during and after the famine; the daily average number of prisoners was 12,202. Education was afforded in 1880–81 by 12,878 schools, attended by 327,808 pupils; the expenditure was £284,873, of which £86,641 was contributed by the state. The chief educational institutions are the Madras university, the provincial college of Combaconum, the Madras Christian college, the Doveton Protestant college, S. P. G. high school at Tanjore, medical college, civil engineering college, Lawrence asylum, school of agriculture, school of ordnance artificers and school of arts, and the military orphanage at Utakamand in memory of the late Sir Henry Lawrence.

Climate and Health.—The climate varies in different parts of the presidency, being determined by the very diverse geographical conditions. The Nílgiri hills enjoy the climate of the temperate zone, with a moderate rainfall, and a thermometer rarely exceeding 80° F., and sometimes falling to the freezing-point. On the Malabar coast the south-west monsoon brings an excessive rainfall, reaching 150 inches in the year at certain spots. The rain clouds hanging on the slope of the Western Gháts sometimes obscure the sun for month after month. Along the eastern coast and on the central table-lands the rainfall is comparatively low, but the heat of the summer months is excessive. At Masulipatam the thermometer frequently rises to above 110° F. in the shade. The whole coast of the Bay of Bengal is liable to disastrous cyclones, which not only wreck the shipping in the roads, but have repeatedly overwhelmed the low-lying ports. The most prevalent diseases are fevers, diarrhœa, dysentery, and other bowel complaints, cholera, and small-pox.

History.—Until the English conquest the whole of southern India had never acknowledged a single ruler. The difficult nature of the hill passes and the warlike character of the highland tribes forbade the growth of great empires, such as succeeded one another on the plains of Hindustán. The Tamil country in the extreme south is traditionally divided between the three kingdoms of Pandya, Chola, and Chera. The west coast supplied the nucleus of a monarchy which afterwards extended over the highlands of Mysore, and took its name from the Carnatic. On the north-east the kings of Kalinga at one time ruled over the entire line of seaboard from the Krishna to the Ganges. Hindu legend has preserved marvellous stories of these early dynasties, but our only authentic evidence consists in their inscriptions on stone and brass, and their noble architecture. The Mohammedan invader first established himself in the south in the beginning of the 14th century. Alá-ud-dín, the second monarch of the Khiljí dynasty at Delhi, and his general Malik Kafur conquered the Deccan, and overthrew the kingdoms of Karnataka and Telingána, which were then the most powerful in southern India. But after the withdrawal of the Musalmán armies the native monarchy of Vijayanagar arose out of the ruins. This dynasty gradually extended its dominions from sea to sea, and reached a pitch of prosperity before unknown. At last, in 1565, it was overwhelmed by a combination of the four Mohammedan principalities of the Deccan. At the close of the reign of Aurangzeb, although that emperor nominally extended his sovereignty as far as Cape Comorin, in reality South India had again fallen under a number of rulers who owned no regular allegiance. The nizám of the Deccan, himself an independent sovereign, represented the distant court of Delhi. The most powerful of his feudatories was the nawáb of the Carnatic, with his capital at Arcot. In Tanjore, a descendant of Sivají ruled; and on the central table-land a Hindu chieftain was gradually establishing his authority and founding the state of Mysore, destined soon to pass to a Mohammedan usurper.

Vasco da Gama cast anchor off Calicut on the 20th May 1498, and for a century the Portuguese retained in their control the commerce of India. The Dutch began to establish themselves on the ruin of the Portuguese at the beginning of the 17th century, and were quickly followed by the English, who established themselves at Calicut and Cranganore in 1616. Tellicherri became the principal British emporium on the west coast of Madras. The Portuguese eventually retired to Goa, and the Dutch to the Spice Islands. The first English settlement on the east coast was in 1620, at Masulipatam, even then celebrated for its fabrics. Farther south a factory, the nucleus of Madras city, was erected in 1639. Pondicherri was purchased by the French in 1762. For many years the English and French traders lived peacefully side by side, and with no ambition for territorial aggrandisement. The war of the Austrian succession in Europe lit the first flame of hostility on the Coromandel coast. In 1746 Madras was forced to surrender to Labourdonnais, and Fort St David remained the only British possession in southern India. By the peace of Aix-la-Chapelle Madras was restored to the English; but from this time the rivalry of the two nations was keen, and found its opportunities in the disputed successions which always fill a large place in Oriental politics. English influence was generally able to secure the favour of the rulers of the Carnatic and Tanjore, while the French succeeded in placing their own nominee on the throne at Hyderabad. At last Dupleix rose to be the temporary arbiter of the fate of southern India, but he was overthrown by Clive, whose defence of Arcot in 1751 forms the turning point in Indian history. In 1760 the crowning victory of Wandewash was won by Colonel (afterwards Sir Eyre) Coote, over Lally, and in the following year, despite help from Mysore, Pondicherri was captured.

Though the English had no longer any European rival, they had yet to deal with Mohammedan fanaticism and the warlike population of the highlands of Mysore. The dynasty founded by Hyder Ali, and terminating in his son Tipú Sultán, proved itself in four several wars, which terminated only in 1799, the most formidable antagonist which the English had ever encountered (see HYDER ALI and INDIA). Since the beginning of the present century Madras has known no regular war, but occasional disturbances have called for measures of repression. The *pálegárs* or local chieftains long clung to their independence after their country was ceded to the British. On the west coast, the feudal aristocracy of the Nairs, and the religious fanaticism of the Moplás, have more than once led to rebellion and bloodshed. In the extreme north, the wild tribes occupying the hills of Ganjám and Vizagapatam have only lately learned the habit of subordination. In 1836 the *zamíndári* of Gúmsúr in this remote tract was attached by Government for the rebellious conduct of its chief. An inquiry then instituted revealed the wide prevalence among the tribe of Kandhs of human sacrifice, under the name of *meriah*. The practice has since been suppressed by a special agency.

The different territories comprising the Madras presidency have been acquired by the British at various dates. In 1763 the tract encircling Madras city, now Chengalpat district, was ceded by the nawáb of Arcot. In 1765 the Northern Circars, out of which the French had recently been driven, were granted to the Company by the Mughal emperor, but at the price of an annual tribute of £90,000. Full rights of dominion were not acquired till 1823, when the tribute was commuted for a lump payment. In 1792 Tipú was compelled to cede the Baramahál (now part of Salem district), Malabar, and Dindigal subdivision of Madura. In 1799, on the reconstruction of Mysore state after Tipú's death, Coimbatore and Kánara were appropriated as the British share; and in the same year the Mahratta rájá of Tanjore resigned the administration of his territory, though his descendant retained titular rank till 1855. In 1800 Bellary and Cuddapah were made over by the nizám of Hyderabad to defray the expense of an increased subsidiary force. In the following year the dominions of the nawáb of the Carnatic, extending along the east coast almost continuously from Nellore to Tinnevelli, were resigned into the hands of the British by a puppet who had been put upon the throne for the purpose. The last titular nawáb of the Carnatic died in 1855; but his representative still bears the title of prince of Arcot, and is recognized as the first native nobleman in Madras. In 1838 the nawáb of Karnúl was deposed for misgovernment and suspicion of treason, and his territories annexed.

MADRAS, capital of Madras presidency, is situated on the sea-coast in 13° 4′ 8″ N. lat., 80° 14′ 51″ E. long. Although at first sight the city presents a disappointing appearance, and possesses not a single handsome street, it has several edifices of high architectural pretensions, and many spots of historical interest. Seen from the roadstead, the fort, a row of merchants' offices, a few spires and public buildings, are all that strike the eye. Roughly speaking, it consists of the following divisions. (1) Black Town, an ill-built, densely populated block, about a mile square, is the business part of the town, and contains the banks, custom house, high court, and all the mercantile offices. The last, for the most part handsome structures, lie along the beach. On the sea-face of Black Town are the pier and the new harbour. Immediately south of Black Town there is (2) an open space which contains the fort, esplanade, brigade parade ground, Government house, and several handsome public buildings on the sea-face. (3) West and south of this lung of the city come a series of crowded quarters known by

Plan of Madras.

various native names—Chintadrapet, Tiruvaleswarampet, Pudupák, Royapet, Kistnampet, and Mylapur, which bend to the sea again at the old town of Saint Thomé. (4) To the west of Black Town are the quarters of Veperi and Pudupet, chiefly inhabited by Eurasians, and the suburbs of Egmore, Nangambákam, and Perambúr, adorned with handsome European mansions and their spacious "compounds" or parks. (5) South-west and south lie the European quarters of Tanampet and aristocratic Adyar. Amongst the buildings most deserving of notice for their architectural features are the cathedral, Scotch church, Government house, Patcheappah's hall, senate house, Chepauk palace (now the Revenue Board), and the Central Railway station.

Nearly all the most important offices of the presidency, and the headquarters of every department, are located in Madras. Apart from the headquarters staff of the Madras army, that of the central division is also stationed here, with a garrison of 1 European and 3 native infantry regiments, 1 battery of artillery, and the bodyguard of the governor (100 sabres). At St Thomas's Mount are 3 batteries of artillery and a detachment of native infantry. Including these, the garrison of Madras is about 3500 strong, of whom 1200 are Europeans.

The population of Madras city, as ascertained by the census of 1871, was 397,552, including 330,062 Hindus, 50,964 Mohammedans, 12,013 Eurasians, and 3613 Europeans. The annual municipal income is about £53,000. Madras, notwithstanding its exposed situation, ranks third among the ports of India in respect of the number and tonnage of vessels calling and the value of its imports and exports. The port trades with every part of the world, exporting coffee, cotton, grain, hides, indigo, oilseeds, dyes, sugar, and horns, and importing piece goods, iron and other metals, and all kinds of European manufactures. The lighthouse, 125 feet high, is visible from a ship's deck 15 miles at sea. The Madras roadstead, like the whole line of the western coast of India, is liable to be swept by hurricanes of irresistible fury, which occur at irregular intervals of years, generally at the beginning of the monsoons in May and October. The first recorded cyclone was in October 1746, a few weeks after the fort had surrendered to Labourdonnais. A French fleet then lay at anchor in the roads. Five large ships foundered, with 1200 men on board; and scarcely a single vessel escaped with its masts standing. Perhaps the most destructive of these storms occurred in May 1872. On this occasion the registered wind pressure reached a maximum of 53 ℔ to the square foot. In the space of a few hours nine English vessels and twenty native craft were driven ashore. In May 1874 another cyclone broke on the Madras coast, but the ships were warned in time to put to sea and gain an offing. The most recent of these periodical hurricanes occurred in November 1881, when the new harbour works sustained serious damage.

The trade of the town does not depend on any special local manufactures or produce. Such industries as once flourished—weaving, for instance—have decayed, and no others have grown up to replace them. As elsewhere in India, spinning companies have recently been formed, but what effect they are likely to exercise on local trade remains to be seen. With the exception of banks, and enterprises connected with the preparation of produce for export, *e.g.*, cotton-pressing and coffee-cleaning, joint-stock undertakings have not prospered. As the capital of southern India, Madras is the centre on which all the great military roads converge. It is also the terminal station of two lines of railway, the Madras line and the Madras and Tanjore section of the South Indian Railway.

The Buckingham Canal, which passes through an outlying part of the city, connects South Arcot district with Nellore and the Krishna and Godávari system of canal navigation. This long delayed project was undertaken as a famine work.

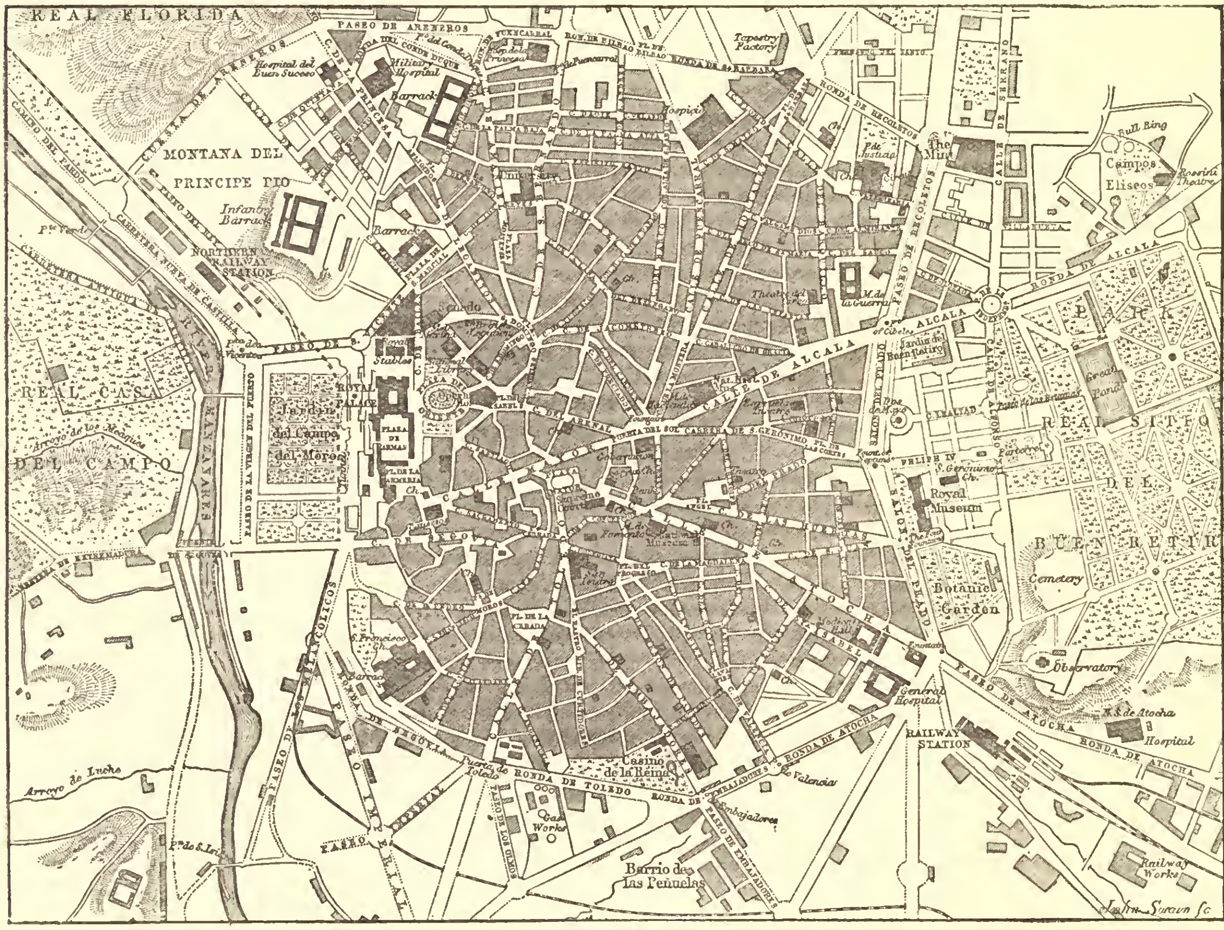
The town of Madras dates from 1639, when Francis Day, chief of the East India Company's settlement at Armagon, obtained a grant of the present site of the city from the rájá of Chandragiri. A factory, with some slight fortifications, was at once constructed, and a gradually increasing population settled around its walls. In 1653 Madras, which had previously been subordinate to the settlement of Bantam in Java, was raised to the rank of an independent presidency. In 1702 Dáúd Khán, Aurangzeb's general, blockaded the town for a few weeks, and in 1741 the Mahrattas unsuccessfully attacked the place. In 1746 Labourdonnais bombarded and captured the fort. The settlement was restored to the English two years later by the treaty of Aix-la-Chapelle, but the government of the presidency did not return to Madras till 1762. In 1758 the French under Lally occupied the Black Town, and invested the fort. The siege was conducted on both sides with great skill and vigour. After two months, the arrival of a British fleet relieved the garrison, and the besiegers retired with some precipitancy. With the exception of the threatening approach of Hyder Ali's horsemen in 1769, and again in 1780, Madras has since the French siege been free from external attack. The town of Saint Thomé, now part of Madras city, was founded and fortified by the Portuguese in 1504, and was held by the French from 1672 to 1674.

MADRID, a province of Spain, one of the five into which New Castile is divided, is bounded on the W., N.W., and N. by Avila and Segovia, on the E. by Guadalajara, on the S.E. by Cuenca, and on the S. by Toledo. The area is 2997 square miles, with a population in 1877 of 593,775, an increase of 104,443 since 1860. Madrid belongs to the basin of the Tagus, being separated from that of the Douro by the Sierra Guadarrama, which skirts the province on the north-west and north. The Tagus itself is the southern boundary for some distance, its chief tributary being the Jarama, which rises in the Somosierra in the north, and terminates at Aranjuez. The Jarama, in turn, is joined by the Henares and Tajuña on the left, and by the Lozoya and Manzanares on the right. The Guadarrama, another tributary of the Tagus, has its upper course within the province. Like the rest of Castile, Madrid is chiefly of Tertiary formation; the soil is mostly clayey, and there are sandy tracts. Agriculture is in a somewhat backward condition; the rainfall is deficient, and the rivers, poor though they are, are not utilized as they might be for irrigation. The chief products are wheat, barley, rye, oats, algarrobas (*Ervum tetraspermum*), pease, chick pease, and various other legumes, wine, oil, flax, hemp, wax, honey, and various fruits. Gardening is carried on to some extent near the capital, though the markets of Madrid receive their most liberal supply of fruits and vegetables from Valencia. Sheep, goats, and horned cattle are reared, and fish are found in the Jarama and other rivers. The province is on the whole treeless; but some wood is grown on the mountain slopes in the north. The Sierra Guadarrama has quarries of granite, lime, and gypsum, and is known to contain iron, copper, and argentiferous lead, but these resources are as yet undeveloped. The manufactures are trifling (coarse cloth, leather, paper, earthenware, porcelain, bricks and tiles, saltpetre, glass and crystal, chocolate, lace); and there is very little commerce beyond that for the supply of the capital with necessaries. The only towns with a population above 10,000 are Alcalá (Complutum) on the Henares, and Madrid; the famous university of the former was transferred to the latter in 1836. Aranjuez (8154), on the Tagus, is also of historical importance.

MADRID, capital of the above province and of Spain, is situated in 40° 24′ 35″ N. lat. and 3° 41′ 51″ W. long., on the left bank of the Manzanares, a subtributary of the Tagus, at a maximum elevation of 2372 feet above the sea-level. The population (397,816 in 1877) was over 400,000 in 1881. The town is nearly in the centre of the kingdom, almost equidistant from the Mediterranean, the Atlantic, and the Bay of Biscay. The site consists of some sandy hills of little elevation, in the midst of an extensive plain, bounded to the view on the north only by the Sierra Guadarrama. The basin in which it stands is of Tertiary formation, consisting of gypsum, marl, and limestone.

Owing to its elevated and exposed situation, the climate of Madrid has some marked peculiarities. In winter the mean temperature is 43° Fahr., and as many as sixteen degrees of frost have been observed; the mean in summer is 76° Fahr., but a temperature of 107° has been registered; and the daily oscillation sometimes amounts to as much as 57°. The readings in sun and shade at the same moment are also widely different. The tendency to inflammatory disorders in the population is, as might be expected from these circumstances, very pronounced; but against it must be set the advantages of a dry atmosphere and a cloudless sky, and in point of fact the city is not exceptionally unhealthy; its salubrity has been much enhanced by the recent introduction of a plentiful supply of pure water from the Lozoya (32 miles distant).

The form of Madrid proper is almost that of a square with the corners rounded off; from east to west it measures rather less than from north to south. It was formerly surrounded by a poor wall, partly of brick, partly of earth, some 20 feet in height, and pierced by five principal gates (*puertas*) and eleven "portillos." Of these gateways only three, the Puerta de Alcalá on the east, the Puerta de Toledo on the south, and the Portillo de San Vicente on the west, now actually exist; the first and the third were erected in the time of Charles III., and the second in honour of the restoration of Ferdinand VII.; all have some architectural pretensions. The Manzanares (or rather its bed, for the stream is at most seasons of the year quite insignificant) is spanned by six bridges, the Puente de Toledo and that of Segovia being the chief. The Puerta del Sol (formerly the east gate and tower of the city, having on its front a representation of the sun—



Plan of Madrid.

whence the name) is now the central plaza, and the favourite lounge and place of most traffic in the city; the animated scene it presents has been described with more or less fulness in almost every book of Spanish travel. On its south side stands the Palacio de la Gobernacion, or Home Office, a heavy square building, by a French architect, J. Marquet, and dating from 1768. From the Puerta del Sol diverge, immediately or mediately, almost all the principal streets of Madrid—eastward by north, the Calle de Alcalá, terminating in the Prado; eastward, the Carrera de San Geronimo, terminating by the Plaza de las Cortes also in the Prado; southward, the Calle de Carretas; westward, the Calle Mayor, which leads to the council chamber and to the palace, and the Calle del Arenal, terminating in the Plaza de Isabel II. and the opera-house; north-westward, the Calles de Preciados and Del Carmen; and northward, the Calle de la Montera, which afterwards divides into the Calle de Fuencarral to the left and the Calle de Hortaleza to the right. Of these the Calle de Alcalá is the finest; it is bordered on both sides with acacias, and contains some elegant buildings, including the museum of natural history, formerly the general custom-house, dating from 1769, and the offices of the Board of Trade (Ministerio de Hacienda) on the north side, and on the south the palace of the duke of Sesto (the site of which is about to be occupied by the new buildings of the Banco de España or Bank of Spain); its irregularity in point of width and level, however, detracts much from its appearance. The Plaza de las Cortes is so called from the Congreso de los Diputados, or House of Commons, on its north side, a building in the Corinthian style, but of little merit; the square contains a bronze statue of Cervantes, by Sola, erected in 1835. The Calle de Carretas ranks with the Carrera de San Geronimo and Calle de la Montera for the excellence of its shops. From the Calle Mayor is entered the Plaza Mayor, a rectangle of about 430 feet by 330, formerly the scene of tournaments, bull fights, autos-de-fe, and similar exhibitions, which used to be viewed by the royal family from the balcony of one of the houses called the Panaderia (belonging to the guild of bakers). The square, which was built under Philip III. in 1619, is surrounded by an arcade; the houses are uniform in height and decoration. In the centre stands a bronze equestrian statue of Philip III., designed by Pantoja, cast by Juan de Bologna, and finished by Pedro Tacca. From the south-east angle of the Plaza Mayor the Calle de Atocha, one of the principal thoroughfares of Madrid, leads to the outskirts of the city; at the south-west angle of the same square the Calle de Toledo begins, the chief mart for the various woollen and silken fabrics from which the picturesque costumes peculiar to the peninsula are made. In the Plaza de Isabel II., at the western extremity of the Calle del Arenal, stands the royal opera-house, the principal front of which faces the Plaza del Oriente and the royal palace. In the centre of the plaza is a fine bronze equestrian statue of Philip IV.; it was designed by Velazquez and cast by Tacca, while Galileo is said to have suggested the means by which the balance is preserved. The gift of the grand-duke of Tuscany in 1640, it stood in the Buen Retiro gardens until 1844.

As compared with other capitals, Madrid has very few buildings of much interest architecturally or otherwise. There is no cathedral. The Basilica de Nuestra Señora de Atocha, on the Paseo de Atocha, a continuation of the Calle de Atocha, originally founded in 1523, after being destroyed by the French was rebuilt by Ferdinand VII.; it contains one of those miraculous images attributed to St Luke with which Spain abounds, and is specially associated in history with the name of Queen Isabella II. The collegiate church of San Isidro el Real, in the Calle de Toledo, dates from 1651; it has no architectural merit, but contains one or two valuable pictures and other works of art. The modern Gothic church of San Geronimo el Real occupies a conspicuous site eastward of the town; it is not at present used as a place of worship. Of secular buildings unquestionably the most important is the royal palace (Palacio Real) on the west side of the town, on a rising ground overhanging the Manzanares. It occupies the site of the ancient Moorish alcazar, where a hunting seat was built by Henry IV.; this was enlarged and improved by Charles V. when he first made Madrid his residence in 1532, was further developed by Philip II., but ultimately was destroyed by fire in 1734. The present edifice was begun under Philip V. in 1737 by Sacchetti of Turin, and was finished in 1764. It is in the Tuscan style, and is 470 feet square and 100 feet in height, the material being white Colmenar granite, resembling marble. To the north of the palace are the royal stables and coach-houses, remarkable for their extent; to the south is the armoury (Museo de la Real Armería), containing what is probably the best collection of the kind anywhere to be met with. After the Palacio Real may be mentioned the royal picture gallery (Real Museo de Pinturas), adjoining the Salon del Prado; it was built about 1785 for Charles III. by Juan de Villanueva, as a museum of natural history and academy of sciences. It contains the collections of Charles V., Philip II., and Philip IV., and the pictures number upwards of two thousand. The specimens of Titian, Raphael, Veronese, Tintoretto, Velazquez, Vandyck, Rubens, and Teniers are numerous and remarkable, giving it a claim to be regarded as the finest picture gallery in the world. The palaces of the grandees are generally noteworthy only for their size. There are some seventeen theatres of all classes. The bull-ring (Plaza de Toros), to the east of the town, accommodates 12,000 spectators; the present building dates from 1874. Of the promenades and open places of public resort the most fashionable and most frequented is the Prado (Paseo del Prado, Salon del Prado) on the east side of the town, with its northward continuation the Paseo de Recoletos. To the south of the town is the Paseo de las Delicias, and on the west, below the royal palace, and skirting the Manzanares, is the Paseo de la Virgen del Puerto, used chiefly by the poorer classes. Eastward from the Prado are the Buen Retiro gardens, with the usual ponds and pavilions, and a poor menagerie. The gardens were formerly the grounds surrounding a royal hunting seat, on the site of which a palace was built for Philip IV. in 1633; it was destroyed during the French occupation.

Modern educational movements have not left Madrid unaffected, and considerable improvements in this respect have taken place within recent years. There are upwards of 100 official primary schools (attended by 4810 boys and 3958 girls), and a large number of private ones; among the other educational instrumentalities the numerous schools connected with various Protestant missions claim special mention. There are two normal schools. The university of Alcalá, founded by Cardinal Ximenes in 1508, was transferred in 1836 to Madrid, and has since that time undergone much reform and extension. In 1882 the teaching staff numbered 88, and the students 7000. Of these 2400 belonged to the faculty of law, 2500 to that of medicine, 400 to that of science, 1400 to that of pharmacy, and 250 to that of philosophy and literature. The faculty of theology was suppressed in 1868, and has not been re-established. Madrid also has schools of agriculture, architecture, civil and mining engineering, the fine arts, veterinary science, and music. The school of military engineering is at Guadalajara. Among the educational institutions may be reckoned the botanical garden, originated in 1781, the national library, with those of the palace, the university, and San Isidro, and the museum of natural science, exceedingly rich in the mineralogical department. The principal learned society is the Royal Spanish Academy, founded in 1713 for the cultivation and improvement of the Spanish tongue. The Academy of History possesses a good library, rich in MSS. and incunabula, as well as a fine collection of coins and medals. There are likewise academies of the fine arts, the exact sciences, moral and political science, medicine and surgery, and jurisprudence and legislation, all possessing libraries. There are also anthropological, economical, and geographical societies, and a scientific and literary athenæum. The charitable institutions include upwards of eighteen hospitals, the largest of which contains 1200 beds; there are three foundling hospitals and six for orphans. The military hospital is large and well conducted. There are very good schools for the blind and for deaf mutes, and a number of asylums of various kinds.

The manufactures of Madrid are inconsiderable; every article of food and clothing, almost without exception, is imported. The most important industries are the manufactures of tobacco and cigars, gold and silver wares, tapestry and carpets, porcelain, hats, mirrors, and beer. Little wine is grown near the capital, and not much fruit; but the markets are well supplied, and regularly, from all quarters of the kingdom. Madrid is still the principal, one might almost say the only, focus of the now largely developed railway system of the peninsula. The suburbs of the town are rapidly extending, especially towards the north and south. The immediate environs are uninteresting. About 6 miles to the north-west lies the fine hunting seat El Pardo, restored by Charles III.

Spanish archæologists have frequently claimed for Madrid a very high antiquity, but the earliest authentic historical mention of the town (Majrít, Majoritum) occurs in an Arab chronicle, and does not take us farther back than to the first half of the 10th century. The place was finally taken from the Moors by Alphonso VI. (1083), and was made a hunting-seat by Henry IV., but first rose into importance when Charles V., benefiting by its keen air, made it his occasional residence. Philip II. created it his capital and "only court" (*única corte*) in 1560. To this day it only ranks, however, as "villa," not as "ciudad." Fruitless attempts were made by Philip III. and Charles III. respectively to transfer the seat of government to Valladolid and to Seville.

MADRIGAL. The notice of this branch of musical art which will be included in the general article MUSIC may here be anticipated by an approximately chronological list, according to nationalities, of the masters who have been chiefly distinguished for their compositions of the class:—*Flanders*: Egide Binchois, Brusnois, Jean Okeghem or Ockenheim, Jean Tinctor, Adrian Willaert, Cyprian di Rore, Jacques Hobrecht, Firmin Caron, Josquin des Près, Alexander Agricola, Antoine Brumel, Pierre de la Rue, Jacques Arcadelt, Claude Goudimel, Philippe Verdelot, Jacques de Wert, Hubert Waelrent, and Orlando di Lasso; *Rome*: Costanzo Festa, Giovanni Pierluigi da Palestrina, Felice and Francesco Anerio, Giovanni Maria, Bernardino Nanini, and Luca Marenzio (styled in his own time "Il più dolce Cigno d'Italia"); *Venice*: Giovanni Croce, Andrea and Giovanni Gabrielli, Costanzo Porta, Orazio Vecchi, and Giovanni Giacomo Gastoldi; *England*: William Cornyshe (father and son), Richard Taverner, Robert Fayrefax, Thomas Phelyppes, Richard Edwards, William Byrd, Thomas Morley, Giles Farnaby, Edward Johnson, Thomas Weelkes, George Kirbye, John Dowland, Michael Este, Thomas Tomkins, John Benet, John Hilton, John Wilbye, Thomas Ford, Thomas Bateson, Richard Allison, John Ward, and Orlando Gibbons, also John Cooper and Peter Philips, who dwelt long in Rome, and published their works under the names respectively of Giovanni Coperario and Pietro Filippi. Many of all these wrote strictly madrigals, that is, continuous compositions abounding in ingenious artifices of imitation of one part by another; others wrote rhythmical songs of four or more parts, or ballets, or fal-las, all of which, being for unaccompanied voices, or for viols instead of voices, are often erroneously ranked as madrigals, though differing entirely in structure from them. The English composers, to Byrd inclusive, produced pieces distinctly of the madrigal class, but described them by other definitions; it was in the year 1588, when Byrd published *Psalms, Sonets, and Songs of Sadness and Pietie*, that the word madrigal was first introduced into England by Nicholas Yonge, a merchant, a lover of music who, having received copies of some foreign compositions in his chests of merchandise, adapted English words to these, and printed a collection under the title *Musica Transalpina*, the success of which stimulated the powers of English writers that had already been proved, and excited others to emulate their example. The art of madrigal composition was never practised in Germany, and it died out in other countries early in the 17th century. The knowledge of the works that endear the madrigal writers to lovers of a high and most pure form of music was revived, and has since been kept alive, by the Madrigal Society. This was founded in 1741 by John Immyns, an attorney, and its original members were mechanics or small tradesmen; it held its first meeting at the Twelve Bells Tavern in Bride Lane, made many migrations to other houses of entertainment, and has its present home at the Freemasons' Tavern, where its members are of a far higher social caste than the men who associated themselves for the practice of contrapuntal vocal music when the rank and fashion of the land went to worship Farinelli at the Italian opera, and to take part with the followers of the king or the prince of Wales in supporting one or other of the opposition establishments for its performance. In 1811 the society offered a prize for the composition of a madrigal, which was won by William Beale. The same incentive has occasionally been repeated. This encouragement, and still more the love for the class of music engendered by the public performance of madrigals by large choral societies during the last fifty years, have incited later composers to more or less successful imitations of the style, especially distinguished among whom was Robert Lucas Pearsall (1795–1856).

MADURA, a district in the south of the Madras presidency, India, lying between 9° 4′ and 10° 44′ N. lat., and 77° 14′ and 79° 20′ E. long., is bounded on the N. by Coimbatore, Trichinopoli, and Tanjore districts, E. and S.E. by the sea, S.W. by Tinnevelli district, and W. by Travancore state. Broadly speaking, it consists of a section of the plain stretching from the mountains east to the sea, coinciding with the basin of the Vaigái river, and gradually sloping to the south-east. The plain is broken in the west by the outlying spurs of the Gháts, and by a few isolated hills and masses of rock scattered over the country. The most important spur of the Gháts is that known as the Palni hills, which project east-north-east across the district for a distance of about 54 miles. Their highest peaks are more than 8000 feet above sea-level, and they enclose a plateau of about 100 square miles in area, with an average height of 7000 feet. A sanatarium has been recently established on this plateau, at Kodáikanal, and coffee planting is here successfully carried on. Farther east a confused group of hills, known as the Sirumalais, the highest of which has an elevation of nearly 4000 feet, clusters round the village of Nattam. Among isolated rocks may be mentioned the precipitous fortress of Dindigal, and the "Elephant Rock," the "Cow Hill," and the sacred Skandamalia—all in the immediate vicinity of Madura town. The chief river is the Vaigái, which divides the district into two almost equal portions. Very little forest is found in any part of the district. The cultivated plain is absolutely barren of trees, except where a newly-planted avenue marks a line of road. Groves of palmyra and cocoa-nut palms flourish along the sea-coast and river banks. Among the wild products of the Palni hills are nutmeg, cinnamon, and pepper. The predominant geological formation is granite. Syenite occurs in large boulders. A gravelly bed of laterite, which runs across the district, is quarried for building purposes; and sandstone is said to extend along the whole length of the sea-coast. Mineral products include saltpetre, salt, lime, chalk, and graphite. Iron in various forms is found, but it is nowhere worked profitably, even by the rude native processes. Gold is washed in some of the streams. Several kinds of opal, chalcedony, jasper, garnet, and rock-crystal are found.

The census of 1871 showed a total population of 2,266,615 persons (1,112,066 males and 1,154,549 females), spread over an area of 9502 square miles, and inhabiting 5459 villages and 443,513 houses. Hindus numbered 2,062,768, and Mohammedans 132,833; and the Catholics at the present day number about 60,000, under the charge of the missions of the Jesuits and of the Church of Goa. The Protestant population are under the charge of an American mission, first established in 1834. The principal towns are Madura city (51,987), Dindigal (12,818), Palni (12,801), Rámnád (15,442), Tirumangalam (5772), Parambakudi (6284), Sivagangá (7392), Killakarai, Aruppukotai, and Periyakulam. The only municipalities are Madura and Dindigal.

Of a total area of 9502 square miles, 6507 belong to *zamíndári* or permanently assessed estates. The total area of Government lands in occupation in 1875–76 was 1,013,000 acres, of which 806,630 were under cultivation. The chief food crops are rice, *cholam* (*Holcus saccharatus*), *kambu* (*Holcus spicatus*), *ragí* (*Eleusine coracana*), *varagu* (*Paspalum frumentaceum*), *samái* (*Panicum miliaceum*), and several kinds of pulses. Other crops include oil-seed, tobacco of excellent quality, and a little indigo and cotton. The rainfall is small and variable in its seasons. Every possible means of storing up surplus water has been resorted to from time immemorial. An important engineering project, known as the Periyár scheme, has long been under consideration, by which the abundant rainfall on the farther slope of the Travancore hills might be diverted into the drainage basin of the Vaigái. Salt is manufactured at certain stations on the coast as a Government monopoly. Handsome turbans fringed with gold cloth, and a peculiar kind of red cloth, are specialities of Madura town. Considerable sea-borne trade is carried on by native craft, chiefly with Ceylon. Rice and other food grains, gingelly oil, spices, cloth, salt fish, tobacco, red ochre, and earthenware are the principal exports. The district is traversed by the South Indian railway from Tinnevelli to Trichinopoli. The total imperial revenue in 1875–76 amounted to £393,448, of which £280,067 was derived from the land. Education in 1876–77 was afforded by 424 schools, attended by 12,509 pupils. Besides ordinary diseases, Madura possesses three special scourges:—endemic fever, which sometimes rages with exceptional severity; cholera, disseminated by pilgrims to the sacred temple at Rámeswaram; and the well-known "Madura foot." This last complaint, known to science as *morbus pedis entophyticus*, is a species of fungus which spreads over the whole foot in a mass of tubercles. Its primary cause seems to be unknown.

History.—Madura was the seat of the Pandian monarchy, which ruled over this part of India from the 5th century B.C. to the end of the 11th century of our era. The last of the Pandiá kings is said to have exterminated the Jains, and conquered the neighbouring kingdom of Chola; but he was in his turn overthrown by an invader from the north, conjectured to have been a Mohammedan. In 1324 a Moslem army under Malik Kafur occupied Madura, and the Hindus were held in subjection for a period of fifty years. Subsequently Madura became a province of the Hindu empire of Vijáyanagar. In the middle of the 16th century the governor Viswanáth established an hereditary rule which lasted for a century. The greatest of the line was Tirumala Náyak (1623–1659), whose magnificence and military exploits are recorded in the contemporary letters of the Jesuit missionaries. He adorned Madura with many public buildings, and extended his empire over the adjoining districts of Tinnevelli, Travancore, Coimbatore, Salem, and Trichinopoli. His repudiation of the nominal allegiance paid to the rájá of Vijáyanagar brought him into collision with the sultán of Bijápur, and Mohammedans, after the lapse of three centuries, again invaded Madura, and compelled him to pay them tribute. After the death of Tirumala the kingdom of Madura gradually fell to pieces. In 1740 the district fell into the hands of the nawáb of the Carnatic, and the line of the Náyaks was extinguished. In 1762 British officers took charge of Madura, in trust for Wallah Jah, the last independent nawáb of the Carnatic, who finally ceded his rights of sovereignty to the East India Company in 1801.

MADURA, the chief town and headquarters of Madura district, is situated on the south bank of the Vaigái river in 9° 55′ 16″ N. lat., and 78° 9′ 44″ E. long., with a population (1871) of 51,987, being the fourth largest town in the Madras presidency. Its principal architectural feature is the great temple, forming a parallelogram 847 feet by 744 feet, surrounded by nine gopuras, one of which is 152 feet high. The principal structure is the "Hall of a Thousand Pillars" (the actual number being 997). The other buildings comprise the celebrated palace of Tirumala Náyak, the most perfect relic of secular architecture in Madras. Its ruins cover a large area of ground, and a considerable sum of money has been recently assigned by Government for the restoration of the building. Only second in importance to the palace is the Vasanta or Puthu *mantapam*, which still exists in complete preservation, and is said to have been built as a summer retreat for the god Sundareshwara, a form of Siva. On the opposite bank of the river is the Tamakam, a two-storied building of quaint architecture, said to have been erected as a stand from which to view sports and combats. Last is the Teppukulam or great tank, situated 1½ miles to the east of the town, and measuring 1200 yards each way. Once a year its banks are illuminated by (it is said) 100,000 lamps, while the idols from the pagoda are drawn round it on a *teppam* or raft.

MADURA, in High Javanese *Madunten*, an island of the East Indian Archipelago, separated by the shallow Strait of Madura from the east end of Java. It extends from about 112° 32′ to 114° 7′ E. long., and is divided into two nearly equal portions by the parallel of 7° S. lat.; the area is estimated at 2100 square miles. As the few travellers who have visited Madura have been for the most part content to follow the highways which, though running the whole length of the island, never strike very far inland either from the north or the south coast, a considerable part of the country is but vaguely known to Europeans. It may be safely asserted, however, that the general configuration is fairly simple,—the island being a plateau-like prolongation of the limestone range of northern Java, with frequent interchange of hill and dale, culminating towards the east in Gunong Pedjudan or Tambuko at a height of 1542 feet. Hot springs are not unfrequent; and in the valley between Gunong Geger and Bandjar lies the mud volcano of Banju Ening. "Round the coast runs a girdle of tropical vegetation, broken only here and there by small white peaks with steep perpendicular cliffs;" but, except in a few alluvial tracts in the lower courses of the streams, the soil is thin and poor, and better fitted for pastoral than agricultural purposes. Maize is by far the most important of the crops; it is planted after rice in the non-irrigable sawahs, and often before it in the irrigable; in the tagal fields it is sometimes sown thrice in a single year, frequently along with *katjang* (various kinds of native beans). European enterprise has not yet invaded the island; there is only one sugar plantation, Tedjeh, near Pamakasan, established in 1835. Much attention is paid to the rearing of cattle,—the small Madura oxen being greatly prized in Java, and consequently forming a regular article of export. Petroleum is found in small quantities in all the departments, but the most valuable product of the island is its salt (hence perhaps the name Madura; Sansk. *Mandura*, salt). The manufacture, a Dutch Government monopoly, was formerly carried on in several places, as at Brantah and Bunder (where the salt pans now serve as fish ponds), but in 1870 Sumenep was made the sole establishment for Java and Madura, and it still remains by far the most important, though its annual production of 875,000 cwts. has since 1875 to be supplemented by Ragung and Pangaringan. The population of Madura was in 1879 returned as 768,992,—472 Europeans (mostly at Maringan near Sumenep), 3702 Chinese, 1445 Arabs and other Orientals, and 763,373 natives. These last constitute one of the three great races of Java and Madura, and speak a distinct language, for which compare JAVA, vol. xiii.

The following are the places of chief note in the island. Kamal at the south-west corner is the point where people usually cross from Java. Bangkalang is the large and flourishing chief town of Madura proper, with the old palace of the sultan and the residences of the princes of the blood; the mosque is adorned with the first three suras of the Koran, thus differing from nearly all the mosques in Java and Madura, though resembling those of western Islam. In the vicinity once stood the Erfprins fort. Arisbaya (less correctly Arosbaya) is the place where the first mosque was built in Madura, and where the Dutch sailors first made acquaintance with the natives. The once excellent harbour is now silted up. Ajermata, so called from its salt-springs, is the burial-place of the princes of Bangkalang. Pamakasan, though a town of considerable extent, presents nothing worthy of notice apart from the regent's residence. Sampang, the seat of an important market, seems hardly so flourishing as in Valentyn's days. The town or *kota* of Sumenep had 15,000 inhabitants in 1846; and there are populous Malay, Arab, and Chinese villages between the town and the European settlement of Maringan. On a hill in the neighbourhood, with a fine outlook over the Bay of Sumenep, lies Asta, the burial-place of the Sumenep princes; and Nâta Kusuma's mausoleum excels everything of the kind in Java.

Madura formerly consisted of three native states—Madura or Bangkalang, Pamakasan, and Sumenep. Dutch authority was represented by an assistant resident, and the whole island considered part of the Java residency of Surabaya. The separate residency of Madura was constituted in 1857. On the death of the second sultan of Bangkalang (1847) the title had been reduced to that of panembahan;

and in 1872 the new ruler was deprived of the right of collecting taxes, and made a Government pensioner, while his territory was split into the two Dutch "departments" of Madura and Sampang. The sultan of Sumenep was in like manner succeeded by a panembahan in 1853; and the death of the panembahan in 1879 afforded an opportunity of enlarging the Government control. There are thus four "departments" in Madura,—Pamakasan, Madura, Sumenep, and Sampang. The first three are also regencies, and the fourth a subregency of Bangkalang; but Pamakasan alone has the full regency organization. The number of village communities is 1271.

The best systematic account of Madura will be found in Professor Veth's *Java*, vol. iii., the proof sheets of which have, by the author's courtesy, been consulted for this article. See also Bleeker, in *Indisch. Archief.*, i., and *Tijds. van Ned. Ind.*, ix.; C. de Groot in *Nat. Tijds. van Ned. Ind.*, iv.; Hoevell, *Reis over Java*, ii.; Zollinger, "Jets over de Nat. geschied. van Madura," in *N. Tijds. van Ned. Ind.*, xvii.; Jukes, *Voyage of the "Fly"*; and Hageman in *Tijds. van Ned. Ind.*, 1858.

MÆCENAS, C. CILNIUS, is, from two different points of view, a prominent representative man of the ancient world. He was the first, and one of the most capable and successful, of those who filled the office of a great minister under the Roman empire. He was also, if not the first, certainly the most fortunate and influential among the patrons of Roman literature. It is in the latter capacity that he is best known. Among all the names, royal, noble, or otherwise eminent, associated with the patronage of letters, none either in ancient or modern times is so familiarly known as that of Mæcenas. Yet, if we had any contemporary history of the establishment of the empire, possessing the same permanent interest which the poetry of Virgil and Horace possesses, it is probable that his influence in shaping the political destinies of the world would have been as amply recognized as his influence on its literature.

The date and place of his birth are unknown. He first appears in history in the year 40 B.C., when he is employed by Octavianus in arranging his marriage with Scribonia, and afterwards in negotiating, along with Pollio and Cocceius Nerva ("aversos soliti componere amicos," Hor., *Sat.*, i. 5, 28), the peace of Brundisium, and the reconciliation with Antony, which was confirmed by the marriage of the latter with Octavia. From the fact that he was then the most trusted friend and agent of the future emperor it is likely that he had been associated with his fortunes from the time when he came forward to claim his inheritance after the death of Julius Cæsar; and expressions in Propertius (ii. 1, 25–30) seem to imply that he had borne some share in the campaigns of Mutina, Philippi, and Perusia. He may have been a few years older than Octavianus, who began to play the foremost part in Roman politics before he was twenty years of age. The men of the Augustan age great in action and literature were all born within a few years of one another. Agrippa, the right hand of Augustus in war as Mæcenas was in peace, was born in the same year as his master; and there is no indication in the relations of Mæcenas to Augustus or to his friend Horace that he stood towards either of them in the relation of an older to a younger man. Although the place of his birth is unknown, we learn from Horace and Propertius that he prided himself on his ancient Etruscan lineage, and claimed descent from the princely house of the Cilnii, who, as is recorded by Livy (x. 3), excited the jealousy of their townsmen by their preponderating wealth and influence at Arretium in the 4th century before our era. He probably prized the glories of his paternal and maternal ancestry (Hor., *Sat.*, i. 6, 3) as compensating him for his original social inferiority to the members of the great Roman houses; and the fact dwelt on so prominently by his panegyrists, that, through all his life, he preferred the position of a great commoner to the new honours of the senate and of the Roman magistracies, may have been the result as much of pride in his provincial ancestry as of a politic desire to disarm the jealousy of his master or of the Roman aristocracy. Cicero, in his defence of Cluentius, speaks of a C. Mæcenas as one of the most substantial members of the equestrian order during the tribunate of Drusus (91 B.C.), and as one of those who preferred the position their fathers had enjoyed before them to the higher rank obtainable through office (Cic., *Cluent.*, 56, 153). From the identity of the *prænomen* and the rarity of the *cognomen* it is not unlikely that he may have been the grandfather, or perhaps the father, of the future minister. It was in accordance with the policy of Julius Cæsar to choose his confidential friends from men of this order, as he chose his tools from a less reputable class; and the two most trusted friends and ministers of his successor would both have been regarded as "novi homines" by the representatives of the great senatorian families. The testimony of Horace (*Odes*, iii. 8, 5) and his own literary tastes imply that he had profited by the highest education of his time. His great wealth may have been in part hereditary, as there was no district of Italy in which the inequalities of wealth and station were greater than in Etruria;[1] but he owed his position and influence in the state to his early adherence to and close connexion with Augustus. Among the charges brought against him by Seneca, one of the most prominent is that he had been spoiled by his excessive good fortune.

From the year 40 B.C. his influence as the confidential adviser of Octavianus seems to have been thoroughly established. It was in the following year that Horace was introduced to him, and he had before this received Varius and Virgil into his intimacy. In the "Journey to Brundisium," which took place in the year 37 B.C., Mæcenas and Cocceius Nerva are described as "missi magnis de rebus uterque Legati," and were again successful in patching up, by the treaty of Tarentum, a reconciliation between the two claimants for supreme power. During the Sicilian war against Sextus Pompeius in 36 B.C., he was sent back to Rome, and was entrusted with supreme administrative control in the city and in Italy. He is again found acting as vicegerent of Octavianus during the campaign of Actium, when with great promptness and secrecy he crushed the conspiracy of the younger Lepidus; and during the subsequent absences of his chief in the provinces he held the same position. During the latter years of his life he fell somewhat out of favour with his master, or his services were less needed. Perhaps the freedom with which, in the earlier stages of his career, he had offered advice and told unpleasant truths had become distasteful. One cause for a comparative coolness between the old friends was said to be the emperor's relations with Terentia, the wife of Mæcenas, to whom he was uxoriously attached. Perhaps the ennui resulting from the cessation of a life of constant vigilance and activity may account for the state of sleepless restlessness and fever in which he passed the last three years of his life. He died in the year 8 B.C., leaving the emperor heir to his wealth, and affectionately commending his friend Horace, who only survived him a few days, to his protection.

Opinions were much divided in ancient times as to the personal character of Mæcenas; but the testimony as to his administrative and diplomatic ability was unanimous. He enjoyed the credit—or discredit, as the adherents of the republic must have regarded it—of sharing largely in the establishment of the new order of things,[2] of reconciling parties, and of carrying the new empire safely through many dangers. To his influence especially was attributed

[1] The lines of Propertius (iv. 8, 27–8)—

> Et tibi ad effectum vires det Cæsar et *omni*
> *Tempore tam faciles insinuentur opes*—

show that his position under the empire also brought very substantial additions to his original fortune.

[2] This is implied by the long speech which Dion Cassius puts into his mouth, recommending the establishment and prompting the policy of the new empire (Dion Cass., lii. 14–40).

the humaner policy of Octavianus after his first alliance with Antony and Lepidus. Even Seneca, who shows a very bitter animus against him, admits that he deserved the credit of clemency,—although he attributes it to effeminacy rather than to true humanity. The highest tribute paid to him in his capacity of minister is to be found in the least eminent of the poets whose genius he fostered. "The true trophies of Mæcenas," says Propertius, "will be his loyalty."[1] And in another elegy he addresses him as "fidele caput." One great testimony both to his loyalty and to his tact is the saying of Augustus, when he had made public the scandal concerning his daughter Julia, "that all this would never have happened if Agrippa or Mæcenas had lived" (Sen., *De Ben.*, vi. 32). The only instance in which he is said to have acted with indiscretion as a minister was in his betrayal to his wife Terentia of his knowledge of the conspiracy in which her brother Licinius Muræna was involved.

The best summary of his character as a man and a statesman is that of Velleius (ii. 88), who describes him as "in critical emergencies of sleepless vigilance far-seeing and knowing how to act, but in his relaxation from business more luxurious and effeminate than a woman." The latter is the aspect of his character on which Seneca chiefly dwells. He draws attention to the enervating effect which his good fortune had even on his literary style. We need not ask how far "the stately mansion on the Esquiline" outdid in luxury the "gardens of Seneca the millionaire" ("Senecæ prædivitis hortos").[2] Mæcenas was certainly a man who combined an epicurean love of pleasure with a thorough devotion to business; and verses of his own are quoted against him indicative of an unmanly clinging to life after the loss of all that makes life valuable. These may have been written in the feverish unrest of his last years, when he was no longer himself; but expressions in the *Odes* of Horace (ii. 17, 1), written at a much earlier period, seem to imply that he was deficient in the robustness of fibre characteristic of the average Roman. His style of dress and his indolent lounging walk exposed him to animadversion; and the Maltinus of Horace's *Satires* (i. 2, 25) was supposed by some ancient commentators to be a sketch of the great man, drawn before the poet was admitted to his intimacy. Probably there may have been some affectation or politic dissimulation in this assumption of a character so alien to the standard of the aspirants to public honours at Rome. It was an exaggerated form of that indifference to appearances and conventionalities which made him satisfied with the position of an eques, and induced him to choose his intimate associates from poets of obscure and provincial origin. His ambition was to be the second man in the empire, and to enjoy the reality without the show of power. A similar character is attributed by Tacitus to Sallustius Crispus, who, after the death of Mæcenas, most enjoyed the favour of Augustus.

His character as a munificent patron of literature is not only acknowledged gratefully by the recipients of it in his own time, but is attested by the regrets of the men of letters of a later age, expressed through the mouths of Martial and Juvenal. His patronage was exercised, not from vanity or a mere dilettante love of letters, but with a view to the higher interest of the state. He recognized in the genius of the poets of that time, not only the truest ornament of the court, but a power of reconciling men's minds to the new order of things, and of investing the actual state of affairs with an ideal glory and majesty. The change in seriousness of purpose between the *Eclogues* and the *Georgics* of Virgil was, in a great measure, the result of the direction given by the statesman to the poet's genius. A similar change between the earlier odes of Horace, in which he declares his epicurean indifference to affairs of state, and the great national odes of the third book is to be ascribed to the same guidance. He endeavoured also to divert the less masculine genius of Propertius from harping continually on his love to themes of public interest.

But, if the motive of his patronage had been merely politic, it never could have inspired the affection which it did in its recipients. The great charm of Mæcenas in his relation to the men of genius who formed his circle was his simplicity, cordiality, and sincerity. Although not particular in the choice of some of the associates of his pleasures, he admitted none but men of worth to his intimacy, and when once admitted they were treated like equals. That loyalty which was his own distinction in his public life was, if we may trust the evidence of Horace, the characteristic of his own relations to his intimates, and of their relations to one another. But, while loyal to all, to Horace he was bound by a closer tie. Among the great friendships of history, none is more certainly attested, or more honourable to both parties, than that between the poet and the statesman. Much of the wisdom of Mæcenas probably lives in the *Satires* and *Epistles* of Horace. It has fallen to the lot of no other patron of literature to have his name associated with works of such lasting interest as the *Georgics* of Virgil, the first three books of Horace's *Odes*, and the first book of his *Epistles.* Such a fortune can scarcely have been altogether undeserved. Accepting as literally true the disparaging statements of Seneca, admitting the weakness, and perhaps the vanity, which were the blots in his character, and considering at the same time the difficulties of an unprecedented position, we must allow that few ministers of an irresponsible monarch have accomplished so much with such immunity from the baser and more violent passions, for the gratification of which that position holds out unlimited opportunities. As a minister and friend of the emperor he compared favourably, both as regards capacity and character, not with men of the stamp of Sejanus and Tigellinus, but with Seneca. Few men have used the influence of a grand seigneur with such enlightened beneficence, with such lasting results on human culture and civilization, with such genuine simplicity and cordial loyalty. (W. Y. S.)

MAESTRICHT, or MAASTRICHT, the chief town of the province of Limburg, in the Netherlands, lies, as the name expresses, at the *trecht* or crossing of the Maas (Meuse), where the Romans erected a military post on the road between Bagacum (Bavay) and Colonia Agrippina (Cologne). Aix-la-Chapelle is 18 miles east-south-east, and Liége 18 miles south by west. The baths discovered in 1840 in the Groote Stokstraat show that the settlement at Trajectum ad Mosam became a place of some considerable importance. The town is divided by the river into two parts—the larger portion, or Maestricht proper, on the left bank, and the smaller portion, distinguished as Wijk, on the right. A stone bridge of eight arches connecting the two took the place of a wooden structure as early as 1280, and was greatly improved in 1828 and 1836. Formerly a fortress, Maestricht is still a considerable garrison town, but its ramparts were dismantled 1871–78; formerly the seat of a bishop, it still bears a strongly Roman Catholic impress; and, in modern times more especially, it has developed into a great centre of commerce and industry. The churches and religious foundations are almost the only buildings of note, the chief exceptions being the town-house, completed in 1683, and the solitary Protestant church, Janskerk (13th century). The church of St Servatius was, according to one account, rebuilt and enlarged as early as the time of Charles the Great. It is now 260 feet in length, and

[1] Propert., *El.* iv. 9, 34; ii. 1, 36. [2] Juv. x. 16.

in the varied character of its Gothic architecture bears evidence of the frequency with which it has been restored and altered. The high altar has a Descent from the Cross by Anthony Vandyck. The saint whose name it preserves obtained great reputation in Maestricht by transferring his bishopric thither from Tongres, and his miracle-working relics became the occasion of a great septennial fair which was formerly of great service to the city. The Church of Our Lady (Lieve-Vrouwe-kerk), possibly founded in the 6th century, has two very ancient crypts and an 11th century choir of exceptional beauty, but in the nave has suffered severely from a restoration in 1764. St Matthyskerk was founded by the cloth-weavers' guild in the 13th century; and, though the present Gothic building of St Martin's (in Wijk) was erected so late as 1859, the original church was one of the oldest in the city, and is said by tradition to have occupied the site of one of the old heathen temples. The twelve hospitals, the poor-house, the orphanage, and most of the other charitable foundations are Roman Catholic institutions, and neither the administrative bodies nor the educational establishments are free from ecclesiastical influence. Though Maestricht is no doubt mainly indebted for its commercial prosperity to its position on the river, it did not begin to reap the full advantages of the situation till the removal of the fortifications and the opening of the railways (Aix-la-Chapelle, 1853; Hasselt, 1856; Liége, 1861; Vanlo, 1865, &c.). At first a trade was carried on in wine, colonial wares, alcoholic liquors, and salt; but now, besides Regout's well-known earthenware, glass, and crystal factory, there are establishments for the making of arms, tools, lead, copper, and zinc work, &c., as well as tobacco and cigar factories. The Maestricht beer also is highly esteemed. The population, which was 18,000 in the beginning of the century, was 28,917 on January 1, 1882.

Maestricht was taken and plundered by the Normans (881 and 884), by Bishop Henry of Guelders (1267), by Adolph de la Marck (1334), and by the people of Liége (1407 and 1408). In the war with Spain it was successively besieged by the Spaniards, the prince of Orange, Prince Maurice, and Frederick Henry (1579, 1580, 1594, 1632); and in the struggle between Louis XIV. of France and William III., and again during the French Revolution and the Napoleonic period, it paid the penalty of its frontier position—witness the sieges of 1673, 1676, 1701, and 1793. During the revolution of 1830 it was invested by the Belgians. Among the more peaceful memories of the place is the marriage of Otto IV. with Mary of Brabant. The people of Maestricht have a special dialect of their own;[1] but French and Dutch are in use among the upper classes. In the neighbourhood of the town are the great sandstone quarries of Petersberg, one of the most extraordinary labyrinths of subterranean excavation in the world.

MAFFEI, Francesco Scipione, Marchese di (1675–1755), Italian archæologist and man of letters, was born at Verona on June 1, 1675. He studied for five years in Parma at the Jesuit college, and afterwards from 1698 at Rome; and in 1703-4 he took part as a volunteer in the war of succession, fighting on the Bavarian side at Donauwerth. In 1709 he began at Padua along with Apostolo Zeno and Valisnieri the *Giornale dei letterati d'Italia*, a literary periodical which had but a short career; and subsequently an acquaintance with the actor Riccoboni led him to exert himself for the improvement of dramatic art in Italy. His *Merope*, a tragedy, appeared in 1713; *Teatro Italiano*, a small collection of works for presentation on the stage, in 1723–25; and *Le Ceremonie*, an original comedy, in 1728. From 1718 he became specially interested in the archæology of his native town, and his investigations resulted in the valuable *Verona Illustrata* (1731–32). Maffei afterwards devoted four years to travel in France, England, Holland, and Germany. He died at Verona on February 11, 1755. A list of his very numerous works will be found in the *Biographie Générale*. A complete edition of them appeared at Venice (28 vols. 8vo) in 1790.

[1] While the North Limburg dialects, says Professor Gallée of Utrecht, are largely corrupted with Dutch forms and words, the Maestricht or South Limburg dialect (to which those of Hasselt, St Fruiden, and Sittand are nearly akin) has remained comparatively free from such admixture. Its phonology is peculiarly interesting both in itself and because its history can be traced to an early date by authentic documents. The Old Frankish psalms and the Limburg sermons are written in it; and it was also the original dialect of the St Servatius Legend (ed. by Bormanns) now transcribed in the Belgian Limburg dialect, and of Veldeke's *Æneid* (ed. by Behoghel), now in Middle High German. About these works consult Cosyn, *Taal en letterbode* iii., v., vi.; and in regard to the modern dialect Mone's *Anz. für Kunde der teutschen Vorzeit*, 1836; *Belgisch. Museum*, iii.; Franquinet in Jager's *Archief*, iii.; and Winkler's *Nederduitsch en Friesch dialecticon* i. Specimens will be found in Firmenich's *Völkerstimmen* and Leopold's *Van de Schelde tot de Weichsel*.

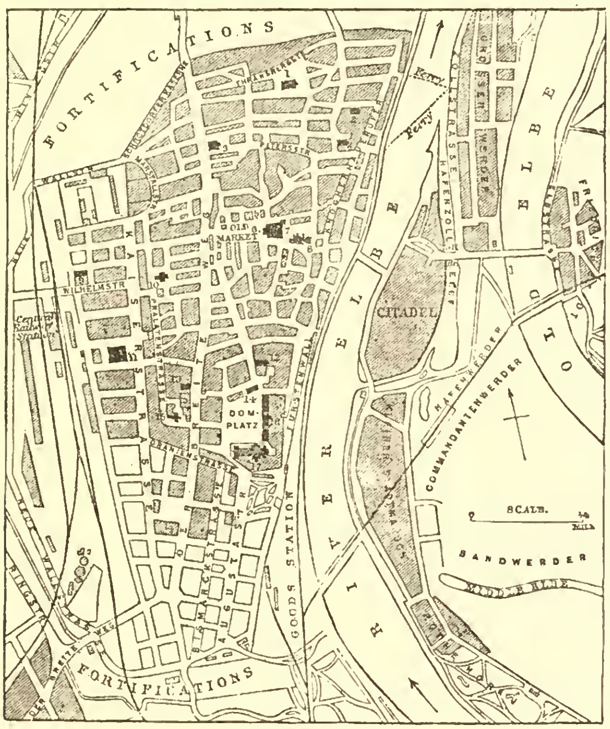
MAFRA, a town of Portugal, in the province of Estremadura and district of Lisbon, lies near the Atlantic coast, about 20 miles to the north-west of Lisbon, and had a population in 1878 of 3231. It is remarkable for its cloister-palace, built by John V. in 1717–32, in consequence of a vow made during a dangerous illness to build a convent for the poorest friary of the kingdom,—which proved to be a small Franciscan settlement here. The architect, Ludovici, took the Escorial for his model; but the imitation is still less successful than the original. The building, which is in the form of a parallelogram measuring upwards of 800 feet from north to south and 700 feet from east to west, is said to contain 866 rooms, and to be lighted by no fewer than 5200 windows. The centre is occupied by the domed church, sumptuously built of marble, and richly adorned with statues and other objects of art. The conventual buildings (which are no longer used as such) contain 300 cells; and the library numbers 30,000 volumes. Adjoining the palace are fine gardens and pleasure grounds.

MAGDALA (more correctly *Makdala*), a natural stronghold in the country to the south of Abyssinia, situated about 200 miles inland from the Gulf of Aden, in 11° 22′ N. lat. and 39° 25′ E. long. The basaltic plateau of which it consists rises 9110 feet above the level of the sea, and forms along with the neighbouring height of Salassye (9160 feet), with which it is connected by the ridge of Salamgye (8650 feet), a comparatively small and narrow outrunner of the Amara Seint plateau. It is about three quarters of a mile in length by less than half a mile in breadth, and lies more than a thousand feet higher than the neighbouring plain of Arogye. To the south runs the Kukullo Ravine and to the north and the west the Bashilo and the Wark Waha Ravines, all of which ultimately drain into the Abai, and thus belong to the basin of the Nile. Chosen by King Theodore of Abyssinia as his principal stronghold in the south, Magdala owes its celebrity to the fact that, as the place of imprisonment of the English captives, it became the goal of the great English expedition of 1868. At the time of its capture it contained huts for a permanent population of about three thousand, a royal residence of the most meagre pretensions, a still more insignificant church, and a large treasure-house stored with arms, ecclesiastical furniture, and vast quantities of Abyssinian manuscripts. The whole rock was burned bare by order of Sir Robert Napier, and on the departure of the English it was seized by Mastwat, queen of the Wollo Gallas, in whose country it is situated.

See Markham, *History of the Abyssinian Expedition*, 1869; and Rassam, *British Mission to Theodore*, 1869. Both contain plans and views of Magdala.

MAGDEBURG, the capital of the Prussian province of Saxony, and one of the strongest fortresses in Germany, is situated in 52° 8′ N. lat. and 11° 40′ E. long., mainly on the left bank of the Elbe, which here divides into three branches. It consists of the town proper and of the four suburbs of Friedrichstadt, Neustadt, Sudenburg, and

Buckau; the last three of these are separated from the town by the ramparts and glacis, but are all included within the new line of advanced bastions. In the Elbe, between the old town and the Friedrichstadt, lies an island called the Werder, occupied by the citadel, and united with both banks by bridges. With the exception of the Breiter Weg, a handsome thoroughfare running from north to south, the streets of the town proper are narrow and crooked. Along the Elbe, however, extends a fine promenade named the Fürstenwall, at one end of which stands a monument in commemoration of the Franco-German war. To the south of the inner town is the Friedrich-Wilhelm's Garten, a beautiful park laid out on the site of the celebrated convent of Bergen, which was founded in 937 and suppressed in 1810. By far the most important building in Magdeburg is the cathedral, a handsome and massive structure of the 13th and 14th centuries, exhibiting an



Plan of Magdeburg.

1. St James's Church.
2. Walloon Church.
3. St Catherine's.
4. St Peter's.
5. Statue of A. W. Franke.
6. Statue of Otho the Great.
7. Rathhaus.
8. St John's Church.
9. School of Art.
10. St Ulrich's Church.
11. Town Theatre.
12. St Mary's (Liebfrauenkirche).
13. Dutch Reformed Church.
14. Higher Courts.
15. Post-Office.
16. Government Buildings.
17. Cathedral.

interesting blending of Romanesque and Gothic architecture. The two fine towers were completed about 1520. The interior contains the tombs of the emperor Otho the Great and his wife Editha, an English princess, and the fine monument of Archbishop Ernest, executed in 1497 by Peter Vischer of Nuremberg. The Liebfrauenkirche, the oldest church in Magdeburg, is an interesting Romanesque edifice of the 12th and 13th centuries. The chief secular buildings are the town hall, built in 1691 and enlarged in 1866, the theatre, the governor's house, the central railway station, and the exchange. The Breiter Weg and the old market contain numerous fine private houses in the style of the Renaissance. In front of the town-hall stands an equestrian statue of the emperor Otho the Great, erected towards the close of the 13th century. The favourable situation of Magdeburg, in the very heart of Germany, and on the Elbe below all its principal affluents, has made it one of the most important commercial towns in the empire, and it is also the focus of several important railways. The chief articles of commerce are agricultural and colonial products, manufactured goods, and wine. The town and its suburbs contain numerous manufactories of woollen, cotton, and silk goods, sugar, spirits, tobacco, organs and pianos, chocolate, and chicory. Magdeburg is the head-quarters of the 4th corps of the German army, and the seat of the provincial court of appeal and administrative offices, of a Lutheran consistory, and of a superintendent general of the Evangelical (Reformed) Church. It also contains two gymnasia, two "Realschulen," schools of art, medicine, surgery, and mining, and numerous scientific and charitable institutions. The population of Magdeburg in 1880 was 97,539, or, including Neustadt and Buckau, 137,109.

Magdeburg, which was in existence as a small trading settlement at the beginning of the 9th century, owes its early prosperity chiefly to the emperor Otho I., who established a Benedictine convent here in 937 (see above). In 968 it became the seat of an archbishop, who was also primate of Germany, and exercised sway over an extensive territory. By the 13th century Magdeburg had become a flourishing commercial town and an important member of the Hanseatic League. Its bench of sheriffs (*Schöppenstuhl*) became celebrated, and "Magdeburg law," securing the administrative independence of municipalities, was adopted in many parts of Germany, Poland, and Bohemia. During the Middle Ages the citizens were almost constantly at variance with the archbishops, and by the end of the 15th century had become nearly independent of them. It should, however, be noted that Magdeburg never became a free city of the empire. The town embraced the Reformation in 1524, and was thenceforth governed by Protestant administrators or archbishops. On the refusal of the citizens to accept the "Interim," Magdeburg was besieged by Maurice of Saxony in 1550, and capitulated in 1551 on favourable terms. During the Thirty Years' War the city was twice besieged, and suffered terribly. It successfully resisted Wallenstein for seven months in 1629, but was stormed and sacked by Tilly in 1631. The whole town, with the exception of the cathedral, the Frauenkirche, and about 140 houses, was burned to the ground, and 30,000 of its 36,000 inhabitants were butchered without regard to age or sex. The town recovered from this deadly blow with wonderful rapidity. In 1648 the archbishopric was converted into a secular duchy, to fall to Brandenburg on the death of the last administrator, which happened in 1680. In 1806 Magdeburg was taken by the French and annexed to the kingdom of Westphalia, but it was restored to Prussia in 1814, on the downfall of Napoleon. Otto von Guericke, the inventor of the air-pump, was burgomaster of Magdeburg at the time of Tilly's siege. Carnot died here in exile, and is buried in the cemetery, and Luther was at school here and sang in the streets for bread with other poor choristers.

See Rathmann, *Geschichte der Stadt Magdeburg*, 1800–17; Hoffmann, *Chronik der Stadt Magdeburg*, 1843–50; Barthold, *Geschichte der deutschen Städte*, 1850.

MAGELLAN, Ferdinand, in Portuguese Fernão de Magalhães (*c.* 1470-1521), who, though he did not survive to return home with his ship, well deserves the title of the "first circumnavigator," was born about 1470, and (according to the somewhat questionable authority of his will, dating from 1504) at Villa de Sabroza in the district of Villa Real, Traz os Montes. His family was "hidalgo," and he seems to have spent his boyhood in the household of Queen Leonora, consort of John II. of Portugal. For several years he was in active service in the East Indies. It was he who, in 1510, gave Siqueira timely warning of the plot of the people of Malacca, thus probably saving his countrymen from annihilation; and, along with Serrano, he commanded the ships sent out under Abreu for the discovery of the Spice Islands. On his return from the East, Magellan was sent to Azamor in Morocco; and this brief episode in his career is memorable for the wound which left him lame for the rest of his life, and for the beginning of the troubles which determined his future course. Contrary to what he had a right to expect, the king (Manuel) refused Magellan's application for an increase of the pay assigned to him as a member of the royal household; and the manner of the refusal added insult to what he considered injury. In company with another malcontent of note, Ruy Faleiro the astronomer, he formally renounced his nationality, and went to offer his services to the court of Spain. Word was no sooner brought to Manuel of the schemes proposed to the Spaniards than he felt the mistake he had committed; but all the efforts put forth by special agents to allure his alienated subjects back to their allegiance, or to thwart their negotiations, proved of no avail. The bishop of Burgos, Juan Rodriguez de Fonseca, had taken the matter up, and things had gone too far for Magellan to retrace his steps. On August 10, 1519, the expedition set sail; to find his way by a western route to the Spice Islands of the East was the task which its commander had undertaken. When more than three years afterwards, on September 6, 1522, the "Victoria" cast anchor in a Spanish port, the captain, Sebastian del Cano, had a strange tale to tell of mingled triumph and tragedy. While the squadron lay in Port St Julian, on the Patagonian coast, three of Magellan's Spanish captains had defied him and conspired against him, and it was only by a rapid execution of summary vengeance that he had maintained his authority. At a later date the "Antonio," at the instigation of Gomez, the Portuguese pilot, his personal enemy, sailed home to Spain with evil reports, at the very moment of success, when the Strait of the Eleven Thousand Virgins, or of the Patagonians, now known as the Strait of Magellan, had been explored almost to the Pacific. The strait was passed on November 28, 1520; and, though Magellan had not quite reached the Spice Islands when he fell in conflict with the people of Zebu, 27th April 1521, his task was virtually accomplished. The name Magellan's Land—long given to Patagonia and that hypothetical continent of which Tierra del Fuego was considered only a portion—had disappeared from our maps, but has again been bestowed by Chili on the territory she claims in the extreme south.

No record of his exploits has been left by Magellan himself; and contemporary accounts are less detailed and consistent than could be wished. The best is that of Antonio Pigafetta, a volunteer in the fleet. It is printed in Ramusio, and exists in four early MS. copies, three in French and one in Italian. The Italian was printed in 1801 by Amoretti. Along with five minor narratives an English version appears in Lord Stanley of Alderley's *First Voyage round the World by Magellan*, 1874 (Hakluyt Society's Publications, vol. lii.). See also J. G. Kohl, *Gesch. der Entdeckungsreise . . . zur Magellan's Strasse* (Berlin, 1877), and Ramon Guerrero Vergara, *Los descubridores del Estrecho de Magellanes*, Santiago de Chile, 1880.

MAGGIORE, Lago (French, *Lac Majeur*; in Italian also frequently *Lago Verbano*; Latin, *Verbanus*), is the westmost of the great lakes of northern Italy. In accordance with its popular name it has long been reputed the largest of them all; but though in length it somewhat surpasses Lago di Garda, it does not cover so extensive an area. Of the total surface of 82 square miles, 65 belong to Italy, and the remaining 17 to the Swiss canton of Tessin or Ticino. The length from north to south, between 45° 43′ and 46° 10′ N. lat., is 38 miles; the breadth, generally between 2 and 4 miles, is increased to 6 or 7 at the junction of the Toce valley on the west. The Ticino, the leading tributary of the Po, enters at the one end of the lake and escapes at the other. The very interesting geological problems which Lago Maggiore suggests are not yet fully cleared up. (See Taramelli, *Il cantone Ticino meridionale ed i paesi finitimi*, Bern, 1880, forming vol. xvii. of the materials for the geological map of Switzerland.) The whole of the west side and the east side as far south as Val Travaglia are shut in by a region of gneiss and schists, while the remaining portion presents dolomites, calcareous rocks, and conglomerates, mingled with strongly developed moraines. On Dufour's great map of Switzerland the greatest depth is given as 2801 feet, opposite Pino; but this is probably much in excess, as in G. B. Maggi's topographical map of the lake (Turin, 1857) the highest figure registered along the medial line is only 1233 feet between Barbe and Lavello, and at the laying of a telegraph line in 1860 Salis found no more than 337 between Vira and Locarno. The ordinary height of the surface above the sea is about 640 feet. Between the lowest and highest water-mark, however, there is a difference in ordinary years of nearly 12 feet, and in very exceptional cases of twice as much. For not only is the Ticino subject to floods, but the lake receives a number of considerable streams (the Toce, the Maggia, the Verzasca, the Tresa, &c.), and some of these bring down the surplus waters of other lakes—Lugano, Varese, and Orta. The flood of 1868, which exceeded by about 6 feet the greatest that had been known for centuries, so deepened and enlarged the outlet of the river that the level of the lake was permanently reduced by about a foot and a half, and alterations had to be made at the various ports to suit the new condition of things. (See Paolo Gallizia in *Atti del Coll. degli Ingegn. ed Archit. in Milano*, 1879.) At least twenty-three species of fish are caught in Lago Maggiore; and the fisheries are of value enough to be closely preserved by the proprietors.


Lago Maggiore.

The principal towns and villages round the lake are the following,—the first being in Switzerland, and the others in Italy:—Locarno (population in 1880, 2645), at the mouth of the Maggia, one of the alternate capitals of the canton of Ticino; Cannobio (2000), famous from the 15th century for its tanneries, and with paper-mills and silk-works; Luino (2000), the original home of the Luini family, and the scene of one of Garibaldi's exploits in 1867, commemorated on the spot by a statue of the victor; Laveno (1500), formerly an Austrian naval harbour; Intra (4500), a busy manufacturing town—cotton, glass, silk, &c.; and Pallanza (4200), a flourishing little city with a large cathedral, a penitentiary, &c., and altogether the most important place on the lake. The celebrated Borromean Islands, lying off Pallanza, have been already described, vol. iv. p. 64; compare Medone, *Le isole Borromee*, with views by Falkenstein (Novara, 1840). As the St Gotthard and St Bernardino routes meet at Bellinzona, much of the trade between Italy and the north used to pass by way of the lake and the high roads that skirt its banks; and the opening of the St Gotthard railway, which joins the Italian system at Pino on the east side, and goes as far as Locarno on the west side, will bring back some of the traffic which the earlier railways diverted into other channels. The first steamboat was launched on the lake in 1826.

See P. Morriggia, *Ist. della Nobiltà del Lago Maggiore*; Amoretti, *Viaggio ai tre laghi*; Vagliano, *Rive del Verbano*.

MAGHIÁNA, the chief town and headquarters of Jhang district, Punjab, India, is situated in 31° 17′ N. lat. and 72° 21′ E. long., and had a population in 1868 of 10,525 (Hindus, 5192; Mohammedans, 4698; Sikhs, 306; and "others," 329). It has a considerable trade with Kandahar, large exports of country cloth, and a fluctuating business in grain from the fertile lowlands of the Rávi. The civil station lies to the east of the town, and consists only of a court-house and treasury, sessions bungalow, jail, church, and three or four residences of officials. Maghiána forms a single municipality with Jhang town, which lies 3 miles to the north. The united population is 19,649.

Origin of term. MAGIC[1] has its name from the *magi*, Greek *μάγοι*, the hereditary caste of priests among the ancient Persians, thought to be of Median origin (Spiegel, *Avesta*, vol. ii. p. vi.). Among the magi the interpretation of dreams was practised, as appears from the story of the birth of Cyrus (Herodotus, i. 107); later writers describe them in both a sacerdotal and magical capacity, Lucian (*Makrob.*, 4) calling them a prophetic class and devoted to the gods, while Cicero (*De Divinatione*, i. 23, 41) writes of them as wise men, augurs, and diviners. In such supernatural crafts the magi seem to have much influenced the Western nations, to judge by their name having passed into a set of classical terms (*μαγεία*, *μαγεύω*, *magia*, *magice*, &c.) applied to sorcery, enchantment, and occult science in general. In the New Testament soothsaying and sorcery are so designated (Acts viii. 9, xiii. 6); while the astrologers who divine the birth of the King of the Jews by the appearance of a star in the east are called magi (Matt. ii.).

Magical beliefs and practices. The word magic is still used, as in the ancient world, to include a confused mass of beliefs and practices, hardly agreeing except in being beyond those ordinary actions of cause and effect which men accustomed to their regularity have come to regard as merely natural. Thus magical rites are difficult even to arrange in systematic order. A large proportion of them belong properly to the general theory of religion, inasmuch as their efficacy is ascribed to the intervention of spiritual beings. Thus the ghosts of the dead are called up by the necromancer to give oracles or discover hidden treasures, or sent to enter men's bodies and afflict them with diseases or to cure them, or in a score of ways to do the behests of the magician, whose spells or incantations are thought powerful enough to control the will even of such divine beings as can drive the winds and give or withhold the rain. It must be noticed, on the other hand, that many magical arts show no connexion with spirits at all, or, even if ghosts or demons or gods have to do with them, the nature of these beings does not of itself account for the processes employed or the effects believed to result. This non-spiritual element in magic depends on imagined powers and correspondences in nature, of which the adepts avail themselves in order to discover hidden knowledge, and to act on the world around them by means beyond the ordinary capabilities of men. Thus by mere effort of will, by traditional formulas and rites, or by working on symbolic fancies, the sorcerer believes he can bewitch others to sickness or death, the astrologer reads the future in the aspects of the stars, the augur attends to omens from the cries of birds and beasts, the haruspex prophesies by the heart or liver of a slaughtered animal, and other classes of diviners judge of the hidden past and the yet more hidden future by the falling of lots or dice, the twitching of their own fingers or the tingling of their ears, and a host of other facts of nature which, as the educated world has now found out, have no practical connexion with the magical meanings or effects assigned to them. The great characteristic of magic is its unreality. Its methods have often an ideal coherence which may be plainly traced, but practical effect they have none, and so they may be altered or transposed without being made worse or better. One remarkable consequence of this is the fixity with which some magical formulas framed thousands of years ago hold on almost unchanged to this day. To understand this, it must be borne in mind that, if there were any practical use in such rules as those for divining by the cries of animals, the old rules would have been improved by experience into new shapes. But, they being worthless and incapable of improvement, this motive of change is absent, and the old precepts have held their ground, handed on by faithful but stupid tradition, from age to age. When the test of practical efficacy comes in upon the magic art, it is apt either to destroy it utterly or to transform it into something more rational, which passes from supernatural into natural science.

Magic of lower races. Magic is to be reckoned among the earliest growths of human thought. The evidence for its remote antiquity lies partly in its presence among all races of mankind, the ruder tribes especially showing it in such intelligible shapes that the beginnings of magical crafts may be fairly supposed to have arisen in the oldest and lowest periods of culture. An example may be taken from the wild natives of Australia, whose whole life is pervaded by the belief, and embittered by the terror, of sorcery. They imagine the sorcerers, armed with their mysterious power called *boyl-ya*, to come moving along in the sky, invisible except to other sorcerers; they enter the bodies of men, and feed stealthily on them, not eating the bones, but consuming the flesh; the native feels the pain as the boyl-ya enters him like a bit of pointed quartz, and in this shape of quartz crystal the evil can be extracted by another sorcerer. The sorcerer has other means of attacking his victim: he can creep near to him when asleep, and bewitch him to death by merely pointing at him a leg bone of a kangaroo; or he can steal away his kidney fat, where, as the natives believe, a man's power dwells; or he can call in the aid of a malignant demon to strike the poor wretch with his club behind the neck; or he can get a lock of hair, and roast it with fat over the fire till its former owner pines away too, and dies. The Australians, like other low tribes in the world whose minds are thus set on imaginary causes of death, hardly believe a man can die unless by being slain or bewitched. When a native dies what we call a natural death, they ascribe it to magic. Then other magic must reveal the hostile sorcerer who has done him to death: either the corpse itself will seem to push its bearers in the direction of the murderer, or the flames of the grave-fire are seen to flicker towards where he is, or some insect will be seen creeping towards his home; and, when the next of kin thus discover the magic enemy, they set off to take vengeance with earthly weapons. The sorcerer has kindlier duties when he sits by a sick man and charms and charms till he recovers, or sucks out the disease from his body in the shape of a stone spear-head or a fish bone, or brings out the ailment along a string, the other end of which he draws between his own lips till it is covered with blood, telling the bystanders (who believe it) that this blood came along the string out of the sick man. Not disease and cure only, but other events of life, come within the scope of native magic. Storm and thunder are the work of the sorcerers; they can bring rain and make the rivers swell, or burn up the land with drought. Shooting stars and comets are to the natives omens of disaster; the great hawk's cry in the night portends the death of a child, whose soul the bird is carrying off; but when a man's finger-joints crack he stretches out his arm, for in that direction some one is doing him a kindness.[2]

[1] The etymology of the word is seen in the terms "art magic," or the "magic art"; French, *art magique*; Latin, *magica ars*.

[2] For these and other details see Grey, *Journals of Expeditions*; Waitz, *Anthropologie der Naturvölker*, vol. vi.; Brough Smyth, *Aborigines of Victoria*; Fison and Howitt, *Kamilaroi and Kurnai*, &c.

Taken together, such a repertory of the demonology and witchcraft of a special group of savage tribes shows remarkable correspondence in principle with the magic which once flourished in the civilized world, and which still lingers in peasant folklore. The very details often agree so much as to raise the question whether the magic of savages may sometimes have been borrowed from the lower class of colonists. The superstitions of the peasant are in fact what the savage would readily assimilate, as belonging to a state of mind like his own, and there is even evidence of European charms and omens having been sometimes borrowed by native tribes of Australia or America. It was necessary to mention this, if merely to point out that such borrowing has been only slight and superficial. It in no way upsets the general principle that the magic of the lower races was developed among them, fitting as it does with their low level of knowledge. Every book of travels in savage and barbaric countries shows the influence of the native magician, who, often at once sorcerer and established priest, and sometimes even chief of his tribe, by the aid of spirits and other supernatural means interferes in every act of life. Thus in the Pacific islands the Europeans found a whole class of sorcerers living by making diseases, their method being the familiar one of burning or otherwise practising on some morsel of hair or remnant of food, so as to send disease into its owner, by a malignant spirit tying knots in his inside till he writhed with agony. Every sick man was a source of profit to the sorcerer who was believed to have brought on the disease by burning his rubbish, and of course had to be bought off by liberal presents. In these Pacific islands a fact most important in the theory of magic everywhere comes into view with particular distinctness—that such magical arts prove effective through the patient's own imagination; when he knows or fancies that he has been bewitched he will fall ill, and he will actually die unless he can be persuaded that he has been cured. Thus, wherever sorcery is practised with the belief of its victims, some system of exorcism or some protective magical art becomes, not only necessary, but actually effective, a mental disease being met by a mental remedy to match it.[1] At the discovery of America, the Spaniards found the native sorcerers throwing themselves into delirious ecstasy by snuffing a narcotic powder, their ravings in this state being held to be conversation with departed souls, through whose help they were able to cure the sick by expelling the disease. The class to which these sorcerers belong extends over South America, and is generally known under the name of *payé* (or allied terms). The sorcerer is described as being initiated by living in some wild spot till by fasting and self-torture he attains his supernatural craft, becoming able to see spirits, to consecrate bits of bone or stone into powerful amulets, to make good or bad weather, to gain mystic powers over familiar birds and beasts, to take omens from their cries or from the itching of his own skin, which latter symptom an Abipone diviner declared to portend an attack from a tribe of enemies, in spite of the missionary, who irreverently set it down to fleas. The old arts of the payés, their malicious witchcraft with herbs and hair, the use of narcotics to produce ecstasy, and their mental excitement by drumming, rattling, and dancing are still to be met with in the wild districts of Guiana and Brazil. In North America practitioners of the same kind are generally known as "medicine-men," from the French colonists calling them *médecins*, as being the native doctors; the term is really appropriate to barbaric magicians in all parts of the world, whose arts of causing and curing disease generally include considerable knowledge of herbs powerful as poisons and remedies, of simple stopping of wounds and bandaging hurt limbs, in fact of medicine in its elementary state, as yet not separated from the magic with which it was at first inextricably mixed up. The medicine-man's apparatus includes the sorcerer's usual music, the rattle and the drum, simple and primitive instruments whose constant association with the lower magic bears witness to the beginnings of music and magic having been associated together when civilization was yet in its low stages of development. The American sorcerer carries a "medicine-bag" made with the skin of his guardian animal, which protects him in fight, cures the bites of serpents, and strikes at a distance as a spiritual weapon. He knows magic chants of power over the elements; he can by sucking and blowing extract disease-animals from the sick; he can make pictures and images and pierce them with thorns so as to kill the men or animals they represent; and he can compel love by practising on the heart of the picture of the beloved one.[2] In Africa the native sorcerer bears the name of *mganga* among the west and central negro tribes, *nyanya* among the Zulus of the south. He is the rain-maker, an office of the utmost importance among tribes who may perish of famine and disease after a long drought. In his craft a principal part is played by what the English in Africa (using the Portuguese word *feitiço*, charm or amulet) call "fetiches," which are claws, fangs, roots, stones, and any other odds and ends fancied to be inhabited by spirits or invested with superhuman power. These fetiches the negroes trust in for good and against evil fortune, with a confidence which no failure can shake further than to cause the unlucky bearer to discard a particular fetich which has failed, and to replace it by a more successful one. The African mganga has intercourse with demons; and, being called on every day to predict the fortune of a fight or a bargain, or to discover lost or stolen cattle, he professes to gain information from the spirits, or uses his various modes of divination, such as taking omens from the cries of the eagle or the owl, the swimming of berries, or the moving of sticks in his own hands as they twitch spasmodically in nervous excitement. As with magicians everywhere, his trade is profitable but dangerous, for if his arts of killing have been successful beyond bearing, or still worse if public opinion decides that he has wilfully withheld the rain, he may be drowned or burned as miserably as one of the many victims he has done to death.[3] These instances are selected to give an idea of the sorcerers of the lower races and their modes of working, which are remarkable for their uniformity in the most distant regions, among tribes who can have had no communication or connexion since remote ages. Where, however, such races as the African negroes come in contact with such foreigners as the Arabs, who though more civilized than themselves have not outgrown the magical stage, they borrow their more cultured magical arts, such as divination by lots. In this way the natives of Madagascar appear to have borrowed from the Arabs a system of lucky and unlucky days of birth, which, carried out with stupid ferocity, has cost the lives of thousands of children, born truly in an evil hour, for when the magician declares their birth ill-omened their fate is settled at once by putting them to death.[4]

Turning now to the cultured nations of antiquity, among

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[1] See Ellis, *Polynesian Researches*; Turner, *Nineteen Years in Polynesia*; Polack, *Manners and Customs of New Zealanders*; Waitz, vols. v., vi.

[2] See Waitz, vol. iii.; Martius, *Ethnographie Amerikas*; *Letters of Columbus*; Dobrizhoffer, *Abipones*; Schoolcraft, *Indian Tribes of North America*.

[3] See Burton, *Lake Regions of Central Africa*; Wood, *Natural History of Man*, vol. i.; Callaway, *Religious System of Amazulu*, &c.

[4] See Ellis, *Madagascar* vol. ii. chaps. vi., xv.; Dahle in *Antananarivo Annual*, 1876.

Egyptian magic. whom the art of writing consolidated and developed false as well as true science, we find magic in full vogue, hardly differing in principle from that of the illiterate barbarians, but worked into more elaborate system and ritual. Of ancient Egyptian magic various original documents have been preserved, containing formulas, mostly of religious magic,—that is, acting through the aid of deities invoked. For instance, there are hymns against dangerous animals in the water, and spells for remaining in the country; and the power ascribed to such formulas appears from passages like the following:—"I confide in the efficacy of that excellent written book given to-day into my hand, which repels lions through fascination, disables men, ... which muzzles the mouths of lions, hyænas, wolves, ... the mouth of all men who have bad faces, so as to paralyse their limbs," &c. Ancient as Egyptian magic is, it has evidently grown up from still earlier forms, as is shown by that plainest symptom of old traditional lore, the relying on ancient or foreign epithets as words of power over the gods. This practice appears in the ancient papyri, and goes on to later ages, when the god Set is invoked by other mystically powerful names which he must obey, such as "Joerbeth." The medical art in ancient Egypt shows an interesting combination of practical and magical remedies. The practical recipe might contain nitre or cedar chips, or deer horn, or various other ingredients administered in ointment or drunk in beer, but with this the magical formula was also required to deal with the demon-cause of the ailment. Thus an emetic was given with the following formula, "O demon who art lodged in the stomach of M., son of N., thou whose father is called Head-smiter, whose name is Death, whose name is cursed for ever!" &c. It must be remembered that such formulas, foolish as they seem to modern education, had and still have great efficacy in relieving the mind of the superstitious patient, and giving a fair chance to diet and medicaments. Their appearance in medicine so ancient as that of Egypt is good historical evidence how the old magical treatment was encroached upon by natural remedies, though then and for many ages afterwards the physicians, wise in their generation, thought it best not to discard the supernatural charm. The Egyptians divided out the limbs and organs of the human body, putting each under the special care of a god, a system which, like many other details of their magic, has lasted on into the modern world. From the astrological point of view they made a calendar of lucky and unlucky days, according to which for instance on the 19th of the month Athor one must not embark on the Nile, while a child born on the 5th of the month Paopi will be killed by a bull; traces of this set of precepts may be discerned still in the modern Egyptian almanac. Another point deserving attention is the appearance in early Egypt of the distinction between good and bad magic. Magical curative arts were practised by learned scribes or priests, and were doubtless in high esteem, but when it came to attracting love by charms or philtres, or paralysing men by secret arts, this was held to be a crime. As long ago as the time of Rameses III. it is recorded that one Hai was accused of making images and paralysing a man's hand, for which he was condemned to death; this was doubtless the ordinary bewitching by an image or picture, here already mentioned among the lower races, and to be mentioned again as not forgotten among ourselves.[1]

Babylonian-Assyrian magic. Still more prominent among the ancient nations who brought magic into its pseudo-scientific stage were the Babylonians, whose supernatural arts were adopted and continued among the Assyrians. No savage tribe ever filled their world with more swarming hosts of nature-spirits and demons; only these more cultured nations dealt systematically with them by set formulas of propitiation and expulsion. The cuneiform writings preserve numerous documents of this kind, such as "From the burning spirit of the entrails which devours the man, from the spirit of the entrails which works evil, may the king of heaven preserve, may the king of earth preserve!"—"The god . . . . shall stand by his bedside. Those seven evil spirits he shall root out, and shall expel them from his body; and those seven shall never return to the sick man again." The magic power believed to reside in the secret names of the gods was recognized by the Babylonians, one of whose famous myths relates how by the utterance of these mystic names the goddess Ishtar was delivered from Hades. In the rites of the magician priests, this kind of supernatural power resided in sacred texts, whether chanted or tied on as phylacteries. In divinatory magic the Babylonians had elaborate codes of rules, of which many have been preserved. Thus omens were drawn from prodigies, such as "when a woman bears a child and at the time of birth its teeth are cut, the days of the prince will be long." So with omens from animals: "if a dog goes to the palace and lies down on a throne, that palace will be burned." A remarkable passage, Ezekiel xxi. 21, mentions three modes of divination practised by the king of Babylon as he stood at the head of the two ways: "he shuffled arrows, he consulted teraphim, he looked in the liver." The arrow-divination or belomancy here mentioned was done with pointless arrows marked and drawn as lots. They are often represented on Babylonian and Assyrian cylinders, and their use was kept up among the Arabs till the time of Mohammed. The Babylonian rules of haruspication, or examining the entrails of animals, were most minute, to judge from the omens of prosperity or misfortune to be drawn from the twisting and colour of the intestines of an ass. Diodorus Siculus (ii. 29, &c.), in his account of the Chaldæan priests, mentions with evidently good information their hereditary skill in various branches of magic, their use of purifications, sacrifices, and chants, to avert evil and obtain good, their foretelling by omens, dreams, prodigies, &c. But it is on their astrology that he deservedly lays the greatest stress. The five planets, which they called "interpreters," they held to portend events by their rising and setting and their colour, foretelling the wind or rain or heat, comets also, and eclipses of the sun and moon, and earthquakes, and atmospheric changes, beneficial or harmful, both to nations and kings and common men. The Babylonian calendars still remain to show how eclipses were brought into connexion with floods, invasions, good and bad harvests,—such ideas being worked out, not by mere arbitrary fancy, but from such fancied regularities as that the same weather and the same famines and pestilences tended to recur in a cycle of twelve years. To the Babylonian astrological system belong the stars of men's nativities, the planetary houses, the twelve signs of the zodiac (probably invented in observatories in Babylon), while the fixed stars are associated with the planets and gods in a system which is seen at a glance to be the astrology which later nations of Asia and Europe have followed since with servile faithfulness.[2]

Egypt and Babylon, as these brief notices show, were the chief sources whence the world learnt what may be called the higher branches of occult science, and from the historical point of view the magical rites and beliefs of other ancient Eastern nations, such as Asia Minor and India, are of little importance. It was mainly through Greece and Rome that magic was consolidated and

[1] *Records of the Past*, vols. vi., x.; Maspero, *Hist. Anc. des Peuples de l'Orient*, p. 84; F. Chabas, *Le Papyrus Magique Harris.*

[2] See Sayce in *Records of the Past*, vols. i., iii., v.; *Trans. Soc. Biblical Archæology*, vols. iii., iv.; Lenormant, *Magie chez les Chaldéens*, and *Divination chez les Chaldéens.*

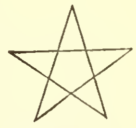
Greek and Roman magic.

developed in Western civilization. In these classic nations there may be traced the rude old magic inherited from barbaric ancestors, to which in later times were added ceremonies and calculations imported as Oriental wisdom. Ancient literature shows the Greeks as a people whose religion ran much into the consultation of oracle-gods at many temples, of which the shrine of Apollo at Delphi was the chief. No rite could keep up more perfectly the habit of savage religion than their necromancy (νεκρομαντεία, νεκυομαντεία) or consulting ghosts for prophecy; there was a famous oracle of the dead near the river Acheron in Thesprotia, where the departing souls crossed on their way to Hades (Herod., v. 92). The myth of Circe turning the companions of Odysseus into swine shows the barbaric belief in magical transformation of men into beasts, and the classic sorcerer was believed to turn himself into a wolf by spells like the medicine-man of some modern savage tribe. Not less clearly does the story of Medea and her caldron typify the witch-doctress with her pharmacy (φαρμακεία) powerful both to kill and bring to life. The worship of Hecate, the moon, sender of midnight phantoms, lent itself especially to the magician's rites, as may be seen from this formula to evoke her: "O friend and companion of night, thou who rejoicest in the baying of dogs and spilt blood, who wanderest in the midst of shades among the tombs, who longest for blood and bringest terror to mortals, Gorgo, Mormo, thousand-faced moon, look favourably on our sacrifices!" This magical record, preserved by an early Christian writer, may be compared with the poetic picture in Theocritus's idyll of the sorceress (*Idyll.*, ii.), where the passionate witch cries in similar words to Hecate, the moon, to shine clear while she compels by sacrifice her faithless lover, and goes through her magic ritual of love and hate, striving to force her beloved home to her by whirling the brazen rhomb, scattering his bones with the scattered barley, melting him to love by the melting wax, casting into the fierce flames a torn shred of his cloak and laurels to crackle and blaze and be consumed that his flesh shall be consumed likewise. This ancient witchcraft ascribed magic power to such filth as pounded lizards and the blood of creatures untimely dead, revolting messes made familiar to moderns by Shakespeare, who introduces real magic recipes in the witches' caldron in *Macbeth.* The early Greeks lived in the same fear as southern nations still do of the arts of "fascination" (βασκανία, Lat. *fascinatio*) worked by envious praise, or ill-wishing, or the evil eye; and they sought to avert these bad influences by the means still in use, spitting and symbolic gestures, and the use of charms and amulets. As to ancient Rome, much of the magic in the Latin poets, such as Virgil and Horace, is only Greek sorcery in a Latin dress. But severe Roman laws against those who practised such malefic arts as making hail and spoiling the crops show that here also the sorcerer was at his usual work. What is more remarkable is the high official place given to divination in old Rome, where every public act was done under magical sanction. The *auspex*, or bird-viewer, and the *augur*, whose similar name seems to refer also to omens from the flight and cries of birds, in fact carried on supernatural divination not by omens from birds only, but by a variety of magical processes forming a complex traditional system, partly adopted from the Etruscans, as to which some curious remarks have come down to us in the treatise *On Divination* by Cicero, himself an augur, though living in the days when the ancient lore was falling into contempt. The Roman divination was, as its name implies, a religious system of consulting the gods, who sent the signs to guide mankind. Jupiter, the Heaven-father himself, was heard and seen in thunder and lightning; wherefore these heavenly manifestations were of the highest import, observed by the augur in the *templum* or division of the sky marked out with his *lituus* or curved wand; there was no better omen than when Jove lightened on the left. Among birds, the fierce eagle, Jove's messenger, gave the highest presage of victory, while the owl with its dismal cry was unluckiest. The good or ill signs given by many birds depended on whether they were on the right or left hand, and the sacred chickens gave their omens according as they were eager or not to feed, and dropped crumbs on the ground. All prodigies were recorded as portents in Roman affairs; and those which Livy mentions year by year, whether they were real or fictitious, in either case had their effect on the minds of men who saw national signs in a heavy hailstorm, a calf born with two heads, or a bullock found when sacrificed to have no heart. It was in quest of such portents that the haruspex made his professional examination of the entrails of the victims, and reported the aspects of the head of the liver or cleft of the lungs, as a sacred guide to warriors and statesmen in the conduct of national affairs. Public divination being on this footing, it is not to be wondered at that, in the time of the empire, foreign soothsayers thronged to Rome to practise their craft among rich and credulous dupes. It appears that the magic of Egypt and Babylon still held a prominent place, for Juvenal refers to both in his sixth satire, where he rails at the superstitious women of his time for putting their trust in Chaldæan astrologers, all the more if under the laws against magicians they had been put in prison or banished, while ladies would not go out for a drive or take a meal without consulting their book of lucky and unlucky hours, which bore the Egyptian name of *Petosiris.*

In the classic world, however, the growth of knowledge and accurate reasoning began to have their effect in bringing magic to the test of facts, and proving its failure. Greek philosophy, with its physical theories of the universe, had shaken the old religion, and with it the old magic. Though the Romans kept it up as a matter of statecraft, the judgment of statesmen and philosophers revolted from it, holding rather with Ennius, who pointed out the absurdity of the hungry fortune-teller promising others wealth and begging a drachma for himself, or with Cato, who wondered that one diviner could meet another and not burst out laughing. These are both quoted by Cicero, with other passages argued quite in the modern spirit, as where he asks on what principle a raven's croak should be propitious on the right but a crow's on the left, or how a chicken eating a cake could help dropping crumbs. Historically attacks of this kind have a particular value, as recording many magical details which we do not know from the believers themselves. Of such details Pliny's *Natural History* is full, though he hates magic as the most fraudulent of arts; and among the most instructive accounts of classic astrology must be reckoned the treatise written against it by Sextus Empiricus. Had sceptical philosophy had its way, magic would have perished ages earlier out of the civilized world. But there were other influences already at work, not only to preserve it, but even to give it another great expansion before its final decay.

Philosophic and theurgic magic.

The Pythagorean philosophy, while on the one hand bringing in the science of Egypt and Babylon, and developing it into Greek mathematics and physics, on the other hand favoured the growth of magic by mystical speculations, such as those on numbers. Not that the Pythagoreans began this delusive science, which had long been at home in Babylon, where the occult powers of the planetary 7 and the zodiacal 12 were recognized, and spiritual arithmetic was carried so far as to indicate good deities by whole numbers and evil demons by fractions. But the Pythagoreans developed it further in their mystic symbolism of the active 1 and the passive 2, the sacred 4 of space proceeding from the 1, the 7 of intelligence, the 8 of love, and the 10 of the universe. Whatever rational thought may at first have been veiled under all this, its literal nonsense suited the magical mind, and its effects may be traced in magical literature ever since. With such speculations was combined an animistic system of spirits pervading the world, ranging from gods and demons down to the souls of beasts and plants. Both in mystic symbolism and in the doctrine of demons the mind of Plato followed the Pythagorean track, and at a later period the tendency towards magical speculation came out strongly among the Neo-Platonists, when enthusiasts, not content with speculating about the dæmonic powers of the universe, sought to establish personal relations with them, and use them for their own ends. The treatise on the Egyptian mysteries ascribed to Iamblichus is an interesting record of this phase of thought. Alexandria became the especial home of systems of theurgic magic, in which invocations, sacrifices, diagrams, talismans, were employed with rule and method, as though they were really effective. Much of this delusive craft has perished or become unintelligible, but its once considerable hold on men's minds may be traced in such relics as the gem-talismans of the Gnostics, still objects of curiosity to archæologists; among their formulas is the celebrated *Abraxas*, the Greek letters of which (Αβραξας, Αβρασαξ) stand with astronomical significance for the number 365. The theurgy which came down into mediæval and modern Europe is strongly marked with Jewish magical speculation. After the captivity, the Jews worked out a classification and nomenclature of angels and demons. On the one side are ranged such celestial powers as Gabriel and Raphael, while against them stand such beings as BEELZEBUB (*q.v.*) and Ashmodai or Asmodæus (Tobit, chap. iii., &c.), who is clearly the great evil demon Aeshma-daeva of the Persian religion. Many centuries afterwards, in European magic books of the Middle Ages we find the remains of these theurgic systems still handed on. Their elaborate folly may be best realized by looking into such books as Francis Barrett's *Magus*, or Horst's *Zauber-Bibliothek*, where the actual rites and formulas for raising demons are given. The evocations, with their uncouth jumbles of sacred names, have some historical interest from their strangely mixed traces of ancient religions, preserved by charlatans whose blunders show how little they understood the words they copied. We can fancy the magician in his black robe embroidered with mystic characters, waving his wand as he invokes at one breath the great demons "Acheront," "Ashtaroth," "Asmodi," names which the modern student recognizes as borrowed from the ancient religions of three different countries—Greece, Phœnicia, Persia. Of all the sources of this branch of magic, the Jewish tradition is the chief. The magician relies on the power of divine Hebrew names, such as the *shem hammephorash* or the name Jehovah in its true pronunciation, with which Solomon and other wonder-workers of old did marvellous things. He draws powerful spells from the KABBALAH (*q.v.*) of the later Jews, with its transposed letters and artificial words,—using for instance the name *Agla*, formed from the initials of the Hebrew sentence—"Thou art a mighty God for ever." But in compelling the spirits he can use Hebrew and Greek in admired confusion, as in the following formula (copied with its mistakes as an illustration of magical scholarship in its lowest stage)—"Hel Heloym Sother Emmanuel Sabaoth Agla Tetragrammaton Agyros Otheos Ischyros Athanatos Jehova Va Adonai Saday Homousion Messias Eschereheye!" One of the most curious features of the demon-evocation is the use of the pentagram, an essential adjunct of the magic circle, whose effect in barring the passage of Mephistopheles is described in a well-known scene in Goethe's *Faust*. This symbol is an interesting proof of tradition from the Pythagoreans. It is a geometrical figure for the construction of the regular pentagon (Euclid, iv. prop. 11), now familiar to school-boys, but which to the school of Pythagoras was so wondrous a novelty that they used it as a sign of fellowship (see Bretschneider, *Geometrie vor Euklides*, p. 85), and it afterwards became a magical symbol, still to be seen in use in every country from Ireland to China.



Pentagram.

The magic of the Moslem world is in part adopted from Jewish angelology and demonology, and in part carries on Babylonian-Greek astrology, as systematized by such writers as Paul of Alexandria and Claudius Ptolemy. Thus the proceedings of the Moslem magician, as met with in the *Thousand and One Nights*, mostly run parallel with those familiar in Europe, in their fumigations and incantations, talismans (τετελεσμένα), horoscopes, and almanacs or calendars of lucky and unlucky days. In fact a modern Zadkiel in England would find himself on common ground with his brother practitioner in Baghdad or Delhi.[1] In other districts of Asia, more peculiar developments of magic have been preserved. To mention a few of the most noteworthy, the Sanskrit literature in India is rich in ancient magical precepts and hymn-charms.[2] The ancient Hindu magic is religious, turning on the actions of demons (*bhûta*) in causing disease by possession, and their exorcism and compulsion, as well as power obtained over higher spirits by sacrifices, austerities, and formulas or charms (*mantra*). From their connexion with early Aryan customs, these rites sometimes throw light on European practices derived from the same stock. Thus the magical practice of going round "with the sun," well known as *deisil* in Highland superstition, and kept up in England in the rule of passing the decanter "through the button-hole," appears to be a rite of Aryan sun-worship belonging to remote antiquity, for (under the name of *pradaxina*) it forms part of the Hindu marriage ceremony handed down from Vedic times.[3] Buddhism as well as Brahmanism had its magical side, and its literature of magic formulas (*tantra*). The "red-cap" lamas of Tibet, with their pretended miracles of breathing fire, swallowing knives, and ripping themselves up, are curious as reminding us of the time when these tricks, now come down among us to jugglers' feats, were regarded as supernatural. In the low Buddhism of the Mongols, mixed with native barbarism, the *shamans* or sorcerer-priests, with their rude sacrifices and demon-dances, are among the most remarkable types of their ancient class. In this part of Asia, and farther east, a somewhat remarkable system of divinatory magic has grown out of the reckoning of days, months, and years by a zodiac-calendar, whose signs *ape*, *horse*, *dog*, &c., are combined in series with the elements, male and female, so that a year may be called that of the "female fire-dog." It was inevitable that such a system should lead the magicians to draw omens from its signs. They do so in a most elaborate way, interfering with their presages on every occasion of life, beginning when the child undergoes its ceremonial washing, and has its fate defined by the signs it is born under, as "in the element fire, under the red sign in the year of the tiger, in the month of the sheep and day of the hog, in the fortieth division of the day under the influence of the ninth star," &c. This quaint science seems, however, not altogether native, for the influence of

[1] See, for instance, Herklot's translation of the *Qanoon-e-Islam*.
[2] See Weber, *Omina et Portenta*, and volumes of *Indische Studien*.
[3] Haas, in *Indische Studien*, vol. v. p. 257; Pictet, *Origines Indo-Européennes*, part ii., p. 498.

Babylonian and Greek scientific and magical ideas has extended across Asia, even into China. The magic of this latter country is remarkable for its various and elaborate modes of divination. These may be obtained from mediums possessed by spirits, and giving oracles by speech or writing with the "descending pencil," as has lately been done by "spiritualists" in Europe. But higher authority is given to divination by throwing sacred lots, as the two wooden *ka pwe*, which fall with the flat or rounded side up. The results of such processes of divination, in themselves meagre, may be brought to any required elaborateness by the use of the "eight diagrams" obtained by combinations of the whole line (—) and the broken line (--). These, primarily interpreted as representing the male and the female principle (*yang*, *yn*), perfect and imperfect, heavenly and earthly, are referred by systematic fancy to elements, qualities, tempers, &c., and interpreted in the celebrated Chinese classic book called the *Y-king* into a collection of oracular responses.[1] The *feng-shui*, or "wind-and-water" magic, is a system the practitioners of which regulate the building of houses and tombs by their local aspects; it has of late come under the notice of Europeans from the unexpected impediments it has placed in their way when desirous of building or constructing railways on Chinese soil.[2]

Magic in Christendom.

In the lower stages of civilization the distinction between religion and magic hardly appears, the functions of priest and sorcerer being still blended, as was long since pointed out by Meiners (*Geschichte der Religionen*, book xii.). As established religions were formed among nations of a higher grade, the separation became more distinct between the official rites of the priesthood and those practised by castes of magicians, rivalry often becoming serious between them. Thus in ancient Egypt there appear, on the one hand, the miracles worked by divinities under official sanction of the priesthood, and, on the other hand, the unlicensed proceedings of sorcerers, who indeed doubtless deserved ill of society by practices done by detestable means or for detestable ends, such as bewitching by hurtful demons, or administering love-potions. Here we come into view of the distinction still expressed by the terms "white magic" and "black magic." Laws were made against magic in these ancient times, but it must be remembered that then and for thousands of years later, the opposition to magic had seldom anything to do with the sceptical doubts of its reality which arose among the classic philosophers. Magic was none the less believed in for being hated and proscribed; and when a soothsayer was looked upon as a false prophet the inference was, not that magic was unreal, but that this particular magician was pretending to supernatural power he did not possess. The Levitical law prohibits sorcery under penalty of death (Levit. xx. 27). Among the early Christians sorcery was recognized as illegal miracle; and magic acts, such as turning men into beasts, calling up familiar demons, raising storms, &c., are mentioned, not in a sceptical spirit, but with reprobation. In the changed relations of the state to the church under Constantine, the laws against magic served the new purpose of proscribing the rites of the Greek and Roman religion, whose oracles, sacrifices, and auguries, once carried on under the highest public sanction, were put under the same ban with the low arts of the necromancer and the witch.[3] As Christianity extended its sway over Europe, the same antagonism continued, the church striving with considerable success to put down at once the old local religions, and the even older practices of witchcraft; condemning Thor and Woden as demons, they punished their rites in common with those of the sorcerers who bewitched their neighbours, and turned themselves into wolves or cats. Thus gradually arose the legal persecution of witches, which went on through the Middle Ages under ecclesiastical sanction both Catholic and Protestant. The literature of the Middle Ages does not contribute many new elements to the study of magic, which was carried on under the old traditional systems. But it shows on the one hand how unbroken the faith of even the educated classes remained in the reality of magic, and on the other hand that its more respectable branches, such as astrology and alchemy, were largely followed, and indeed included in their scope much of the real science of the period (see the works of Thomas Aquinas, Gerbert, Roger Bacon, Cornelius Agrippa, &c.). The final fall of magic began with the revival of science in the 16th and 17th centuries, when the question whether the supposed effects of magic really take place or not was raised, and decided against it. In our day the occult sciences are rapidly dying out in the educated classes of the civilized world, though astrology still has its votaries, and the communications in "spirit circles" by possessed mediums and spirit-writing are what would in old times have been classed as necromancy. The magic which holds its place most firmly in Europe has come down by tradition in popular folk-lore, which is full of precepts for bewitching and averting witchcraft, and divining by omens. Among the practices which occur to everyone's mind are foretelling changes of the weather by the moon's quarters, taking omens from seeing magpies and hearing a dog howl at night, the fear of spilling salt, observation of the shroud in the candle and the stranger in the tea-cup, the girls' listening to the cuckoo to tell how soon they will be married, pulling off the row of leaves to settle what the lover's calling will be, and perhaps even compelling him to come by a pin stuck through the rushlight. Nor has the wizard forgotten how to cure inflammation with a "thunderbolt," generally an ancient stone or bronze hatchet dug up in the fields, nor how to punish an enemy by means of a heart stuck full of pins and hung in the chimney. These are but a few out of hundreds to be found in Brand's *Popular Antiquities* and the volumes published by the Folklore Society, or in the similar collections from every country of Europe. If any one wonders that popular magic still enjoys much credit in the peasant class, it should be remembered that even the educated world still shows a remarkable unreasonableness in connecting causes and effects. Thus the old magical belief survives that a loadstone, because it draws steel, will also draw out pain. Peasants may well carry a magnet in their trousers' pocket against rheumatism when better-informed people will wear with as great confidence a "galvanic belt," though any electrician will tell them it has not the power to hurt or cure a fly. One of the most favourable proofs of the changed public opinion in England is seen in the laws, where the penalties of the old statute against those who keep familiar demons are abolished, and the time-honoured charge has disappeared from the commission of the peace to inquire of all "inchantments, sorceries, art magic, trespasses, forestallings, regratings, &c." But persons pretending to exercise witchcraft, sorcery, enchantment, or conjuration, or undertaking to tell fortunes or pretending by occult or crafty science to discover lost or stolen goods, may be imprisoned under 9 Geo. II. c. 5, or fortune-tellers dealt with as rogues and vagabonds under 5 Geo. IV. c. 83, or they may be prosecuted for obtaining money under false pretences.

Origin of magic.

Looked at as a series of delusions, magic is distasteful to the modern mind, which, once satisfied of its practical futility, is apt to discard it as folly unworthy of further notice.

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[1] See Mohl, *Y-king*; Pauthier, *Livres Sacrés de l'Orient*.

[2] See Eitel, *Handbook of Chinese Buddhism*; Edkins, *Folklore of China*, p. 65.

[3] For an excellent account of the classical and mediæval history of magic see Maury, *La Magie et l'Astrologie*.

This, however, is hardly doing it justice, for in the early developments of the human mind both religion and science were intimately connected with magic, whose various branches, unfruitful as they may be, are nevertheless growths from the tree of knowledge. The universal diffusion of magical ideas among mankind, excepting only the limited class who have abandoned them through higher education, shows that we are here in presence of a deep-seated intellectual process, while the strong likeness in the principles of magic among the rudest tribes points to its having sprung up under most ancient and primitive conditions. The connexion between magic and religion in its lower stages is obvious from the impossibility of separating them, inasmuch as in every country sorcerers and diviners, savage or civilized, are found invoking the aid of ghosts, demons, or gods, to give them information or execute their will. So far as magic is ascribed to the influence of spirits, its theory belongs to the animistic philosophy developed in the lower levels of civilization, where all the powers of life and nature are set down to spiritual beings (see Animism). A chief part of the magician's business being to converse with spirits and gain their help, he sets about this in various ways. More often than not the spirit is considered to be a human ghost, which behaves much as it did while it was still a living man's soul; or if it is called a demon or deity, still these are beings modelled on the human soul. Thus their manner of hearing prayers and receiving offerings is like human intercourse, especially in the frequent cases where the sorcerer is a "medium" possessed by the spirit, who is considered to inhabit his body like his ordinary soul, and to give oracles speaking by his human voice. In such supposed interviews with spirits there is plenty of delusion and fraud, but nothing specially magical; and, in fact, were the whole craft of the sorcerer of this spiritualistic kind, there would be no practical distinction between the sorcerer and the priest, and magic would fall into its place as an inferior branch of religion. It is because magical practices are by no means accounted for altogether by the doctrine of spirits, but involve other special explanations of their own, that it is found convenient to make magic a department by itself. Such explanation is needed in ordinary magical practices, like that of the American medicine-man, who draws a deer on a piece of bark and shoots at it, expecting thereby to kill a real deer next day, or of the Tongan soothsayer, who spins a cocoa-nut as a teetotum, in order to discover a thief by noticing towards whom the monkey-face of the nut is looking when it stops. The magical train of thought which leads men to resort to such devices is childishly simple. It is merely imperfect reasoning, the mistaking of an ideal connexion for a real one, the confusion of ineffective analogy with effective cause. Our minds go with those of the barbaric magicians so far as to recognize the analogy between shooting an animal and its picture; we see as plainly as they that the cocoa-nut as it were looks in a particular direction. The difference is that, in the magical stage of thought, these are taken to be real connexions, while more advanced knowledge discards them as ideal. As Wilhelm von Humboldt well remarks, "Man begins by seeking the connexion even of external phenomena in the region of thought; . . . . pure observation, still more experiment, follow at a wide distance after ideal or phantastic systems. Man's first attempt is to govern nature through its idea."

So much of the intellect of mankind has been spent since remote antiquity on magic that it may seem hard to believe the chief secret of the occult sciences to be after all nothing but bad reasoning. This at any rate is very unlike the theories propounded by those who have condemned magic as a real craft made known to man by diabolical influence, or by those who have thought to find in its mystic precepts relics of antique wisdom. The question is not, however, an abstruse one, for every reader has the means of satisfying himself by inspection of a few magical processes, as to what amount of reason really goes to making them. In a large proportion of cases there may be perceived, not absolute nonsense, but a kind of half-formed sense stopping short of practical value. There being an evident relation between an object and the thought of it, it becomes one of the chief practices of the sorcerer to try to make things happen by thinking about them. Thus he so "takes the will for the deed" that when he "ill-wishes" his enemies, and looks upon them with the "evil eye," he believes that he does them direct harm. On the other hand, those who know or suspect that such influence has been used against them suffer in reality from fear, often even dying of it. The belief in this mysterious power furnishes an explanation which is resorted to when any one falls ill or has any misfortune, and thus the belief in witchcraft among savages leads to constant enmity and revenge. Nor is this state of things to be traced only in what is called the uncivilized world, for those who have much intercourse with English country folks may still meet with instances of some cow or child firmly believed to have been "overlooked," the death of which may possibly be revenged on a neighbouring cottager, supposed to be the witch. Whenever a good or evil wish is uttered in words, it becomes a blessing or curse. When these are addressed to some deity or demon, they are in fact prayers, but when they are merely expressed wishes, without reference to any spiritual being, then their supposed effects are purely magical. Thus, in an ancient Hindu love-charm, the girl expects to bring back an offended lover by repeating the formula, "May thy heart devour itself for me, may thy dry mouth water for me!" &c. Still more does this kind of magic explain itself in the various rites where some object is used as a symbol, and the association of ideas transfers whatever is done to it to the person it represents. Thus Ovid's sorceress (*Heroid.*, vi. 91)—

> "simulacraque cerea fingit,
> Et miserum tenuis in jecur urget acus."

King James in his *Dæmonology* says that "the devil teacheth how to make pictures of wax or clay, that by roasting thereof the persons that they bear the name of may be continually melted or dried away by continual sickness." By a similar association of ideas, any object which has belonged to a person may be thus practised on, as has been already here mentioned among the South Sea islanders, or, to take a case nearer home, when in 1618 two women were executed at Lincoln for burying the glove of Henry Lord Rosse, so that, "as that glove did rot and waste, so did the liver of the said lord rot and waste." By like reasoning, when internal disease is ascribed to knots within the patient's body, it becomes a branch of witchcraft to tie magic knots, which produce their corresponding effect within the victim. Kindlier though not less delusive operations of misunderstood analogy are found in attempted cures by sympathetic magic, on the same principle which malignant sorcerers would have used in giving the disease itself. Thus knots are untied in order to untie internal complications in the sick beast, and weapons treated to cure by sympathy the wounds they made:—

> "But she has ta'en the broken lance,
> And washed it from the clotted gore,
> And salved the splinter o'er and o'er.
> William of Deloraine in trance,
> Whene'er she turned it round and round,
> Twisted, as if she galled his wound.
> Then to her maidens she did say
> That he should be whole man and sound
> Within the course of a night and day."
> —*Lay of the Last Minstrel*, iii. 23.

The herbs used as medicaments in the infancy of medicine appear to have been chosen for magical rather than medical motives, by a kind of reasoning which comes out very plainly among Chinese physicians, who administer the heads, middles, and roots of plants to cure their patients' heads, bodies, and legs respectively. In like manner European doctors long followed the "doctrine of signatures," which was in fact mere magic,—prescribing euphrasy or "eye-bright" for complaints of the eyes, because of the likeness of an eye in the flower, and treating small-pox with mulberries because their colour made them proper to diseases of the blood (see Pettigrew, *Superstitions of Medicine and Surgery*). The same easily-understood though practically absurd principle may be seen to have guided the processes of divination, many of which show plainly the association of ideas that suggested them. Thus, in the Roman augury already mentioned, there is no difficulty in following the fancy which made the war-eagle give an omen of victory, but attached a doleful foreboding to the melancholy owl. The same half-rational meaning explains the reversal of omens accordingly as they come on the right or left, that is, the good or bad hand. Any one who glances through one of the cheap dream-books still bought by servant-maids, which fairly represent the ancient books on *oneiromancy*, such as that of Artemidorus, will find many of the analogies still intelligible on which they are founded, as that to dream of washing one's hands presages relief from anxiety, while he who dreams of losing a tooth will lose a friend. The ancient art of *chiromancy*, or telling fortunes by the hand, goes on the evident analogy between the lines of the palm and the diverging courses of human life; closely allied to this is *scapulimancy* or divining by the cracks of a shoulder-blade put into the fire. Of divination by lots, so common that the term for throwing lots (*sortes*) has passed into *sorcery*, there are many varieties. Some are quite pictorial, such as the Maori diviner's sticks set up in the ground to show by their standing or falling the fate of the warriors they represent. But this strong analogy is not necessary, for it only requires a particular lot to be mentally associated with a particular idea to make the diviner believe that the fall of that lot makes that idea true. It would be tedious to go at length through other details of magic where the same key of imperfect analogy applies. But it may be pointed out that this explanation is nowhere more conclusive than in astrology. The very foundation of the science of the horoscope lies in the mere analogy between the rising of a star above the horizon and the birth of a man. Such circumstances as whether a planet is in conjunction or opposition alter their effect on the "native" in corresponding ways. The names of gods, happening to be given also to certain planets, are taken as omens, so that because a planet bears the name of Mercury it is brought into fanciful connexion with wisdom, and in like manner the planet Venus with love. Each planet having a colour assigned to it, the aspect of Mars or Saturn is believed to tell one, when in quest of a thief, whether he will have on red or black clothes. So the arbitrary names of the signs of the zodiac are made into presages, a just person being found under the sign of Libra, and charms against bugs being effective in the sign of Cancer. For convenience some of these examples are taken from modern handbooks of astrology, but in principle the old starcraft has changed little in the course of ages. In the study of magic it is necessary further to notice that precepts which seem quite arbitrary, not showing even fanciful half-reason, are often explained on further examination, which gives the key to the symbolic process by which they are formed. For instance, it would hardly be guessed why Cancer should be a sign involving movableness, but Scorpio firmness, were it not known that this result is obtained by arranging the twelve signs in order as they stand, as successively movable, fixed, and double (see Proclus, *Paraphrasis*, i. 15). Considering the antiquity of magic, the wonder is not that so much of its sense should be lost, but that so much is still intelligible.[1] Various other causes may be traced in the occult sciences, among which can only be mentioned here *rhabdomancy* or the use of the divining rod, by which the cunning man professes to discover water springs, murderers, or hidden treasure. Here it is evident that the decision is really arrived at by the diviner himself, not by the twig, and the same is true of various similar arts. From the earliest times also tricks of sleight-of-hand, &c., have been passed off by magicians as miracles to deceive their dupes; our language still testifies to this in the use of the word *conjuror*, the wonder-worker carrying on the old juggling, although no longer evoking demons to give him his mysterious power.

Hitherto magic has been dealt with on its delusive and harmful side, this being what most practically manifests itself in history. Yet it must be borne in mind that in its early stages it has been a source of real knowledge. True as it is that misunderstood facts and misleading analogies have produced its delusions, its imperfect arguments have been steps towards more perfect reasoning. Analogy has always been the forerunner of scientific thought, and, as experience corrected and restricted it into real effectiveness, from age to age whole branches of what was magic passed into the realm of science. The vague and misleading parts which could not be thus transformed were left behind as occult science, and thus the very reason why magic is almost all bad is because when any of it becomes good it ceases to be magic. From this point of view the intellectual position of magic is well expressed by Adolf Bastian (*Rechtsalterthümer*, p. 242):—"Sorcery, or, in its higher expression, magic, marks the first dawning consciousness of mutual connexion throughout nature, in which man, feeling himself part of the whole, thinks himself able to interfere for his own wishes or needs. So long as religion fills the whole horizon of culture, the vague groping of magic contains the first experiments which lead to the results of exact science. Magic is the physics of mankind in the state of nature. It rests on the beginning of induction, which remains without result only because in its imperfect judgments by analogy it raises the *post hoc* to the *propter hoc*, &c." The nature-spirits and demons with which the magician has so much to do represent indeed the notion of physical cause in the rudimentary science of the lower races, while the association of ideas on which his sorcery and divination is based has much the same relation to the scientific induction which succeeds it. That this view is sound is best shown by noticing the great departments of science whose early development is known to have taken place through magic. Astronomy grew up in Babylon, not through quest of mechanical laws of the universe, but through observation of the heavens to obtain presages of wars and harvest; while even in modern times Kepler's discoveries in physical astronomy were led up to through mystic magical speculations. In alchemy appears the early history of chemistry, which only emancipated itself in modern ages from its magical surroundings. The astrological connexion of the metals each with its planet was one of its fundamental ideas, of which the traces are still to be found in the name of the metal "mercury," and that of "*lunar* caustic" for silver nitrate. Lastly, the history of medicine goes back to the times when primitive science accepted demoniacal possession as the rational means of accounting for disease, and magical operations with herbs originated their more practical use in materia medica. (E. B. T.)

[1] For details of the association of ideas in magic see Tylor, *Early Hist. of Mankind*, chap. vi., and *Primitive Culture*, chap. iv.

MAGIC, White. Under this head is included the art of performing tricks and exhibiting illusions by aid of apparatus, excluding feats of dexterity in which there is no deception, together with the performances of such automaton figures as are actuated in a secret and mysterious manner. Conjuring by prestidigitation, or sleight of hand, independently of mechanical apparatus, is referred to under Legerdemain.

Whether or not the book of Exodus makes the earliest historical reference to this natural magic when it records how the magicians of Egypt imitated certain miracles of Moses "by their enchantments," it is known that the Egyptian hierophants, as well as the magicians of ancient Greece and Rome, were accustomed to astonish their dupes with optical illusions, visible representations of the divinities and subdivinities passing before the spectators in dark subterranean chambers. From the descriptions of ancient authors we may conjecture that the principal optical illusion employed in these effects was the throwing of spectral images of living persons and other objects upon the smoke of burning incense by means of concave metal mirrors. But, according to the detailed exposure of the tricks of the magicians given by Hippolytus (*Ref. Om. Hær.*, iv. 35), it appears that the desired effect was often produced in a simpler way, by causing the dupe to look into a cellar through a basin of water with a glass bottom standing under a sky-blue ceiling, or by figures on a dark wall drawn in inflammable material and suddenly ignited. The flashes of lightning and the rolling thunders which sometimes accompanied these manifestations were easy tricks, now familiar to everybody as the ignition of lycopodium and the shaking of a sheet of metal. The ancient methods described by Hippolytus (iv. 32) were very similar.

Spectral pictures or reflexions of moving objects, similar to those of the camera or magic lantern, were described in the 14th and 16th centuries. Thus, in the *House of Fame*, bk. iii., Chaucer speaks of "appearances such as the subtil tregetours perform at feasts"—pictorial representations of hunting, falconry, and knights jousting, with the persons and objects instantaneously disappearing; exhibitions of the same kind are mentioned by Sir John Mandeville, as seen by him at the court of "the Great Chan" in Asia; and in the middle of the 16th century Benvenuto Cellini saw phantasmagoric spectres projected upon smoke at a nocturnal exhibition in the Colosseum at Rome. The existence of a camera at this latter date is a fact; for the instrument is described by Baptista Porta, the Neapolitan philosopher, in his *Magia Naturalis* (1558). And the doubt how magic lantern effects could have been produced in the 14th century, when the lantern itself is alleged to have been invented by Athanasius Kircher in the middle of the 17th century, is set at rest by the fact that glass lenses were constructed at the earlier of these dates,—Roger Bacon, in his *Discovery of the Miracles of Art, Nature, and Magic* (about 1260), writing of glass lenses and perspectives so well made as to give good telescopic and microscopic effects, and to be useful to old men and those who have weak eyes. Towards the end of last century Comus, a French conjuror (the second of the name), included in his entertainment a figure which suddenly appeared and disappeared about 3 feet above a table,—a trick explained by the circumstance that a concave mirror was among his properties; and a contemporary performer, Robert, exhibited the raising of the dead by the same agency. Early in the present century Philipstal gave a sensation to his magic lantern entertainment by lowering unperceived between the audience and the stage a sheet of gauze upon which fell the vivid moving shadows of phantasmagoria.

A new era in optical tricks began in 1863 when John Nevil Maskelyne, a Cheltenham artist in jewellery, invented a wood cabinet in which persons vanished and were made to reappear, although it was placed upon high feet, with no passage through which a person could pass from the cabinet to the stage floor, the scenes, or the ceiling; and this cabinet was examined and measured for concealed space, and watched round by persons from the audience during the whole of the transformations. The general principle undoubtedly was this:—if a looking-glass be set upright in the corner of a room, bisecting the right angle formed by the walls, the side wall reflected will appear as if it were the back, and hence an object may be hidden behind the glass, yet the space seem to remain unoccupied. This principle, however, was so carried out that no sign of the existence of any mirror was discernible under the closest inspection. Two years later the same simple principle appeared in "The Cabinet of Proteus," patented by Tobin and Pepper of the Polytechnic Institution, in which two mirrors were employed, meeting in the middle, where an upright pillar concealed their edges. In the same year Stodare exhibited the illusion in an extended form, by placing the pair of mirrors in the centre of the stage, supported between the legs of a three-legged table having the apex towards the audience; and as the side walls of his stage were draped exactly like the back, reflexion showed an apparently clear space below the table top, where in reality a man in a sitting position was hidden behind the glasses and exhibited his head ("The Sphinx") above the table. The plane mirror illusion is so effective that it has been reproduced with modifications by various performers. In one case a living bust was shown through an aperture in a looking-glass sloping upward from the front toward the back of a curtained cabinet; in another a person stood half-hidden by a vertical mirror, and imitation limbs placed in front of it were sundered and removed; and in another case a large vertical mirror was pushed forward from a back corner of the stage at an angle of 45 degrees, to cover the entrance of a living "phantom," and then withdrawn. Maskelyne improved upon his original cabinet by taking out a shelf which, in conjunction with a mirror, could enclose a space, and thus left no apparent place in which a person could possibly be hidden. He introduced a further mystification by secretly conveying a person behind a curtain screen, notwithstanding that, during the whole time, the existence of a clear space under the stool upon which the screen is placed is proved by performers continually walking round. And the illusion reached its height when he revealed or "vanished" a succession of persons out of a light shell obelisk or "Cleopatra's Needle," with a sheet of paper interposed between this cover and the stool it stood upon, thus intercepting the apparently only available avenue of approach. The principle of reflecting by means of transparent plate-glass the images of highly-illuminated objects placed in front, so that they appear as if among less brilliantly lighted objects behind the glass, was employed in the "ghost" illusions of Sylvester, of Dircks and Pepper, of Robin, and of some other inventors,—the transparent plate-glass being, in some cases, inclined forwards so as to reflect a lime-lighted object placed below the front of the stage, and in other arrangements set vertically at an angle so as to reflect the object from a lateral position.

Among the acoustic wonders of antiquity, fabled or real, were the speaking head of Orpheus, the golden virgins, whose voices resounded through the temple of Delphi, and the like. Hippolytus (iv. 4) explains the trick of the speaking head as practised in his day: the voice was really that of a concealed assistant who spoke through the flexible gullet of a crane. Towards the close of the 10th century Gerbert (Pope Sylvester II.) constructed (says

William of Malmesbury) a brazen head which answered questions; and similar inventions are ascribed to Roger Bacon, Albertus Magnus, and others. In the first half of the 17th century the philosopher Descartes made a speaking figure which he called his daughter Franchina; and the superstitious captain of a vessel had it thrown overboard. In the latter part of the same century Thomas Irson, an Englishman, exhibited at the court of Charles II. a wooden figure with a speaking-trumpet in its mouth; and questions whispered in its ear were answered through a pipe secretly communicating with an apartment wherein was a learned priest able to converse in various languages. Beckmann, in his *History of Inventions* (about 1770), relates his inspection of a speaking figure, in which the words really came through a tube from a confederate who held a card of signs by which he received intelligence from the exhibitor. Somewhat later was shown in England the figure of an infant suspended by a ribbon, having a speaking-trumpet in its mouth,—an illusion in which two concave mirrors were employed, one of them concentrating the rays of sound into a focus within the head of the figure; and the mirror nearest the figure was hidden by a portion of the wall-paper which was perforated with pin-holes. In 1783 Giuseppe Pinetti de Wildalle, an Italian conjuror of great originality, exhibited among his many wonders a toy bird perched upon a bottle, which fluttered, blew out a candle, and warbled any melody proposed or improvised by the audience,—doing this also when removed from the bottle to a table, or when held in the performer's hand upon any part of the stage. The sounds were produced by a confederate who imitated song-birds after Rossignol's method by aid of the inner skin of an onion in the mouth; and speaking-trumpets directed the sounds to whatever position was occupied by the bird. About the year 1825 Charles, a Frenchman, exhibited a copper globe, carrying four speaking-trumpets, which was suspended in a light frame in the centre of a room. Whispers uttered near to this apparatus were heard by a confederate in an adjoining room by means of a tube passing through the frame and the floor, and answers issued from the trumpets in a loud tone. And of late years have appeared more than one illusion of a similar order, in which the talking and singing of a distant person issue from an isolated head or figure by aid of ear-trumpets secretly contained within parts in which, from their outside form, the presence of such instruments would not be suspected. It is probable that the automaton trumpeters of Kaufmann and of Maelzel were clever deceptions of the same kind. As described in the *Journal de Mode*, 1809, Maelzel's life-size figure had the musical instrument fixed in its mouth; the mechanism was wound up, and a set series of marches, army calls, and other compositions was performed, accompaniments being played by a real band. Mechanical counterparts of the human lips, tongue, and breath, both in speech and in playing certain musical instruments, have, however, been constructed,—as in Vaucanson's celebrated automaton flute-player, which was completed in 1736; the same mechanician's tambourine and flageolet player, which was still more ingenious, as, the flageolet having only three holes, some of the notes were produced by half-stopping; Abbé Mical's heads which articulated syllables, and his automata playing upon instruments; Kempelen's and Kratzenstein's speaking-machines, in the latter part of last century; the speaking-machine made by Fabermann of Vienna, closely imitating the human voice, with a fairly good pronunciation of various words; the automaton clarionet-player constructed by Van Oeckelen, a Dutchman, and exhibited in New York in 1860, which played airs from a barrel like that of a crank-organ, and could take the clarionet from its mouth and replace it; and, lastly, Maskelyne's two automata, "Fanfare" (1878) playing a cornet, and "Labial" (1879) playing a euphonium, both operated by mechanism inside the figures and supplied with wind from a bellows placed separately upon the stage.

Lucian tells of the magician Alexander in the 2d century that he received written questions enclosed in sealed envelopes, and a few days afterwards delivered written responses in the same envelopes, with the seals apparently unbroken; and both he and Hippolytus explain several methods by which this could be effected. In this deception we have the germ of "spirit-reading" and "spirit-writing," which, introduced in 1840 by Anderson, "The Wizard of the North," became common in the *répertoire* of modern conjurors,—embracing a variety of effects from an instantaneous substitution which allows the performer or his confederate to see what has been secretly written by the audience. The so-called "second-sight" trick depends upon a system of signalling between the exhibitor, who moves among the audience collecting questions to be answered and articles to be described, and the performer, who is blindfolded on the stage. As already stated, the speaking figure which Stock showed to Professor Beckmann, at Göttingen, about 1770, was instructed by a code of signals. In 1783 Pinetti had an automaton figure about 18 inches in height, named the Grand Sultan or Wise Little Turk, which answered questions as to chosen cards and many other things by striking upon a bell, intelligence being communicated to a confederate by an ingenious ordering of the words, syllables, or vowels in the questions put. The teaching of Mesmer and feats of alleged clairvoyance suggested to Pinetti a more remarkable performance in 1785, when Signora Pinetti, sitting blindfold in a front box of a theatre, replied to questions and displayed her knowledge of articles in the possession of the audience. Half a century later this was developed with greater elaboration, and the system of telegraphing cloaked by intermixing signals on other methods, first by Robert-Houdin in 1846, then by Hermann in 1848, and by Anderson at a later period. Details of the system of indicating a very large number of answers by slight and unperceived variations in the form of question are given by F. A. Gandon, *La Seconde Vue Dévoilée*, Paris, 1849.

Fire tricks, such as walking on burning coals, breathing flame and smoke from a gall-nut filled with an inflammable composition and wrapped in tow, or dipping the hands in boiling pitch, were known in early times, and are explained by Hippolytus (iv. 33). At the close of the 17th century Richardson astonished the English public by chewing ignited coals, pouring melted lead (really quicksilver) upon his tongue, and swallowing melted glass. Strutt, in *Sports and Pastimes of the People of England*, relates how he saw Powel the fire-eater, in 1762, broil a piece of beefsteak laid upon his tongue,—a piece of lighted charcoal being placed under his tongue which a spectator blew upon with a bellows till the meat was sufficiently done. This man also drank a melted mixture of pitch, brimstone, and lead out of an iron spoon, the stuff blazing furiously. These performers anointed their mouths and tongues with a protective composition.

Galen speaks of a person in the 2d century who relighted a blown-out candle by holding it against a wall or a stone which had been rubbed with sulphur and naphtha; and the instantaneous lighting of candles became a famous feat of later times. Baptista Porta gave directions for performing a trick entitled "many candles shall be lighted presently." Thread is boiled in oil with brimstone and orpiment, and when dry bound to the wicks of candles; and, one being lighted, the flame runs to them all. He says that on festival days they are wont to do this among the Turks. "Some call it Hermes his ointment." In 1783

Pinetti showed two figures sketched upon a wall, one of which put out a candle, and the other relighted the hot wick, when the candle was held to their mouths. By wafers he had applied a few grains of gunpowder to the mouth of the first, and a bit of phosphorus to that of the other. A striking trick of this conjuror was to extinguish two wax candles and simultaneously light two others at a distance of 3 feet, by firing a pistol. The candles were placed in a row, and the pistol fired from the end where the lighted candles were placed; the sudden blast of hot gas from the pistol blew out the flames and lighted the more distant candles, because in the wick of each was placed a millet-grain of phosphorus. A more recent conjuror showed a pretty illusion by appearing to carry a flame invisibly between his hands from a lighted to an unlighted candle. What he did was to hold a piece of wire for a second or two in the flame of the first candle, and then touch with the heated wire a bit of phosphorus which had been inserted in the turpentine-wetted wick of the other. But in 1842 Louis Döbler, a German conjuror of much originality, surprised his audience by lighting two hundred candles instantaneously upon the firing of a pistol. This was the earliest application of electricity to stage illusions. The candles were so arranged that each wick, black from previous burning, stood a few inches in front of a fine nozzle gas-burner projecting horizontally from a pipe of hydrogen gas, and the two hundred jets of gas passed through the same number of gaps in a conducting-wire. An electric current leaping in a spark through each jet of gas ignited all simultaneously, and the gas flames fired the candle wicks.

Robert-Houdin, who opened his "Temple of Magic" at Paris in 1845, originated the application of electromagnetism for secretly working or controlling mechanical apparatus in stage illusions. He first exhibited in 1845 his light and heavy chest, which, when placed upon the broad plank or "rake" among the spectators, and exactly over a powerful electromagnet hidden under the cloth covering of the plank, was held fast at pleasure. In order to divert suspicion Houdin showed a second experiment with the same box, suspending it by a rope which passed over a single small pulley attached to the ceiling; but any person in the audience who took hold of the rope to feel the sudden increase in the weight of the box was unaware that the rope, while appearing to pass simply over the pulley, really passed upward over a winding-barrel worked as required by an assistant. Remarkable ingenuity was displayed in concealing a small electromagnet in the handle of his glass bell, as well as in his drum, the electric current passing through wires hidden within the cord by which these articles were suspended. In one of Houdin's illusions—throwing eight half-crowns into a crystal cash-box previously set swinging—electricity was employed in a different manner. Top, bottom, sides, and ends of an oblong casket were of transparent glass, held together at all the edges by a light metal frame. The coins were concealed under an opaque design on the lid, and supported by a false lid of glass, which was tied by cotton thread to a piece of platinum wire. Upon connecting the electric circuit, the platinum, becoming red-hot, severed the thread, letting fall the glass flap, and dropping the coins into the box.

Down to the latter part of last century no means of secretly communicating *ad libitum* motions to apparently isolated pieces of mechanism had superseded the clumsy device of packing a confederate into a box on legs draped to look like an unsophisticated table. Pinetti placed three horizontal levers close beside each other in the top of a thin table, covered by a cloth, these levers being actuated by wires passing through the legs and feet of the table and to the confederate behind a scene or partition. In the pedestal of each piece of apparatus which was to be operated upon when set loosely upon the table were three corresponding levers hidden by cloth; and, after being examined by the audience, the piece of mechanism was placed upon a table in such a position that the two sets of levers exactly coincided, one being superimposed upon the other. In one "effect" the confederate worked a small bellows in the base of a lamp, to blow out the flame; in another he let go a trigger, causing an arrow to fly by a spring from the bow of a doll sportsman; he actuated a double-bellows inside a bottle, which caused flowers and fruit to protrude from among the foliage of an artificial shrub, by distending with air a number of small bladders shaped and painted to represent them; he opened or shut valves which allowed balls to issue out of various doors in a model house as directed by the audience; and he moved the tiny bellows in the body of a toy bird by which it blew out a candle. Other conjurors added more complicated pieces of apparatus,—one being a clock with small hand moving upon a glass disk as required by the audience. The glass disk carrying the numbers or letters was in reality two, the back one being isolated by ratchet teeth on its periphery hidden by the ring frame which supported it, and, though the pillar-pedestal was separated into three pieces and shown to the spectators, movable rods, worked by the table levers, were in each section duly covered by cloth faces. Another mechanical trick, popular with Torrini, Houdin, Philippe, and Robin, and worked in a similar way, was a little harlequin figure which rose out of a box set upon the table, put his legs over the front of the box and sat on the edge, nodded his head, smoked a pipe, blew out a candle, and whistled a one-note obbligato to an orchestra. Robert-Houdin employed, instead of the table levers, vertical rods each arranged to rise and fall in a tube, according as it was drawn down by a spiral spring or pulled up by whip-cord which passed over a pulley at the top of the tube and so down the table leg to the hiding-place of the confederate. In his centre table he had ten of these "pistons," and the ten cords passing under the floor of the stage terminated at a keyboard. Various ingenious automata were actuated by this means of transmitting motion; but the most elaborate piece of mechanical apparatus constructed by Houdin was his orange tree. The oranges, with one exception, were real, stuck upon small spikes, and concealed by hemispherical screens which were covered with foliage; and the screens, when released by the upward pressure of a piston, made half a turn, and disclosed the fruit. The flowers were hidden behind foliage until raised above the leaves by the action of another piston. Near the top of the tree an artificial orange opened into four portions; while two butterflies attached to two light arms of brass rose up behind the tree, appeared on each side by the spreading of the arms, and drew out of the opened orange a handkerchief which had been borrowed and vanished away.

It is remarkable how many of the illusions regarded as the original inventions of eminent conjurors have been really improvements of older tricks. *Hocus Pocus Junior, The Anatomy of Legerdemain* (4th edition, 1654), gives an explanatory cut of a method of drawing different liquors out of a single tap in a barrel, the barrel being divided into compartments, each having an air-hole at the top, by means of which the liquid in any of the compartments was withheld or permitted to flow. Robert-Houdin applied the principle to a wine-bottle held in his hand from which he could pour four different liquids regulated by the unstopping of any of the four tiny air-holes which were covered by his fingers. A large number of very small liqueur glasses being provided on trays, and containing drops of certain flavouring essences, enabled him to supply imitations of various wines and liquors, according to the glasses into which he poured syrup from the bottle; while by a skilful substitution of a full bottle for an emptied one, or by secretly refilling in the act of wiping the bottle with a cloth, he produced the impression that the bottle was "inexhaustible." In 1835 was first exhibited in England a trick which a Brahman had been seen to perform at Madras several years before. Ching Lau Lauro sat cross-legged upon nothing,—one of his hands only just touching some beads hung upon a genuine hollow bamboo which was set upright in a hole on the top of a wooden stool. The placing of the performer in position was done behind a screen; and the explanation of the mysterious suspension is that he passed through the bamboo a strong iron bar, to which he connected a support which, concealed by the beads, his hand, and his dress, upheld his body. In 1849 Robert-Houdin reproduced the idea under the title of ethereal suspension,—professedly rendering his son's body devoid of weight by administering vapour of ether to his nose, and then, in sight of the audience, laying him in a horizontal position in the air with one elbow resting upon a staff resembling a long walking-stick. The support was a jointed iron frame under the boy's dress, with cushions and belts passing round and under the body. Subsequently the trick was improved upon by Sylvester—the suspended person being shown in several changes of position, while the sole supporting upright was finally removed. For the latter deception the steel upright was made with polished angular faces, apex toward the spectators, and acted in a dim light on the same principle as the mirrors of a Sphinx table. Before lowering the light, the reflector bar is covered by the wood staff set up before it.

The mysterious vanishing or appearing of a person under a large extinguisher upon the top of a table, and without the use of mirrors, was first performed by Comus, a French conjuror very expert in the cups-and-balls sleight-of-hand, who, appearing in London in 1789, announced that he would convey his wife under a cup in the same manner as he would balls. The feat was accomplished by means of a trap in a box table. Early in the present century Chalons, a Swiss conjuror, transformed a bird into a young lady, on the same principle. In 1836 Sutton varied the feat by causing the vanished body to reappear under the crust of a great pie. Houdin "vanished" a person standing upon a table top which was shown to be only a few inches thick; but there was a false top which was let down like the side of a bellows, this distension being hidden by a table-cloth hanging sufficiently low for the purpose, and the person, when covered by the extinguisher, entered the table though a trap-door opening upwards. Robin, in 1851, added to the wonder of the trick by vanishing two persons in succession, without any possibility of either escaping from the table,—the two persons really packing themselves into a space which, without clever arrangement and practice, could not hold more than one. The sword-and-basket trick was common in India many years ago. In one form it consisted in inverting an empty basket over a child upon the ground; after the child had secreted himself between the basket-bottom and a belt concealed by a curtain painted to look like the actual wicker bottom, a sword was thrust through both sides of the basket, the child screaming, and squeezing upon the sword and upon the ground a blood-coloured liquid from a sponge. When the performer upset the basket, the child could not be seen; but another child similarly costumed suddenly appeared among the spectators, having been up to that time supported by a pair of stirrups under the cloak of a confederate among the bystanders. In another form an oblong basket is used large at the bottom and tapering to the top, with the lid occupying only the central portion of the top, and the child is so disposed round the basket that the sword plunged downward avoids him, and the performer can step inside and stamp upon the bottom to prove that the basket is empty. In 1865 Stodare introduced the trick into England, but in a new manner. Upon light tressels he placed a large oblong basket; and after a lady attired in a profuse muslin dress had composed herself and her abundance of skirt within, after the lid had been shut and the sword plunged through the sides, the basket was tilted towards the audience to show that it was empty, and the lady reappeared in a gallery of the hall. The basket was formed with an outer shell to turn down, leaving the lady with her dress packed together lying upon the basket bottom and behind what had formed a false front side,—the principle being the same as in the clown's box, which, when containing a man, is rolled over to display the inside empty. The reappearing lady was a double, or twin sister.

Among the most meritorious and celebrated mechanical illusions have been automaton figures secretly influenced in their movements by concealed operators. In the 17th century M. Raisin, organist of Troyes, took to the French court a harpsichord which played airs as directed by the audience; but, upon opening the instrument, Louis XIV. discovered a youthful performer inside. In 1769 Baron Kempelen, of Pressburg, in Hungary, completed his chess-player, which for a long time remained the puzzle of Europe. It was an illusion,—the merit consisting in the devices by which the confederate player was hidden in the cabinet and body of the figure, while the interior was opened in successive instalments to the scrutiny of the spectators. The first player was a Polish patriot, Worousky, who had lost both legs in a campaign; as he was furnished with artificial limbs when in public, his appearance, together with the fact that no dwarf or child travelled in Kempelen's company, dispelled the suspicion that any person could be employed inside the machine. This automaton, which made more than one tour to the capitals and courts of Europe, and was owned for a short time by Napoleon I., was exhibited by Maelzel after the death of Kempelen in 1819, and ultimately perished in a fire at Philadelphia in 1854. A revival of the trick appeared in Hooper's "Ajeeb," shown a few years ago at the Sydenham Crystal Palace and elsewhere. Still more recently a chess-playing figure, "Mephisto," designed by Gumpel, has been on view. No space exists for the accommodation of a living player within; but, as there is no attempt at isolating the apparatus from mechanical communication through the carpet or the floor, there is nothing to preclude the moving arm and gripping finger and thumb of the figure from being worked by any convenient connexion of threads, wires, rods, and levers. In 1875 Maskelyne and Cooke produced at the Egyptian Hall, in London, an automaton whist-player, "Psycho," which, from the manner in which it is placed upon the stage, appears to be perfectly isolated from any mechanical communication from without; there is no room within for the concealment of a living player by aid of any optical or other illusion, and yet the free motions of both arms, especially of the right arm and hand in finding any card, taking hold of it, and raising it or lowering it to any position and at any speed as demanded by the audience, prove that the actions are directed from without. The arm has all the complicated movements necessary for chess or draught playing; and Psycho calculates any sum up to a total of 99,000,000. What the mysterious means of connexion are has not been discovered; or, at any rate, down to the time of writing this article there has appeared no correct imitation of this joint invention of John Nevil Maskelyne and John Algernon Clarke. Perhaps a still more original automaton is Maskelyne's figure "Zoe," constructed in 1877, which writes and draws at dictation of the audience, yet cannot have a living person within, and could not be more completely severed from all conceivable means of control without. "Zoe," a nearly life-size but very light doll, sits loose upon a cushioned skeleton-stand, of which the solid feet of the plinth rest upon a thick plate of clear glass laid upon the floor-cloth or carpet of the stage. "Psycho," a smaller Oriental figure, sitting cross-legged on a box, is supported by a single large cylinder of clear glass, which, as originally exhibited, stood upon the carpet of the stage, but was afterwards set loose upon a small stool, having solid wood feet; moreover, this automaton may be placed in almost any number of different ways. Thus, from the precautions observed in the isolation of Maskelyne's automata, no current of electricity, no magnetic attraction, no hydraulic or pneumatic force can reach them, or, if it could, would not account for the many and delicate movements which they execute; and there can be no wires, threads, or hairs, passing in any direction away from the figures, seeing that persons from the audience admitted close around the figures while they are in operation could not fail to observe them. It may be mentioned that, in the same year in which "Psycho" appeared, the joint inventors patented a method of controlling the speed of clock-work mechanism by compressed air or gas stored in the pedestal of an automaton, this compressed fluid acting upon a piston in a cylinder and also upon a rotating fan when a valve is opened by "an electrical or other connexion worked by the foot of the performer or an assistant." But it is not known whether the principle obscurely described in the specification was applicable in any way to the invisible agency employed in "Psycho" or in "Zoe," or whether it had reference to some other invention which has never been realized. The whist-playing automaton is affirmed to be the only one of Maskelyne's many subtle inventions in which he received suggestions from another person.

That a mysterious and apparently elaborate mechanical movement may, after all, possess the utmost simplicity is illustrated by the familiar conjuring trick known as "rising cards." Four cards having been chosen by the audience and returned to the pack, this is placed end upwards in a glass goblet, or in a thin case not deep enough to hide the pack, upon the top of a decanter or upon a stick. At command, the cards rise, one at a time, out of the pack; one rises part of the way and sinks back again; one rises quickly or slowly as directed; one comes out feet first, and, on being put back, rises head upwards like the others; and one dances in time to music, and finally jumps out of the pack. At the conclusion there remain only the goblet or the case and the cards, subject to the minutest examination of any one from the audience, without a trace of moving mechanism visible. This was one of the chief *jeux* of Comte, the French conjuror and ventriloquist, at the end of last century, and in varied forms has been popular to the present day. Probably it was suggested by the earlier device of the golden head dancing in a glass tumbler, which is described in *The Conjuror Unmasked*, 1790. Several crown pieces were put in the glass, a small gilded head above them, and a plate or other flat cover laid upon the mouth of the glass; yet the head thus isolated jumped inside the glass so as to count numbers and answer questions. The secret communicator of motion was a fine silk thread attached to the head and passing through a tiny notch cut in the lip of the glass, and so to a confederate who pulls it. In the case of the rising cards the whole of the movements are effected by arranging a single silk thread in the previously prepared pack, passing over some cards and under others, and led behind the decanter or other support to the stage and thence to the confederate. As this infinitely simple mechanical agent is drawn altogether out of the pack after the last card has risen, literally no trace remains of any means of communicating motion to the cards.

Oriental ingenuity, which furnished the original idea of the ethereal suspension trick, contributed the Chinese rings introduced into England in 1834; also the Chinese feat of producing a bowl of water with gold-fish out of a shawl, first seen in England in 1845, and the Indian rope-tying and sack feats upon which the American brothers Davenport founded a distinct order of performances in 1859. Their quick escape from rope bonds in which they were tied by representatives of the audience, the instantaneous removal of their coats in a dark séance, leaving themselves still bound, and their various other so-called "phenomena" were exposed and imitated by Maskelyne, who, in 1860, greatly surpassed any feats which they had accomplished. He proceeded to exhibit himself floating in the air, to show "materialized spirit forms," and to present a succession of wonders of the spirit mediums in novel performances down to the present time. One of Maskelyne's cleverest inventions was the box which he constructed in 1860; it closely fitted when he packed himself in a cramped position within; it was enclosed in a canvass wrapper, corded with any length and complicated meshing of rope, and the knot sealed, yet his escape was effected in the brief space of seven seconds. Taking more time, he performed the converse of these operations except the sealing. Provided with the wrapper and the open box, himself standing outside, he drew a curtain before him to conceal the *modus operandi*, and in a few minutes was found in the box, which, though so small as to permit no limb to be moved more than a few inches, he nevertheless wrapped and corded as exactly as if he had operated from the outside. Partially imitated with trick boxes of larger size, this feat has never been executed under the same conditions by any other conjuror; and the process of escape and repacking has never been fully elucidated. (J. A. CL.)

MAGIC LANTERN is the name given to an optical instrument for projecting on a white wall or screen largely magnified representations of transparent pictures painted or photographed on glass.

The invention of the magic lantern is usually attributed to Athanasius Kircher, who died in 1680, although, according to some, it was known four centuries earlier to Roger Bacon (see p. 207). For long after its discovery the magic lantern was used chiefly to exhibit comic pictures, or in the hands of so-called wizards to summon up ghosts and perform other tricks astonishing to those who were ignorant of the simple optical principles employed. Within the last twenty or thirty years, however, and mainly on account of the invention of photography, the magic lantern has been greatly improved in construction, and its use widely extended. By its means finely executed photographs on glass can be shown greatly magnified to large audiences. The scientific lecturer is thus saved the trouble and expense of preparing large diagrams, besides having his subject better illustrated. When suitably constructed, the magic lantern can be used in the form of a microscope to exhibit on a screen the forms and movements of minute living organisms, or to show to an audience delicate physical and chemical experiments which could otherwise be seen only by a few at a time.

The magic lantern in its simplest form is represented in fig. 1. A is a dark box surmounted by a suitable chimney for carrying off the products of combustion from the source of light L, which is placed in the focus of a spherical reflector. On the side opposite the reflector the box is pierced by a round hole, into which is fitted the metal tube D, which may either be cylindrical or slightly tapered. To the inner end of the tube D is fitted a lens or combination of lenses C called the "condenser." Immediately in front of the condenser, and at right angles to the axis of the tube, is a vertical slit S for receiving the transparent pictures usually called "slides." To the outer end of D is fitted a lens or combination of lenses O called the "objective" or "projecting lens." At a suitable distance from O is placed the screen for receiving the magnified picture —the screen and slit being in the conjugate foci of the lens O. Since the objective reverses, the picture must be inserted in the slit upside down. The objective can be moved backwards and forwards in the tube D by means of a rack and pinion. Since the screen and slide are in the conjugate foci of O the diameter of the picture on the screen has the same ratio to the screen's distance from O that the diameter of the picture on the slide has to the slide's distance from O. The ratio adopted is generally 1 to 3 or 4.

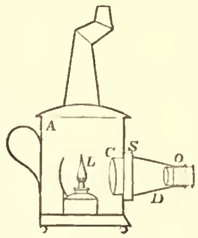


Fig. 1.

Source of Light.—Almost any good source of light can be used in the magic lantern. In the earlier forms a simple oil light was used; and in the toy forms either an oil light or simple gas-flame is still employed. Better effects are obtained from the Argand fountain lamp (fig. 2) or from the common Argand gas burner with a glass chimney. In the sciopticon (fig. 3)—a handy and excellent form recently introduced—a specially constructed paraffin lamp is employed with three parallel flat wicks set edgeways to the condenser. With this lamp a clear, well-defined picture varying from 6 to 10 feet in diameter can be readily thrown on the screen. For the best effects, however, recourse must be had to the oxy-calcium light (fig. 4), in which a small cylinder of lime is heated to intense luminosity in the flame of a spirit lamp through which a jet of oxygen plays; the Oxy-hydrogen Light

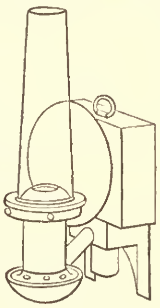


Fig. 2.—Argand Fountain Lamp.

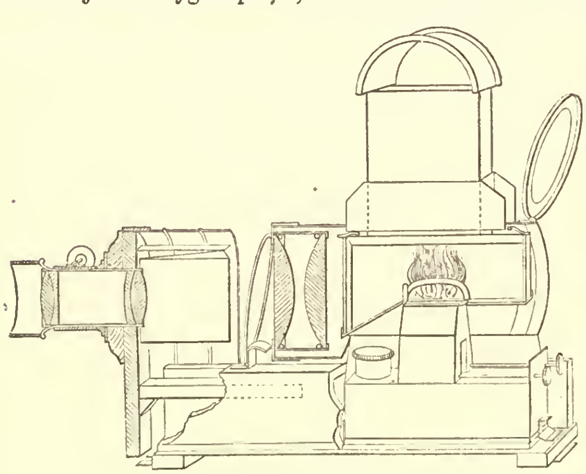


Fig. 3.—Sciopticon.

(*q.v.*); the magnesium light, in which two narrow ribands of magnesium are put through slits by a clock-work arrangement and burn as they advance; or, best of all,—unless when sunlight can be used with the aid of a heliostat (see Heliography),—the electric light.

Condenser and Objective.—The object of the condenser (fig. 5, C) is to collect as much light as possible from the source, and pass it through the transparent picture in the slit. For this purpose the condenser should subtend as large an angle as possible at the source of light. To secure this, the condenser should be tolerably large, and its distance from the light, that is, its focal length, small. Since effective single lenses of large diameter are necessarily of long focus, a really good condenser of considerable diameter and yet of short focus must be a combination of two or more lenses.

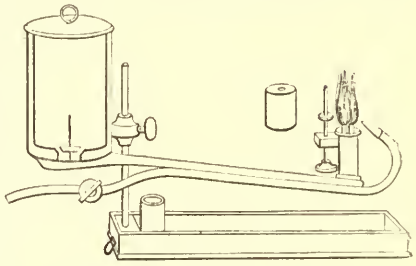
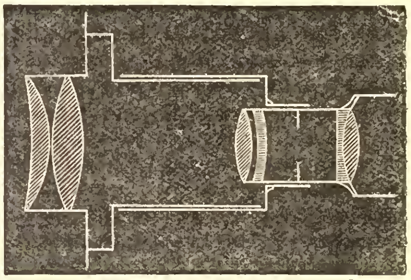


Fig. 4.—Oxy-calcium Lamp.


C O
Fig. 5.—Condenser and Objective.

Let f_1 and f_2 be the focal lengths of two lenses, and f the focal length of their combination. Then, neglecting the thickness of the lenses, we have when the two are close toegther

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}.$$

From which we get $f=\frac{f_1 f_2}{f_1+f_2}$, a fraction which is always less than either f_1 or f_2 provided these are not zero. Suppose, for example, two lenses of 6 and 10 inches focal length respectively; the focal length of their combination will be $\frac{6\times 10}{6+10}=3\frac{3}{4}$ inches.

In the earlier lanterns, as still in the cheaper forms, only a single plano-convex lens or bull's-eye was employed as a condenser. Better effects are produced by two such lenses. Perhaps the best condenser for ordinary work is that proposed by Herschel and represented in fig. 5, C, consisting of a biconvex lens and a meniscus mounted together with the concave side of the meniscus next the light. The diameter of such a condenser is about 6 inches, and its focal length a little over 3 inches. The focus must not be so short as to bring the lens too near the light, and render it liable to crack from the intense heat. In some lanterns this is guarded against by placing a plate of thin glass between the condenser and the light. In the sciopticon (fig. 3) the condenser consists of two plane-convex lenses, each about 4 inches in diameter. Condensers of large diameter are not so essential now as formerly, seeing that small pictures can easily be produced by photography.

The function of the objective (fig. 5, O) is to produce a magnified inverted image of the picture on the screen. In toy lanterns it is a simple double-convex lens of short focus. This, however, can only produce a small picture, and that not very distinct at the edges. The best objective is the portrait combination lens used in ordinary photographic cameras. These are carefully corrected both for spherical and chromatic aberration, which is absolutely essential in the objective, although not so necessary in the condenser. It is essential, however, that the condenser be free from cracks or flaws, as these would appear and mar the picture.

Slides.—These are pictures, painted with transparent water or oil colours, or photographed on pieces of glass. The pieces of glass are usually fixed in small wooden frames for insertion in the slit. If parts of the picture are to be movable, two disks of glass are employed, the one movable in front of the other, the fixed part of the picture being painted on the fixed disk and the movable part on the other. By means of a lever the latter disk is moved in its own plane; and in this way a cow for instance can be represented drinking, or a donkey cutting amusing capers. A lever slide is represented in fig. 6. In the chromatrope

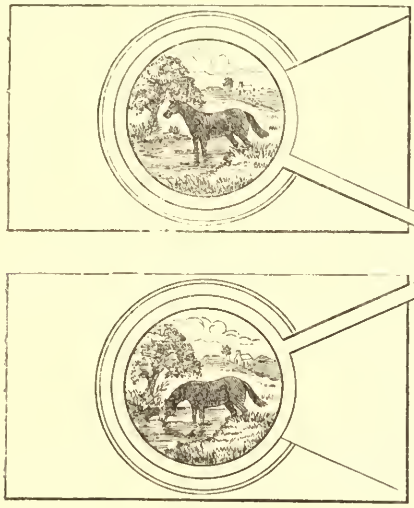


Fig. 6.—Lever Slide.

slide (fig. 7) two circular disks of glass are placed face to face, each containing a design radiating from the centre, and painted with brilliant transparent colours. By a small pinion gearing in toothed wheels or endless bands the disks are made to move in opposite directions in their own plane.

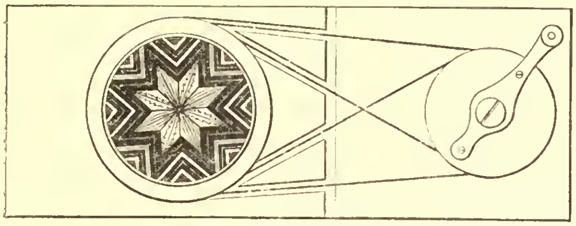


Fig. 7.—Chromatrope.

The effect produced is a singularly beautiful change of design and colour. In astronomical slides the motions of the heavenly bodies, eclipses, the phases of the moon, or the like are similarly represented by mechanical means. Slides can also be made from narrow glass tanks with parallel sides. When these are filled with water containing delicate living organisms the forms and movements of the latter are beautifully seen. Such tanks can also be employed to show such phenomena as the gradual growth of crystals, the electrolysis of water between platinum electrodes, &c. A great variety of physical and chemical experiments can be shown in this way.

Dissolving Views.—For this purpose two magic lanterns are necessary, arranged either side by side or the one on the top of the other. The fronts of the lanterns are slightly inclined to each other so as to make the illuminated disks on the screen due to each lantern coincide. By means of a pair of thin metallic shutters terminating in comb-like teeth, and movable by a rack or lever, the light from either lantern can be gradually cut off at the same time that the light from the other is allowed gradually to fall on the screen. In this way one view appears to melt or dissolve into another. This arrangement was first adopted by Childe in 1811.

Phantasmagoria.—In this arrangement the pictures on the screen appear gradually to increase or diminish in size and brightness. To effect this a semi-transparent screen of cotton or other material is used, the lantern being behind and the audience in front. The lantern is mounted on wheels so that it can be rapidly moved up to or withdrawn from the screen; and an automatic arrangement is provided whereby simultaneously with this the objective is made to approach or recede from the slide so as to focus the picture on the screen in any position of the lantern. In this way a very small picture appears gradually to grow to enormous dimensions.

Lantern Polariscope.—This, perhaps the most beautiful modification of the magic lantern for scientific purposes, consists of an elbow-shaped tube, containing mirrors, lenses, &c., and attached to the front of the lantern in place of the tube containing the objective. It is represented in section in fig. 8. C′ is the usual condenser belonging to the lantern. G is a set of thin glass plates inclined at the polarizing angle 56° 45′ to the axis of the tube. The beam of polarized light from L reflected from G passes through the lenses

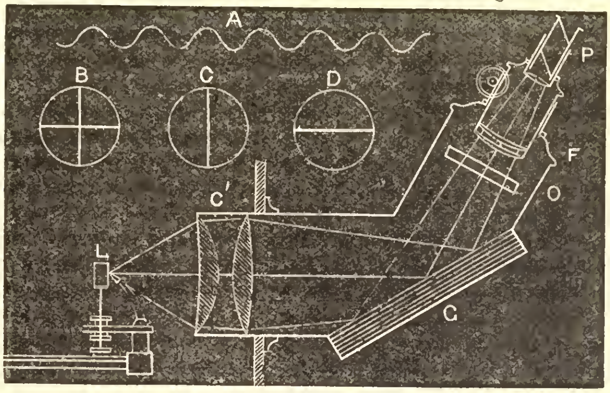


Fig. 8.—Lantern Polariscope.

F and the analysing Nicol's prism P, and falls on the screen. The objects to be examined by the polarized light are placed in the transverse slit O. When thin plates of selenite or other doubly refracting crystals are placed in O, a most beautiful display of complementary colours is produced on the screen by rotating the Nicol's prism. Almost all the experiments on polarized light can be well shown by this arrangement.

The *sciopticon* (fig. 3) is an excellent and convenient lantern, very suitable for all the requirements of the lecturer, as well as for school use in teaching geography, &c.

See Brewster's *Optics*; Ganot's *Physics*; and Chadwick's *Manual of the Magic Lantern*. (J. BL.)

MAGIC SQUARE. A magic square is one divided into any number of equal squares, like a chess-board, in each of which is placed one of a series of consecutive numbers from 1 up to the square of the number of cells in a side, in such a manner that the sum of those in the same row or column and in each of the two diagonals is constant.

From a very early period these squares engaged the attention of mathematicians, especially such as possessed a love of the marvellous, or sought to win for themselves a superstitious regard. They were then supposed to possess magical properties, and were worn, as in India at the present day, engraven in metal or stone, as amulets or talismans. According to the mystic imaginings of the old astrologers relations subsisted between these squares and the planets: a square with only one cell, containing 1, symbolized the unity of the deity; a square of two, containing the four elements, was the symbol of matter; while those of 3, 4, 5, 6, 7, 8 were consecrated respectively to Saturn, Jupiter, Mars, the Sun, Venus, and Mercury. In later times such squares ranked only as mathematical curiosities; till at last their mode of construction was systematically investigated. These squares were at first mere triumphs of the same dogged perseverance as was in later times exhibited by the Dutchman, Ludolph van Ceulen, who, after calculating π to 35 places of decimals, directed, like Archimedes, that it should be engraven on his tomb, though his industry was surpassed by M. de Lagry, who continued the decimal to 127 places. The earliest known writer on the subject was Emanuel Moscopulus, a Greek, who lived in the 4th or 5th century, and whose manuscript is preserved in the National Library at Paris. After him Frenicle constructed magic squares, such that if one or more of the encircling bands of numbers be taken away the remaining central squares are still magical. Subsequently M. Poignard constructed squares with numbers in arithmetical progression, having the magical summations. The later researches of M. de la Hire, recorded in the *Mémoires de l'Académie Royale* in 1705, are interesting as giving general methods of construction. He has there collected the results of the labours of earlier pioneers; but the subject has now been fully systematized, and extended to cubes.

In order to understand the rest of this article diagram A should be carefully examined. A square of 5 has adjoining it one of the eight equal squares by which any square may be conceived to be surrounded, each of which has two sides resting on adjoining ones, while four have sides resting on the surrounded square, and four meet it only at its four angles. 1, 2, 3 are placed along the path of a knight in chess; 4, along the same path, would fall in a cell of the outer square, and is placed instead in the corresponding cell of the original square; 5 then falls within the square. *a*, *b*, *c*, *d* are placed diagonally in the square; but *e* enters the outer square, and is removed thence to the same cell of the square it had left. α, β, γ, δ, ε pursue another, but regular, course; and the diagram shows how that course is recorded in the square they have twice left. Whichever of the eight surrounding squares may be entered, the corresponding cell of the central square is taken instead. The 1, 2, 3, ... , *a*, *b*, *c*, ... , α, β, γ, ... are said to lie in *paths*.

A.

	a	ε	5				ε		
	4	*b*		δ		4			δ
	γ		*c*	3		γ			
		2	β	*d*					
1*e* α					*e*				

Squares whose Roots are Odd.—Diagrams B, C, D exhibit one of the earliest methods of constructing magic squares. Here the 3's in B and 2's in C are placed in

B.

1	4	2	5	3
4	2	5	3	1
2	5	3	1	4
5	3	1	4	2
3	1	4	2	5

C.

2	4	0	3	1
1	2	4	0	3
3	1	2	4	0
0	3	1	2	4
4	0	3	1	2

D.

11	24	2	20	8
9	12	25	3	16
17	10	13	21	4
5	18	6	14	22
23	1	19	7	15

opposite diagonals to secure the two diagonal summations; then each number in C is multiplied by 5 and added to

E.

2	1	5	3	4
3	4	2	1	5
1	5	3	4	2
4	2	1	5	3
5	3	4	2	1

F.

15	5	0	20	10
0	20	10	15	5
10	15	5	0	20
5	0	20	10	15
20	10	15	5	0

G.

17	6	5	23	14
3	24	12	16	10
11	20	8	4	22
9	2	21	15	18
25	13	19	7	1

that in the corresponding number in B, which gives the square D. Diagrams E, F, G give M. de la Hire's method;

H.

				1				
			6		2			
		11		7		3		
	16		12		8		4	
21		17		13		9		5
	22		18		14		10	
		23		19		15		
			24		20			
				25				

I.

11	24	7	20	3
4	12	25	8	16
17	5	13	21	9
10	18	1	14	22
23	6	19	2	15

the squares E, F, being combined as above, give the magic square G. M. Bachet arranged the numbers as in H, where there are three numbers in each of four surrounding squares; these being placed in the corresponding cells of the central square, the square I is formed. He also constructed squares such that if one or more outer bands of numbers are removed the remaining central squares are magical. His method of forming them may be understood from a square of 5. Here each summation is 5×13; if therefore 13 is subtracted from each number, the summa-

J.

−9	12	5	−2	−6
1	7	−11	4	−1
−8	−3	0	3	8
10	−4	11	−7	−10
6	−12	−5	2	9

K.

4	25	18	11	7
14	20	2	17	12
5	10	13	16	21
23	9	24	6	3
19	1	8	15	22

tions will be zero, and the twenty-five cells will contain the series ± 1, ± 2, ± 3, ... ± 12, the odd cell having 0. The central square of 3 is formed with four of the twelve numbers with + and − signs and zero in the middle; the band is filled up with the rest, as in diagram J; then, 13 being added in each cell, the magic square K is obtained.

Squares whose Roots are Even.—These were constructed in various ways, similar to that of 4 in diagrams L, M, N. The numbers in M being multiplied by 4, and the squares L, M being superimposed, give N. The application of

L.

1	3	2	4
4	2	3	1
4	2	3	1
1	3	2	4

M.

0	3	3	0
2	1	1	2
1	2	2	1
3	0	0	3

N.

1	15	14	4
12	6	7	9
8	10	11	5
13	3	2	16

this method to squares the half of whose roots are odd requires a complicated adjustment. Squares whose half root is a multiple of 4, and in which there are summations along all the diagonal paths, may be formed, by observing, as when the root is 4, that the series 1 to 16 may be

O.

p_1	p_2	a_1	a_2
p_3	p_4	a_3	a_4
$-a_1$	$-a_2$	$-p_1$	$-p_2$
$-a_3$	$-a_4$	$-p_3$	$-p_4$

P.

1	−3	11	−9
−5	7	−15	13
−11	9	−1	3
15	−13	5	−7

Q.

9	7	14	4
6	12	1	15
3	13	8	10
16	2	11	5

changed into the series 15, 13, ... 3, 1, − 1, − 3, ... − 13, − 15, by multiplying each number by 2 and subtracting 17; and, *vice versa*, by adding 17 to each of the latter, and dividing by 2. The diagonal summations of a square, filled as in diagram O, make zero; and, to obtain the same

R.

−1	3	5	−7	−33	35	37	−39
9	−11	−13	15	41	−43	−45	47
17	−19	−21	23	49	−51	−53	55
−25	27	29	−31	−57	59	61	−63

in the rows and columns, we must assign such values to the p's and q's as satisfy the equations $p_1 + p_2 + a_1 + a_2 = 0$, $p_3 + p_4 + a_3 + a_4 = 0$, $p_1 + p_3 - a_1 - a_3 = 0$, and $p_2 + p_4$

$-\alpha_2-\alpha_4=0$,—a solution of which is readily obtained by inspection, as in diagram P; this leads to the square, diagram Q. When the root is 8, the upper four subsidiary rows may at once be written, as in diagram R; then, if the square be completed, 65 added to each, and the sums halved, the square is completed. In such squares as these, the two opposite squares about the same diagonal (except that of 4) may be turned through any number of right angles, in the same direction, without altering the summations.

Nasik Squares.—Squares that have many more summations than in rows, columns, and diagonals have been investigated by the Rev. A. H. Frost (*Cambridge Math. Jour.*, 1857), and called Nasik squares, from the town in India where he resided; and he has extended the method to cubes, various sections of which have the same singular properties. In order to understand their construction it will be necessary to consider carefully diagram S, which shows that, when the root is a prime, and not composite, number, as 7, eight letters $a, b, \ldots h$ may proceed from any, the same, cell, suppose that marked 0, each letter being repeated in the cells along different paths. These eight paths are called *normal paths*, their number being one more than the root. Observe here that, excepting the cells from which any two letters start, they do not occupy again the same cell, and that two letters, starting from any two different cells along different paths, will appear together in one and only one cell. Hence, if p_1 be placed in the cells of one of the $n+1$ normal paths, each of the remaining n normal paths will contain one, and only one, of these p_1's. If now we fill each row with $p_2, p_3, \ldots p_n$ in the same order, commencing from the p_1 in that row, the p_2's, p_3's, and p_n's will lie each in a path similar to that of p_1, and each of the n normal paths will contain one, and only one, of the letters $p_1, p_2, \ldots p_n$, whose sum will be Σp. Similarly, if q_1 be placed along any of the normal paths, different from that of the p's, and each row filled as above with the letters $q_2, q_3, \ldots q_n$, the sum of the q's along any normal path different from that of the q_1 will be Σq. The n^2 cells of the square will now be found to contain all the combinations of the p's and q's; and, if the q's be multiplied by n, the p's made equal to $1, 2, \ldots n$, and the q's to $0, 1, 2, \ldots \overline{n-1}$ in any order, the Nasik square of n will be obtained, and the summations along all the normal paths, except those traversed by the p's and q's, will be the constant $\Sigma nq+\Sigma p$. When the root is an odd composite number, as 9, 15, &c., it will be found that in some paths, different from the two along which the p_1 and q_1 were placed, instead of having each of the p's and q's, some will be wanting, while some are repeated. Thus, in the case of 9, the triplets $p_1p_4p_7$, $p_2p_5p_8$, $p_3p_6p_9$, and $q_1q_4q_7$, $q_2q_5q_8$, $q_3q_6q_9$ occur, each triplet thrice, along paths whose summation should be—Σp, 45, and Σr, 36. But if we make $p_1, p_2, \ldots p_9 = 1, 3, 6, 5, 4, 7, 9, 8, 2$, and the $r_1, r_2, \ldots r_9 = 0, 2, 5, 4, 3, 6, 8, 7, 1$, thrice each of the above sets of triplets will equal Σp and Σq respectively. If now the q's are multiplied by 9, and added to the p's in their several cells, we shall have a Nasik square, with a constant summation along eight of its ten normal paths. In diagram T, the numbers are in the nonary scale; that in the centre is the middle one of 1 to 9^2, and the sum of pairs of numbers equidistant from and opposite to the central 45 is twice 45; and the sum of any number and the 8 numbers 3 from it, diagonally, and in its row and column, is the constant Nasical summation, *e.g.*, 72 and 32, 22, 76, 77, 26, 37, 36, 27. The numbers in T being kept in the nonary scale, it is not necessary to add any nine of them together in order to test the Nasical summation; for, taking the first column, the figures in the place of units are seen at once to form the series, $1, 2, 3, \ldots 9$, and those in the other place three triplets of 6, 1, 5. For the squares of 15 the p's and q's may be respectively 1, 2, 10, 8, 6, 14, 15, 11, 4, 13, 9, 7, 3, 12, 5, and 0, 1, 9, 7, 5, 13, 14, 10, 3, 12, 8, 6, 2, 11, 4, where five times the sum of every third number and three times the sum of every fifth number makes Σp and Σq; then, if the q's are multiplied by 15, and added to the p's, the Nasik square of 15 is obtained. When the root is a multiple of 4, the same process gives us, for the square of 4, the diagram U. Here the columns give Σp, but alternately $2q_1$, $2q_3$, and $2q_2$, $2q_4$; and the rows give Σq, but alternately $2p_1$, $2p_3$, and $2p_2$, $2p_4$; the diagonals giving Σp and Σq. If p_1, p_2, p_3, p_4 and q_1, q_2, q_3, q_4 be 1, 2, 4, 3, and 0, 1, 3, 2, we have the Nasik square of diagram V. A square like this is engraven in the Sanskrit character on the gate of the fort of Gwalior, in India. The squares of higher multiples of 4 are readily obtained by a similar adjustment.

S.

a	*g*	*f*	*e*	*d*	*c*	*b*
a	*d*	*g*	*c*	*f*	*b*	*e*
a	*c*	*e*	*g*	*b*	*d*	*f*
a	*f*	*d*	*b*	*g*	*e*	*c*
a	*e*	*b*	*f*	*c*	*g*	*d*
a	*b*	*c*	*d*	*e*	*f*	*g*
0	*h*	*h*	*h*	*h*	*h*	*h*

T.

63	88	74	13	8	21	53	48	34
11	9	25	51	49	35	61	89	75
52	47	36	62	87	76	12	7	26
68	84	73	18	4	23	58	44	33
19	5	21	59	45	31	69	85	71
57	46	32	67	86	72	17	6	22
64	83	78	14	3	28	54	43	38
15	1	29	55	41	39	65	81	79
56	42	37	66	82	77	16	2	27

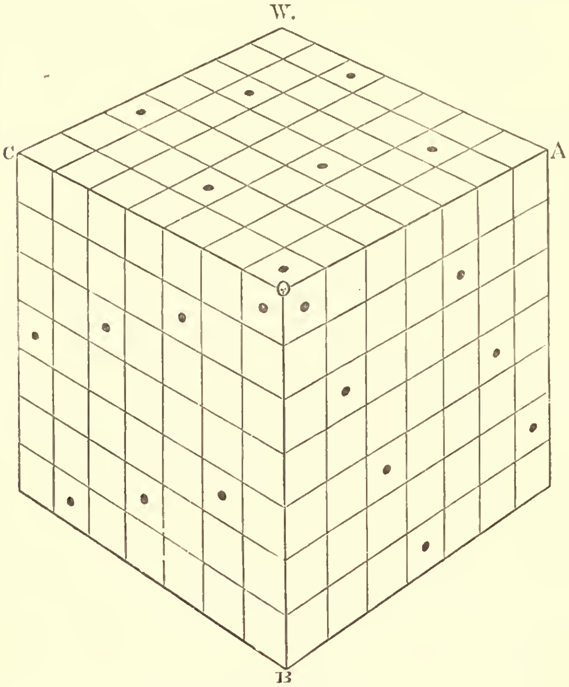
U

p_4q_3	p_2q_4	p_4q_1	p_2q_2
p_3q_1	p_1q_2	p_3q_3	p_1q_4
p_2q_3	p_4q_4	p_2q_1	p_4q_2
p_1q_1	p_3q_2	p_1q_3	p_3q_4

V.

15	10	3	6
4	5	16	9
14	11	2	7
1	8	13	12

A *Nasik cube* is composed of n^3 small equal cubes, here called cubelets, in the centres of which the natural numbers from 1 to n^3 are so placed that every section of the cube by planes perpendicular to an edge has the properties of a Nasik square; also sections by planes perpendicular to a face, and passing through the cubelet centres of any path of Nasical summation in that face. Diagram W shows by dots the way in which these cubes are constructed. A dot is here placed on three faces of a cubelet at the corner, showing that this cubelet belongs to each of the faces AOB, BOC, COA, of the cube. Dots are placed on the cubelets of some path of AOB (here the knight's path), beginning from O, also on the cubelets of a knight's path in BOC. Dots are now placed in the cubelets of similar paths to that on BOC in the other six sections parallel to BOC, starting from their dots in AOB. Forty-nine of the three hundred and forty-three cubelets will now contain a dot; and it will be observed that the dots in sections perpendicular to BO have arranged themselves in similar paths. In this manner, p_1, q_1, r_1 being placed in the corner cubelet O, these letters are severally placed in the cubelets of three different paths of AOB, and again along any similar paths in the seven sections perpendicular to AO, starting from the letters' position in AOB. Next, $p_2q_2r_2$, $p_3q_3r_3$, $\ldots$ $p_7q_7r_7$ are placed in the other cubelets of the edge AO, and dispersed in the same manner as $p_1q_1r_1$. Every cubelet will then be found to contain a different combination of the p's, q's, and r's. If therefore the p's are made equal to $1, 2, \ldots 7$, and the q's and r's to $0, 1, 2, \ldots 6$, in any order, and the q's multiplied by 7, and the r's by 7^2, then, as in the case of the squares, the 7^3 cubelets will contain the numbers from 1 to 7^3, and the Nasical summations will be $\Sigma 7^2 r+\Sigma 7q+p$. If 2, 4, 5 be values of r, p, q, the number for that cubelet is written 245 in the septenary scale, and if all the cubelet numbers are kept thus, the paths along which summations are found can be seen without adding, as the seven numbers would contain $1, 2, 3, \ldots 7$ in the unit place, and $0, 1, 2, \ldots 6$ in each of the other places. In all Nasik cubes, if such values are given to the letters on the central cubelet that the number is the middle one of the series 1 to n^3, the sum of all the pairs of numbers opposite to and equidistant from the middle number is the double of it. Also, if around a Nasik cube the twenty-six surrounding equal cubes be placed with their cells filled with the same numbers, and their corresponding faces looking the same way,—and if the surrounding space be conceived thus filled with similar cubes, and a straight line of unlimited length be drawn through any two cubelet centres, one in each of any two cubes,—the numbers along that line will be found to recur in groups of seven, which (except in the three cases where the same p, q, or r recur in the group) together make the Nasical summation of the cube. Further, if we take n similarly filled Nasik cubes of n, n new letters, $s_1, s_2, \ldots s_n$, can be so placed, one in each of the n^4 cubelets of this



Nasik Cube.

group of n cubes, that each shall contain a different combination of the p's, q's, r's, and s's. This is done by placing s_1 on each of the n^2 cubelets of the first cube that contain p_1, and on the n^2 cubelets of the 2d, 3d, . . . and nth cube that contain $p_2, p_3, \ldots p_n$ respectively. This process is repeated with s_2, beginning with the cube at which we ended, and so on with the other s's ; the n^4 cubelets, after multiplying the q's, r's, and s's by n, n^2, and n^3 respectively,

X.

1	8	29	28	11	14	23	18
30	27	2	7	21	20	9	16
4	5	32	25	10	15	22	19
31	26	3	6	24	17	12	13

will now be filled with the numbers from 1 to n^4, and the constant summation will be $\Sigma n^3 s + \Sigma n^2 r + \Sigma nq + \Sigma p$. This process may be carried on without limit ; for, if the n cubes are placed in a row with their faces resting on each other, and the corresponding faces looking the same way, n such parallelepipeds might be put side by side, and the n^5 cubelets of this solid square be Nasically filled by the introduction of a new letter t ; while, by introducing another letter, the n^6 cubelets of the compound cube of n^3 Nasik cubes

Y.

23	18	11	6	25
10	5	24	17	12
19	22	13	4	7
14	9	2	21	16
1	20	15	8	3

Z.

30	21	6	15	28	19
7	16	29	20	5	14
22	31	8	35	18	27
9	36	17	26	13	4
32	23	2	11	34	25
1	10	33	24	3	12

might be filled by the numbers from 1 to n^6, and so ad infinitum. When the root is an odd composite number the values of the three groups of letters have to be adjusted as in squares, also in cubes of an even root. A similar process enables us to place successive numbers in the cells of several equal squares in which the Nasical summations are the same in each, as in diagrams X.

Among the many ingenious squares given by various writers, this article may justly close with two by Euler, in the *Histoire de l'Académie Royale des Sciences*, Berlin, 1759. In diagram Y the natural numbers show the path of a knight that moves within an odd square in such a manner that the sum of pairs of numbers opposite to and equidistant from the middle figure is its double. In diagram Z the knight returns to its starting cell in a square of 6, and the difference between the pairs of numbers opposite to and equidistant from the middle point is 18.

A model consisting of seven Nasik cubes, constructed by Mr Frost, can be seen in the South Kensington Museum. The centres of the cubes are placed at equal distances in a straight line, the similar faces looking the same way in a plane parallel to that line. Each of the cubes has seven parallel glass plates, to which, on one side, the seven numbers in the septenary scale are fixed, and behind each, on the other side, its value in the common scale. 1201, the middle number from 1 to 7^4, occupies the central cubelet of the middle cube. Besides each cube having separately the same Nasical summation, this is also obtained by adding the numbers in any seven similarly situated cubelets, one in each cube. Also, the sum of all pairs of numbers, in a straight line through the central cube of the system, equidistant from it, in whatever cubes they are, is twice 1201.

A very complete bibliographical index of writers on this subject is given in Professor Lucas's *Récréations Mathématiques*, Paris, 1882. (A. H. F.)

MAGISTRATE. The term magistrate, derived from the Latin *magistratus*, is one of more general and comprehensive meaning than JUSTICE OF THE PEACE, which has already been treated of (vol. xiii. p. 789), and is of far higher antiquity. In its full significance it indicates one side of the universal public relation by which men are connected together as governors and governed—in other words, as magistrates and people. Of magistrates some are supreme, in whom the sovereign power and executive government of the state reside, as the king or queen regnant, or the president of a republic, as of the United States; and such a functionary would formally be designated the first magistrate of the realm or state. Speaking generally, a magistrate may be described as a public civil officer invested with legal or other authority; but the term is more particularly applied to subordinate officers, as justices of the peace and the like, deriving their authority solely from the chief of the state or in virtue of legislative enactment. During the Roman republic the offices of magistrate and judge were distinct and separate. A magistrate was appointed *cum jurisdictione et imperio* ; to a judge belonged only *nuda notio sine jurisdictione et imperio*. The office of the magistrate was to inquire into matters of law ; and whatever business was transacted before him was said to be done *in jure*. The office of the judge was to inquire into matters of fact ; and whatever was transacted before him was said to be done *in judicio*. This distinction is thus clearly defined by Cicero in his well-known oration for Cluentius :—" Legum ministri, magistratus ; legum interpretes, judices." When the magistrate took cognizance both of the law and the fact he was said to administer justice *extra ordinem* ; and the judgment so administered was called extraordinary. The magistrate, when he decided on matters of law, was assisted by a council of ten, called *decemviri litibus judicandis*. To these was added in important cases another council of one hundred and five persons, selected from each tribe, whose judgment was final; this was called *judicium centumvirale*. After the decline of the Roman republic the offices of magistrate and judge were united, by which means all judgments became extraordinary, and the distinction of what was done *in jure* and *in judicio* was abolished. The magistrates were chosen only from the patricians in the early republic, but in the course of time the plebeians shared in these honours. The chief magistrates of Athens were designated archons. They were nine in number, and none were chosen but such as were descended from ancestors who had been free citizens of the republic for three generations. They took an oath that they would observe the laws, administer justice with impartiality, and never suffer themselves to be corrupted. They all had the power of punishing malefactors with death. The chief among them was called archon, and the year took its designation from him,—the *archon eponymus*, who was also constituted a sort of state protector of those who were unable to defend themselves. The Franks, Lombards, and Saxons appear to have been jealous of judicial authority, and averse to removing what concerned a man's private right out of the hands of his neighbours and equals; every ten families are supposed to have had a magistrate of their own election, the tything man of England, the decanus of France and Lombardy. The decanus was the lowest species of judge.

See Blackstone's *Commentaries*, 1825; Cowel, *Law Dict.*, 1717; Geldart's *Hallifax on the Civil Law*, 1836; Hallam, *Middle Ages*.

MAGLIABECHI, ANTONIO (1633–1714), one of the most remarkable bibliophiles of his time, was born at Florence, October 28, 1633, and followed the trade of a goldsmith until 1673, when he received the appointment of librarian to the grand-duke of Tuscany, a post for which he had qualified himself by his vast stores of self-acquired learning. He died on July 4, 1714, bequeathing his large private library to the grand-duke, who in turn handed it over to the city. See LIBRARIES, vol. xiv. pp. 530, 548.

MAGNA CHARTA. See CHARTER, and ENGLAND, vol. viii. pp. 306, 308.

MAGNA GRÆCIA. See GRÆCIA.

MAGNESIA, in ancient geography, was the name of two cities in Asia Minor, both of considerable interest and importance.

(1) A city of Ionia, situated on a small stream flowing into the valley of the Mæander, whence it was commonly called Magnesia ad Mæandrum. It was distant 120 stadia or 15 Roman miles from Miletus, and rather less from Ephesus. According to tradition, as well as the similarity of names, it was founded by a body of colonists from the Thessalian tribe of the Magnetes, with whom were associated, according to Strabo, some Cretan settlers. It was thus not properly an Ionic city, and for this reason apparently was not included among the cities of the Ionic league, though superior in wealth and prosperity to most of them, except Ephesus and Miletus. It was indeed taken and destroyed by the Cimmerians in their irruption into Asia Minor (about 660 B.C.), but was soon after rebuilt, and gradually recovered its former prosperity. It was one of the towns assigned by Artaxerxes to Themistocles for his support in his exile, and there the latter ended his days (449 B.C.). In later times it was chiefly noted for its temple of Artemis Leucophryne, which, according to Strabo, surpassed that at Ephesus in the beauty of its architecture, though inferior to it in size and wealth. The remains of this temple, as well as of the ancient city adjoining it, are still extant, and have been laid open by recent excavations. They are described by M. Texier (*Asie Mineure*, vol. iii.). Magnesia continued under the kings of Pergamum to be one of the most flourishing cities in this part of Asia, but appears to have gradually declined under the Roman empire, and its name disappears from history, though its continued existence is attested by coins as late as the time of Gallienus.

(2) A city of Lydia, about 40 miles north-east of Smyrna, which stood on the southern bank of the river Hermus, at the foot of Mount Sipylus, from which circumstance it was often called for distinction's sake Magnesia ad Sipylum. It is probable from its name that it was founded, like the city of the same name in the valley of the Mæander, by Magnesian colonists from Thessaly; but we have no authority for the fact. Nor is any mention of the town found in history till 190 B.C., when the Syrian king, Antiochus the Great, was defeated under its walls by the Roman consul L. Scipio, who derived from his success in this campaign the surname of Asiaticus. Magnesia became a city of importance under the Roman dominion, and, though nearly destroyed by an earthquake in the reign of Tiberius, was restored by that emperor, and continued to flourish throughout the period of the Roman empire. It was one of the few towns in this part of Asia Minor that retained its prosperity under the Turkish rule; and MANISA (*q.v.*) is at the present day a large and flourishing town with considerable trade.

MAGNESIUM, a metallic element (symbol Mg) forming a basic oxide "magnesia," MgO, which in some form or other is universally disseminated throughout the whole of the earth's crust, apart from the large masses of mineral consisting essentially of magnesia compounds. This accounts for the presence of at least traces of magnesia in the ashes of all plants and animals, and for its presence in almost all natural waters. In these, however, it in general is present only as a quasi-contamination of the lime; in certain mineral waters, on the other hand, known as bitter waters (as those of Epsom, Sedlitz, Püllna), sulphate of magnesia forms the principal solid component. All native chloride of sodium is accompanied by magnesia salts, including the cases of salt-springs and of ocean-water, the latter containing about 0·21 per cent. of magnesia as sulphate and chloride.

Of magnesium minerals we may name the following:—

A. *Silicates.*—(1) Olivine, $SiO_2.2MgO$, occasionally met with in transparent crystals ("chrysolite"), but more frequently embedded as an admixture in lava, basalt, and other rocks; also in meteorites. (2) Augite and (3) hornblende, both $MgO.SiO_2$. The latter more frequently than the former forms independent rocks; both occur abundantly as components of more ordinary mixed rocks, all basalts containing augite as a principal component. (4) Serpentine, $SiO_2 2H_2O.3(SiO_2.2MgO) + 2Aq$ (meaning $2H_2O$ loosely combined),—a very common mineral; there are mountain masses consisting almost of it alone. In all these silicates, and more especially in (2) and (3), the MgO is partly replaced by FeO, CaO, MnO, and other isomorphous oxides, these latter not unfrequently even predominating over the MgO itself. Their names, in fact, represent genera of minerals comprising each numerous species. Asbestos (so remarkable on account of its exceptional structure, which lends itself for the production of fire-proof textile fabrics, paper, pasteboard, &c.) must be mentioned here, as some varieties fall under hornblende, others under chrysotil (included in serpentine). More purely magnesian are—(5) talc, $4SiO_2.3MgO.H_2O$ (Rammelsberg), and (6) meerschaum, $3SiO_2.2MgO + 4(?)H_2O$ (same authority).

B. *Carbonates.*—Of these the most abundant are the dolomites, all compounds of the carbonates of lime and magnesia, $x\text{Ca}.(1-x)\text{Mg.O.CO}_2$, where x may assume almost any value down to zero, which it actually has in "magnesite," $MgOCO_2$. Bitter spar, $MgOCO_2$, is very similar to and isomorphous with Iceland spar, $CaOCO_2$.

C. *Soluble Salts,* known chiefly as occurring in the famous salt-deposits of Stassfurth in Germany:—kieserite, $MgOSO_3.H_2O$ (Epsom salt minus $6H_2O$); carnallite, $MgCl_2.KCl + 6H_2O$; kainite, a hydrated compound of chlorides and sulphates of magnesium and potassium.

Any of these minerals may be used, and A (4), B, and C are actually used for the preparation of magnesium compounds. Starting from magnesite, we need only subject it to gentle ignition to obtain the oxide MgO; treatment with dilute sulphuric or muriatic acid produces the sulphate (EPSOM SALT, *q.v.*) or the chloride, as a solution, contaminated in general,—chiefly with iron, also with alumina, and perhaps lime. The two former, after peroxidation of the iron by chlorine, may be eliminated by digestion with powdered magnesite, and filtered off. The acidified muriate solution, on evaporation and cooling, deposits transparent crystals, $MgCl_2.6H_2O$, very hygroscopic, very readily soluble in water, and (like the anhydrous salt) soluble also in alcohol. When dehydrated by heat it loses acid (HCl), so that the residue is largely contaminated with oxychlorides, $MgCl_2.xMgO$. Certain of these are industrially important as cements, used by dentists and otherwise. A concentrated solution of the chloride, made into a paste with the ignited (CO_2-free) oxide, in a few hours hardens into a stone susceptible of polishing (Sorel). To prepare the anhydrous chloride, the crystallized or dissolved hydrated salt is evaporated with sal-ammonia to dryness, and the residue (a stable double salt) is ignited in platinum. Pure chloride, $MgCl_2$, remains as a clear liquid, solidifying on cooling into a compact aggregate of flexible crystal-leaves of a mother-of-pearl lustre. From the chloride the metal can be produced, either by electrolysing the fused substance, or (more conveniently) by Caron and Deville's method: 600 grammes of the chloride, 480 grammes of powdered fluor-spar, and 230 grammes of finely cut-up sodium are mixed, and thrown, small portions at a time, into a red-hot crucible, which is then well covered. When the reaction, which is violent, is over, the contents are well stirred with an iron rod to cause the small metal-beads to unite into bigger lumps, which, after cooling, are picked from the broken-up mass. Sonstadt (who, along with Mellor, was the first to prepare magnesium industrially) substitutes for plain $MgCl_2$ the double chloride of potassium and magnesium, obtainable synthetically from the hydrated components without the use of sal-ammoniac, or simply by ignition of pure carnallite. To purify the crude metal Sonstadt and Mellor distil it "per descensum" out of an iron crucible provided with a pipe piercing the bottom and reaching up to almost the lid; an atmosphere of coal-gas is established to prevent oxidation of the metal in this operation, as also in the subsequent casting of the ingot.

The metal magnesium has the colour of silver, and remains unchanged in *dry* air; in ordinary air it tarnishes a little more readily than zinc does. It is malleable and ductile, but has little tenacity. The specific gravity is 1·75; thus it is considerably lighter than even aluminium, whose specific gravity is 2·6. It fuses and distils at about the same temperatures as zinc. It is generally sold in the form of thin ribbon, being used for the easy production of highly intense light. The ribbon kindles readily in a candle flame, and then continues burning most intensely by itself, the solid oxide produced radiating out abundant light. A wire 0·3 millimetre (= ·012 inch) thick gives out the light of 74 stearine candles weighing 100 grammes ($\frac{2}{9}$ ℔ avoirdupois) a piece (Bunsen and Roscoe). It used to be employed for photographing at night, but is now superseded by the electric light. Magnesium has the exceptional property of combining (at a bright red heat) directly with nitrogen gas into Mg_3N_2 (Briegleb and Geuther), a greenish-yellow powder, which, when heated in steam, yields magnesia and ammonia, NH_3.

Of magnesium salts the most important is the sulphate, EPSOM SALT (*q.v.*). This salt serves as a raw material for the preparation of two or three medicinally important substances, especially magnesia alba. When epsom salt solution is precipitated by carbonate of soda, the salt $MgOCO_2$, first formed, loses carbonic acid and takes up water, forming a precipitate of the approximate composition $3MgCO_3.Mg(OH)_2 + 2$ to 3 times H_2O. When prepared by cold precipitation it forms a very light, when in the heat a somewhat denser, white powder (magnesia alba levis and ponderosa). This substance holds an important position in the history of chemistry, having served, in the hands of Black, to prove finally the individual existence of magnesia as something distinct from lime, and helped him in establishing the true relation between "caustic" and "mild" alkalies. Before his time the "causticity" was supposed to go into the "mild" substance from the fire; Black showed that it is owing to the loss of a ponderable substance, which he called "fixed air," that is, carbonic acid. It was in this memorable research that for the first time in chemistry the balance was used for the precise determination of quantitative relations.

Magnesia, the oxide MgO, is produced by the gentle ignition of magnesia alba. It is a white powder, absolutely infusible and non-volatile, and not reducible by charcoal, and is used medicinally. The gently ignited oxide combines very slowly with water into the practically insoluble hydrate $MgO.H_2O$. Magnesia when boiled with sugar-water dissolves into a solution of saccharate, and in this form is sometimes administered medicinally in lieu of plain magnesia. Magnesia alba (also the normal carbonate) dissolves rather largely in carbonic acid water. According to R. Wagner, one part of $MgOCO_2$ dissolves in 760 parts of water saturated by carbonic acid under 1 atmosphere pressure. Under 6 atmospheres pressure it requires only 76 parts of carbonic acid water for its solution. Dinneford's "fluid magnesia" is a solution of such bicarbonate of magnesia. The bicarbonate solution, when allowed to stand in air, deposits crystals of hydrated normal carbonate, $MgCO_3 + 3$ or $5H_2O$.

Magnesia preparations play a great part in therapeutics. The oxide and basic carbonate (also the dissolved forms of saccharate and bicarbonate) are used in small doses as anti-acids, in larger ones as very mild purgatives, for children more especially. For the latter purpose, however, the sulphate is generally preferred as acting far more energetically. The nauseous bitter taste of the salt can be concealed, to some extent, by acidification of its solution with dilute sulphuric acid. Citrate of magnesia, being exceptionally free of the "*Bittererde*" taste, was introduced some thirty years ago by the French as a pleasant substitute for Epsom salt, and it has since come much into fashion everywhere, although, weight for weight, it is far less efficient than the sulphate. The preparation of dry soluble citrate offering difficulties, the French originally dispensed it exclusively in the dissolved form of "Limonade au citrate de magnésie," a flavoured, decidedly acid solution of the salt, rendered effervescent by addition of some bicarbonate of soda immediately before corking up. In England it is generally preferred to offer the dry ingredients of the "limonade" in the form of "granular effervescent citrate of magnesia." Magnesia alba is pounded up with an excess of citric acid crystals and a few drops of water to produce a paste of amorphous acid citrate, which is dried at a temperature below 30° C. At higher temperatures the salt would pass into a crystalline, insoluble, and consequently therapeutically valueless modification. The citrate is mixed with bicarbonate of soda, citric acid, and sugar, made into a "dough" with alcohol, granulated, and dried. The granules, when thrown into water, dissolve with effervescence. We must not omit to state here that much of what is sold under the name is a mere concoction in which Epsom salt figures as "citrate."

To test a solution for magnesia, remove whatever can be precipitated by means of sulphuretted hydrogen or sulphide of ammonium; then eliminate lime, baryta, and strontia by precipitation with carbonate of ammonia in the presence of sal ammoniac. The magnesia remains dissolved, and can be precipitated (and detected) by addition of phosphate of ammonia (or soda) and free ammonia; the salt $PO_4MgNH_4.6H_2O$ gradually separates out as a crystalline precipitate. This method of course fails when the magnesia is present from the first as phosphate; but we cannot here enter into a consideration of this or any other exceptionally difficult case. (W. D.)

MAGNETISM

Deriva-tion of the word magnet.

THE word magnetism is derived from the Greek word *μάγνης*, which was applied to an ore of iron possessing a remarkable attractive power for iron, and supposed to have been originally found near the town of Magnesia, in Lydia.[1] Thus Lucretius writes:—

> Quem Magneta vocant patrio de nomine Graii,
> Magnetum quia fit patriis in finibus ortus.

This name is said by Plato[2] to have been given to it by Euripides, and he adds that most call it the Heraclean stone. It is needless here to criticize the above or other derivations that have been given for the word; we merely remark that it is now applied to all the phenomena kindred to that which first drew attention to the magnetic iron ore, viz., a selective attraction for iron.

Plan of the article.

In the following article we shall give, in the first place, a sketch of the leading phenomena of strongly magnetic bodies. We shall then describe a provisional theory sufficient to render a general account of these phenomena, and shall afterwards proceed to render this theory more precise, to develop it to its necessary conclusions, and to compare these with experiment, indicating where the theory is either incorrect or incomplete. Then we shall discuss the paramagnetic and diamagnetic properties of all bodies, as expounded by Faraday; an account will be given of the connexion between the magnetic and the other physical properties of bodies; and, lastly, we shall endeavour to give some idea of the different physical theories that have been proposed in order to give something more than a mere shorthand record of the facts of observation.

LEADING PHENOMENA.

Magnetic knowledge of the ancients.

It appears, from what Lucretius says in the passage above quoted,[3] that the Greeks and Romans were aware, not only that the loadstone, or magnetic iron ore, attracted iron, but also that it endued iron in contact with it with its own peculiar property. Thus an iron ring will hang suspended by the attraction of a loadstone, and from that ring another, and so on, up to a certain number, depending on the power of the stone and the weight, &c., of the rings. They were also aware that the attraction was confined to iron, or at all events was not indiscriminate, and that it was not destroyed by the intervention of other bodies, such as brass, between the magnet and the iron. It appears, too, from the passage—

> Fit quoque ut a lapide hoc ferri natura recedat
> Interdum, fugere atque sequi consueta vicissim, &c.—

that they had an idea that, under certain circumstances, the attraction might be replaced by a repulsion. If, however, we understand aright the latter part of Lucretius's somewhat obscure description of what seems to have been an actual experiment of his own, this notion was in reality a hasty generalization, not justified by the observed facts.[4] In any case there seems no warrant for assuming, as some have done, that the ancients had any definite conception of magnetic polarity.

What they wanted in definite experimental knowledge they supplied by an abundant use of the imagination. We are told, for instance, that the magnet attracts wood and flesh, which was certainly beyond their powers of observation; that it is effective in the cure of disease; that it affects the brain, causing melancholy; that it acts as a love philtre; that it may be used in testing the chastity of a woman; that it loses its power when rubbed with garlic, but recovers it when treated with goat's blood; that it will not attract iron in the presence of a diamond, and much else that was eagerly copied by the wonder-loving writers of the Middle Ages.

Beginning of magnetic science. Mariner's compass.

The science of magnetism made no real progress till the invention of the mariner's compass. The early history of this instrument is very obscure. According to some authorities it was invented in China, and found its way into Europe probably through Arabian sources. The light thrown by recent researches on the literature of the Chinese has apparently thrown doubt upon their claim to this invention,[5] although the knowledge of the loadstone and its attractive property may have been older among them than even among the Greeks. The first accounts of the compass in Europe go back to the 12th century, and, although the instrument described is very rough, it is not spoken of as a new invention. In its earliest form it seems to have consisted simply of an iron needle which was touched with the loadstone and placed upon a pivot, or floated on water, so that it could turn more or less freely. It was found that such a needle came to rest in a position pointing approximately north and south (some accounts say east and west, in which case there must have been a cross piece on the needle to indicate what was probably the important direction for the mariner). As these compasses were made of iron (steel was not used till much later), and were probably ill-pivoted, they must have been very inaccurate; and the difficulty of using them must have been much increased by the want of a card, which was a later addition made apparently by the Dutch.

It is unnecessary to enter into more detail here respecting the early history of the compass, as the matter has been very fully treated in the article COMPASS.[6] We proceed therefore to show the bearing of the invention upon the science of magnetism. It will at once be seen that it involves two scientific discoveries of capital importance:—first, that the loadstone can transmit to iron with which it comes in contact a permanent property like its own; and, secondly, that a loadstone or magnet if suspended freely will turn so that a certain direction in it assumes a fixed position relative to the geographical meridian, a certain part of the magnet turning always towards the north, and the part opposite towards the south. These opposite parts of the magnet are called its "poles."

Axis of a magnet experimentally defined.

To fix our ideas we shall describe a process by which we might definitely determine this direction in the magnet. Following the example of Gilbert, let us consider a spherical magnet. Our reason for dealing with this form in the first instance is to make it perfectly clear that the phenomena depend essentially on something apart from the form of the body. We shall suppose that the magnet is homogeneous as to its mass, so that its centre of gravity

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[1] Gilbert, *De Magnete*, lib. i. chap. ii., says, "Magnesia ad Mæandrum"; but it is uncertain whether this or Magnesia ad Sipylum is meant.

[2] Ἐν τῇ λίθῳ ἣν Εὐριπίδης μὲν Μαγνῆτιν ὠνόμασεν, οἱ δὲ πολλοὶ Ἡράκλειαν (*Ion*, 533 D). See Munro's *Lucretius*, vol. i. p. 662. The other name is from Heraclea in Lydia.

[3] Bk. vi. line 906 *sq.*, and 1042 *sq.*; comp. Plato, *Ion*, *ut supra*, whom there is reason to think he is quoting.

[4] See below, p. 225.

[5] See Möllendorff, *Z. D. M. G.*, xxxv. 76.

[6] It may be mentioned that the statement that Peter Adsiger, in a letter written in 1296, mentions the magnetic declination, appears to be a mistake, arising from the mistranscription of a title. See Wenckebach, quoted by Lamont, *Handbuch des Magnetismus*, p. 449. The passage from Are Frode, quoted by Hansteen, and alluded to in last edition of this encyclopædia, appears also to be of doubtful antiquity. See Poggendorff, *Geschichte der Physik*, p. 99.

coincides with its centre of figure. Suspend this spherical magnet by a fine thread of untwisted silk, attached to any point of its surface, say P. After the magnet has come to rest, mark the vertical plane through the centre which falls in the geographical meridian; this may be done by tracing a great circle on the surface of the magnet. Next find the point P′ in which the vertical through P cuts the surface again, and suspend the magnet by P′, again marking the plane which falls in the meridian. Now, find the plane which bisects the acute angle between the two former planes, mark it by a great circle, and call it the axial plane of P. If we thus find the axial planes of any number of points, we shall find that they all intersect in one common line passing through the centre of the sphere. We may call this line the "axis" of the magnet. Let us mark the points where it cuts the surface; we may call these the "poles" of the magnet. We shall then observe that, however we suspend it, the magnet will always come to rest so that the vertical plane through the axis makes a definite angle with the meridian. This angle (δ) is called the "declination" (also, by sailors, the "variation"); it varies from place to place, and from time to time, but very slowly, so that throughout a limited area of the earth's surface, and for a limited time, it may be regarded as constant.[1]

Poles, north and south.

One end of the axis always turns northwards, and the other always southwards; we shall call the former the "north" and the latter the "south pole," although, for reasons to be afterwards explained, it would be more appropriate to invert the order of these names. Henceforth the vertical plane in which the axis of the magnet comes to rest will be called the magnetic meridian, and the two horizontal directions in this plane magnetic north and magnetic south respectively.

Magnetic meridian.

It must be carefully noticed that there is a certain amount of arbitrariness in our definition of the axis and poles of a magnet. In reality it is only the direction of the axis that is fixed in the body, and not its absolute position. This will be made plain if we repeat all our experiments with the spherical magnet after fastening to it a piece of wax or other non-magnetic body, so as to leave its magnetic properties unchanged, but to throw its centre of gravity out of the centre of figure. Everything will fall out as before, only the axial planes of the different points of suspension will now meet in a line, parallel, it is true, to the axis determined before, but passing through the new centre of gravity. In point of fact, therefore, we might choose any point in the body, draw a line through it in the proper direction, and call this the axis. Hereafter we shall, unless the contrary is stated, draw the axis through the centre of gravity of the body, or through its centre of figure if it has one; and we define the poles, for the present, as the points in which the axis cuts the surface of the magnet, supposing, as will be generally the case, that the line cuts the surface in two points and no more.

Magnetic needle.

Having now obtained a definite idea of the axis of a magnet, and seen that it has, in the first instance at least, nothing to do with the external form of the body, let us proceed to make an artificial magnet of the particular kind usually called a "magnetic needle," and briefly examine its properties. Take a tolerably thin flat piece of pretty hard-tempered steel, of the elongated symmetrical form NS shown in fig. 1. We suppose it, in the first place, in an unmagnetic condition. Let it be pierced by a well-turned axis *ab*, passing accurately through its centre of gravity, and perpendicular to its plane, so that, when the axis is placed on two horizontal knife edges, the needle will rest in any position indifferently. Further, let four very small hooks, *c*, *d*, *e*, *f*, be attached, two (*c*, *d*) to the ends of the axis, and other two (*e*, *f*) to the edges of the needle in a line perpendicular to NS. Now rub the half of the needle

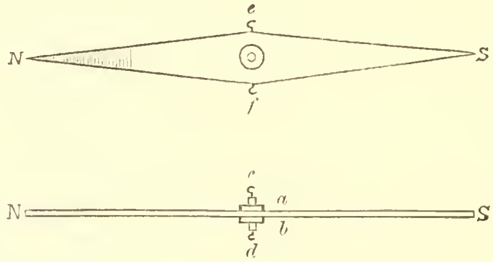

Fig. 1.

towards N with the south pole of the spherical magnet whose properties we have just discussed, beginning the stroke at the middle and ending it at the point of the needle, and for symmetry's sake let us do the same to the other side of the needle, and then repeat this process with the north pole of the sphere on the other half towards S. Let us examine the properties of the needle thus "magnetized." If we suspend it first by the hook *c* and then by the hook *d*, we shall find that in both cases the line joining NS[2] makes very nearly the same angle with the geographical meridian. Hence the magnetic axis must lie in a plane through NS perpendicular to the plane of the needle. A similar experiment with the two hooks *e*, *f* will show that the magnetic axis lies approximately in the plane of the strip, which we may suppose for the present to be infinitely thin. Hence the magnetic axis may be taken to be coincident with the line NS joining the points of the needle. This coincidence is, however, in general only approximate, and in delicate measurements corrections have to be made on that account, of which more hereafter. If we now mount our magnetized needle on a piece of cork or two straws, and float it in a basin of water, or replace its axle by a small cap and set it on a pivot, we have the mariner's compass in its early form. We shall call it a magnetic needle, to distinguish it from the more elaborate compass of the present day. A favourite way of showing the directive property of a magnet, described by Gilbert, is to magnetize a sewing-needle, and lay it very gently, by means of a fork of wire, on the surface of water; it will float and turn until it takes up its position in the magnetic meridian.

A needle mounted in this way, so as to have great freedom to move in a horizontal plane, is of great use in magnetic experiments. Gilbert calls it a "versorium." When very delicate applications are in view, the point of the pivot on which it is mounted must be very hard (say of hard tempered steel or iridium), and the cap should be fitted with an agate or other hard stone having a polished cavity of the form of a blunted cone to receive the pivot. A still better arrangement, also used by Gilbert, is to suspend a short and very light piece of steel wire—a fine sewing needle may be used—by means of a single fibre of silk. The most delicate arrangement of all is to use one of Sir W. Thomson's light galvanometer mirrors with the magnets attached, and follow its movements by means of the lamp and scale as usual. See GALVANOMETER.

Such, with as much of modern accuracy imported into them as was necessary for clearness of exposition, were the facts of magnetism as known up to the beginning of the 16th century.

Discovery of the dip.

Another experiment with our magnetized needle will enable us to describe the next important magnetic discovery. In its unmagnetized condition the needle rested indifferently in any position when its axis was placed on

[1] For the early observations on the declination the reader is referred to the treatment of the subject of terrestrial magnetism in the article METEOROLOGY. At the present time the declination at Greenwich is a little over 18°; at Edinburgh it would be about 4° more.

[2] Or the vertical plane through it, should it happen to be not quite horizontal.

two horizontal knife edges. In the magnetized state this is no longer the case. The axis of the needle now takes up a fixed position, with its north end pointing downwards (fig. 2), and if disturbed will oscillate about that position, and finally settle into it again. The angle which the axis NS makes with the horizon is least when the plane of rotation of the needle is in the magnetic meridian: the angle (ι) in this case is called the "dip," or (by Continental writers) the "inclination." It is greatest, viz., 90°, when the plane of rotation of the needle is vertical and perpendicular to the magnetic meridian. At Greenwich the dip is about 67° 30′ at the present time. If we place the needle with its plane of rotation perpendicular to the line of dip, the equilibrium will be indifferent, as it was in all positions before magnetization; but there is no other position of the magnetized needle for which this is true.

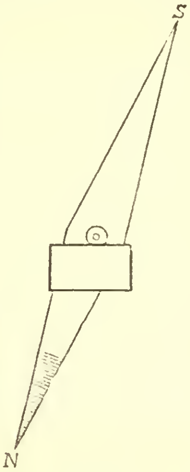

Fig. 2.

The remarks which we made as to variation in space and time of the declination apply also to the dip. The variation from place to place differs, however, in nature from that of the declination. Along a line running in the neighbourhood of the geographical equator, partly north and partly south of it, the dip is zero. North of this line, which is called the magnetic equator, the north end of the needle dips below the horizon; and the angle of dip increases as we go northwards, until, at a point in the Hudson's Bay Territory, the needle dips with its north pole vertically downwards. South of the magnetic equator the south end dips below the horizon; and there is again a point in the southern hemisphere where the south end dips vertically downwards. These points are called the "magnetic poles" of the earth. For further details on this subject we refer the reader to the discussion of terrestrial magnetism in the article METEOROLOGY.

It was in the accurate observation of the declination and dip of the magnetic needle that the science of magnetism arose. The dip appears to have been first observed by Georg Hartmann, vicar of the church of St Sebaldus at Nuremberg (1489–1564), who seems to have been in advance of his age in magnetical matters. In a letter[1] to Duke Albrecht of Prussia, dated 4th March 1544, he writes:— art-ann.

"Besides, I find this also in the magnet, that it not only turns from the north and deflects to the east about 9° more or less, as I have reported, but it points downwards. This may be proved as follows. I make a needle, a finger long, which stands horizontally on a pointed pivot, so that it nowhere inclines towards the earth, but stands horizontal on both sides. But as soon as I stroke one of the ends (with the loadstone), it matters not which end it be, then the needle no longer stands horizontal, but points downwards (*fällt unter sich*) some 9° more or less. The reason why this happens was I not able to indicate to his Royal Majesty."

From this it will be seen that Hartmann had unquestionably observed the tendency of the magnetized needle to dip. His method of observing is of course unsuited for *measurement*, and it is not surprising that he got a result of 9° instead of somewhere about 70°.

In 1576 the dip was independently discovered by Robert Norman, a skilful seaman and an ingenious artificer, according to Gilbert. He was in the habit of making compass needles, and carefully balancing them so as to play horizontally on their pivots before magnetization. He found that, after they were magnetized, they constantly dipped with the north end downwards, so that a counterpoise had to be added to bring them back to the horizon. This led him to construct a special instrument, the prototype of the modern dipping needle, to show this new phenomenon. With this instrument he made the first accurate measurement of the dip, and found it to be 71° 50′ at London.[2] Norman.

The early English magnetic observers, of whom Norman and Burroughs (who wrote an able supplement to Norman's work) were admirable examples, must have done much for the introduction of precise ideas into magnetism. But their fame was speedily eclipsed by William Gilbert of Colchester[3] (1540–1603), whom Poggendorff has justly called the Galileo of magnetism, and whom Galileo himself thought enviably great. In his great work entitled *De Magnete Magneticisque Corporibus et de Magno Magnete Tellure Physiologia Nova*, first published in 1600, we find a complete account of what was known of magnetic phenomena up to his time, with a large number of new ideas and new experimental facts added by himself. We find in Gilbert's work, in a more or less accurate form, nearly all that we shall lay before the reader in the first section of this article, described very much in the language that we shall use. "How far he was ahead of his time is best proved by the works of those who wrote on magnetism during the first few decades after his death. They contributed in reality nothing to the extension of this branch of physical science."[4] Gilbert.

Mutual Action of Like and Unlike Poles.—If we take a magnet whose poles N′, S′ have been determined and marked as above explained, and bring its north pole N′ near the north pole N of a magnetic needle, N will move in a direction indicating repulsion between N and N′. The same result will follow if the south pole S′ of the magnet be brought near the south pole S of the needle. But if S′ be brought near N, or N′ near S, attraction will be indicated. Hence the following fundamental law of the action between two magnets:—*Like poles repel each other; unlike poles attract each other.* It would appear, therefore, that the whole action of one magnet upon another is of a somewhat complicated character, even if we take the simplest view of it that the experimental facts will allow, viz., that the action may be represented by forces acting between the two pairs of points in each magnet which we have defined as north and south poles. On this assumption, the action of N′S′ upon NS would consist of the four forces represented in fig. 3, for all these must exist in accordance with the law just established. Whether this is a sufficient Like magnetic poles repel; unlike attract.

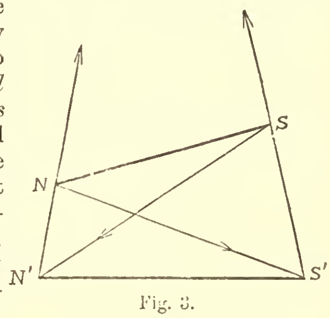

Fig. 3.

[1] Brought to light by Moser. See Dove's *Repertorium der Physik*, ii., 1838. It does not appear that Hartmann's letter was ever before published. Moser is therefore scarcely justified in attacking Norman's priority in this matter, still less in attempting to deny him the credit of first observing the dip by a sound method. Had he read the *Newe Attractive* he could scarcely have fallen into such an error; for in respect of clearness and scientific precision Hartmann's letter, interesting as it is, cannot for a moment be compared with Norman's little work.

[2] He published a work, of which the following description is given in the *Ronalds' Catalogue*:—"The *Newe Attractive*, containing a short discourse of the Magnes or Lodestone, and amongst other his vertues, of a new discovered secret and subtill propertie concernyng the Declyning of the Needle, touched therewith, under the plaine of the Horizon. Now first found out by Robert Norman, Hydrographer. 4to (black letter, scarce), London, 1581."

[3] For details as to his life, see art. GILBERT.

[4] Poggendorff, *Geschichte der Physik*, p. 286.

representation of the most general case, and what the exact law of the forces ought to be, we are not yet in a position to decide. One thing, however, is clear, that the action between two poles must diminish when the distance between them increases; otherwise we should not have been able to make the action of N or S upon N′ prevail, by bringing the one or the other nearer.

It was perhaps the complexity of this analysis (along with the fact that the action of the magnet upon soft iron, which was the earliest discovered magnetic phenomenon, is not a pure case of this action, but involves also another phenomenon, viz., magnetic induction) that prevented for so long the discovery of the elementary law we are now discussing. At all events, it seems to have been a new discovery in the 16th century, if we may judge from a passage in the letter of Hartmann above alluded to. He was certainly aware of the existence of magnetic repulsion in some form or other. It is somewhat difficult to gather from his description what it was exactly that he observed, and he nowhere states the law fully and explicitly. In Norman's *Newe Attractive* [1] we find it clearly stated, and demonstrated by means of a needle floating on water or suspended by a thread;[2] yet he does not appear to claim the fact as his discovery. If, therefore, Hartmann was not the actual discoverer, we may at least conclude that the law became familiar to magnetic philosophers during the thirty years that separated him from Norman.

Mapping out the magnetic field.

Lines of magnetic force.

The Magnetic Field.—We next introduce a method of conceiving and describing magnetic actions which was invented and much used by Faraday. Since a magnet acts upon a magnetic needle placed anywhere in the surrounding space,[3] we call that space the magnetic field of the magnet. Neglecting the earth's magnetism, we may map out this field as follows. Conceive any plane drawn through the axis of the magnet, and place it so that this plane shall be horizontal. Then at any point in this plane place a very small magnetic needle, and note the direction which its axis assumes under the action of the magnet; then proceed to move the centre of the needle in the direction in which its north pole points, and continue the motion so that at each point the centre is following the direction indicated by the north pole. The line thus traced will at last cut the surface of the magnet at some point lying towards its south pole; and if we continue the line backwards, by following the direction continually indicated by the south pole of the needle, it will cut the surface of the magnet at some point lying towards the north pole. Such a line is called a line of magnetic force; and, since one such line can be drawn through every point of the plane, and any number of planes can be taken through the axis of the magnet, we can conceive the whole magnetic field filled with such lines. Fig. 4, taken from Faraday, gives an idea of the distribution of the lines of force in the field of a bar magnet; fig. 5 represents the lines in the field due to two neighbouring like poles.

These diagrams were not obtained by the method we have just described, but by a much simpler process which we shall describe by and by. Their use, so far as we have gone, is to tell us how a small needle, free to move about its centre in any direction, will place itself at any part of the field, viz., it will place its axis along the tangent to the line of force which passes through its centre, its north pole pointing in that direction which ultimately leads to the south pole of the magnet producing the field.

Terella or ideal earth.

Suppose we apply these ideas to a spherical magnet (a terella, or earthkin, as Gilbert calls it). The lines of force in any plane through its axis would be found to run something like the curves in fig. 6. If, therefore, we carried a small needle (suspended from a silk fibre so as to be perfectly free to move in all directions) round the magnet

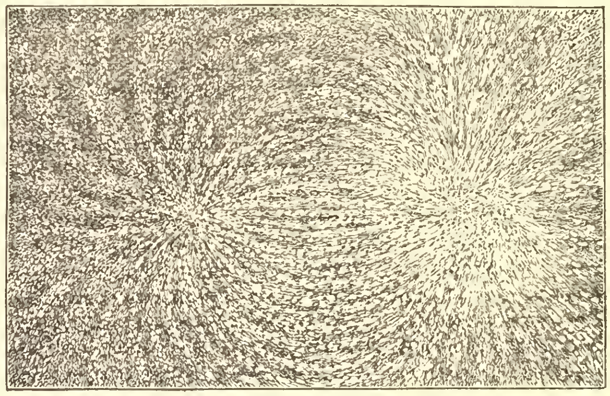

Fig. 4.

in a meridian plane, its axis would constantly remain in the meridian plane, its north pole always point towards the south pole of the spherical magnet, but dip more and more

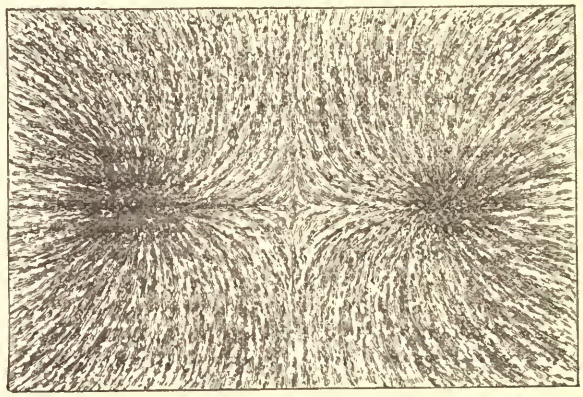

Fig. 5.

below the tangent plane to the sphere as the centre recedes from the equator, and end by pointing straight towards the south pole when the centre reaches the magnetic axis (see fig. 6).

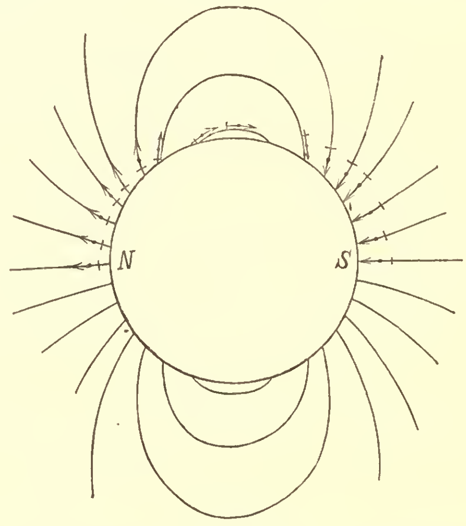

Fig. 6.

When we reflect that in all our experiments the properties of magnets, whether native, such as the loadstone, or artificial, such as the needles magnetized by rubbing with the loadstone, have proved alike, and that every

[1] Chap. i.

[2] See also Gilbert, *De Magnete*, lib. i. cap. v.

[3] Gilbert uses the phrase *orbis virtutis* in a somewhat similar sense.

purely magnetic action on a magnet has its source in some other magnetic body, we are naturally led to the conclusion that the reason why at every point of the earth's surface the axis of a freely suspended magnet assumes a definite position is simply that the earth itself is a great magnet, and that in observing the declination and dip we are simply exploring the magnetic field of the earth. It is true that, according to the experiment above described, the declination would every where be zero, and the magnetic equator would coincide with the geographical, but that arises merely because we assumed our earthkin, for simplicity of explanation, to be symmetrically magnetized, so that its lines of force ran in planes passing through its axis. It remains to be discussed whether the most general assumption, viz., that the earth is a magnetic body, will not account for the facts of terrestrial magnetism. The answer to this question has been given, as we shall see, by Gauss.

This idea, whose simplicity is the truest measure of its greatness, is due to Gilbert, and was by him made the foundation of his work on magnetism. The boldness of his theory will be appreciated when we remind the reader that in his day the dip was but newly discovered, and had been measured only at London, so that Gilbert's very full and clear exposition of this phenomenon, which we have given above, was in fact a scientific prediction, which was not fully verified till long afterwards.[1] Before Gilbert a variety of wild conjectures had been made as to the cause of the directive property of the magnet.[2] Many, like Columbus, Cardan, and Paracelsus, believed that the magnet was attracted by a point in the heavens, possibly some magnetic star. Others supposed that the attracting point was situated in the earth; Fracastorius imagined hyperborean mountains of loadstone situated near but not quite at the north pole; and to this theory others contributed the detail that the magnetism of these mountains was so powerful that ships in these regions have to be built with wooden nails instead of iron ones, which would be instantly drawn out by the magnetic attraction.

It is clear that, if we call that magnetic pole of the earth which lies in the northern hemisphere its north pole, we ought, in accordance with our fundamental law of magnetic action, to call the north-seeking pole of an ordinary magnet a *south* pole. When it is necessary to speak of magnets from this point of view, the difficulty is got over by calling the north-seeking pole the austral pole, and the south-seeking pole the boreal pole. In reality the danger of confusion is more imaginary than real. The reader should be warned, however, that in some French works the ordinary nomenclature is reversed, and that Faraday uses "marked" and "unmarked," and Airy "red" and "blue," in the sense in which north and south are commonly used.

ırth's rce of ansla- on nil.

The Earth's Action on a Magnet is a Couple.—Norman in his *Newe Attractive* (chapters v. and vi.) discusses very acutely the question whether there is any force of translation exerted upon a magnet. He advances three conclusive experiments to prove the negative. First, he weighed several small pieces of steel in a delicate gold balance, and then magnetized them, but could not detect the slightest alteration in their weight, "though every one of them had received vertue sufficient to lift up his fellow." Secondly, he pushed a steel wire through a spherical piece of cork, and carefully pared the latter so that the whole sank to a certain depth in a vessel of water and remained there, taking up any position about the centre indifferently. After the wire was magnetized very carefully, without disturbing its position in the cork, it sank to the same depth as before, neither more nor less, the only difference being that now the wire set itself persistently in a definite fixed direction parallel to the magnetic meridian, the north end dipping about 71° or 72° below the horizon. Thirdly, he arranged a magnetized needle on a cork so as to float on the surface of water, and found that, although it set in the magnetic meridian, there was not the slightest tendency to translation in any direction.[3] He concludes that there is no force of translation on the magnet, either vertical or horizontal. He was evidently somewhat puzzled how to put this result into a positive form, and his "point respective," as he calls it, is not a very clear explanation of the earth's action. What he wanted was the modern idea of a "couple," *i.e.*, a pair of equal but oppositely directed parallel forces acting on the two ends of the needle; but such an idea was not conceived in Norman's day. Gilbert adopts Norman's result in this matter, adding nothing essential, reproducing even Norman's diagram of the spherical cork with the wire through it. It is clear therefore that Gilbert had a forerunner in the practice, as Bacon had in the theory, of inductive science; for Norman says, speaking of the mass of fables that had passed for truth in geography, hydrography, and navigation before his time, "I wish experience to bee the leader of Writers in those Artes, and reason their rule in setting it downe, that the followers bee not led by them into errors, as oftentimes have beene seene."

Magnetism a molecular property.

The Magnetic Property is Molecular.—Apart altogether from the question as to how we are to represent the action of a magnet upon other magnets, there arises another quite distinct question, as to where the cause of this action resides. That these two questions are really distinct, although there has always been a tendency in the more superficial treatises on the subject to confuse them, will be obvious from the fact that we shall afterwards obtain more than one perfectly general way of representing the action of a magnet at external points, whereas there must be one and only one cause of this action. A very old experiment[4] at once throws considerable light on this point. If we break a bar magnet into two pieces, it will be found that each of these is itself a magnet, its axis being in much the same direction as that of the original magnet, and its poles in corresponding positions, see fig. 7.

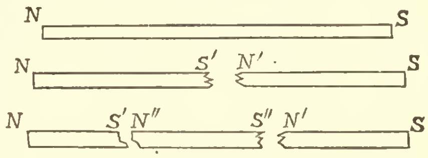

Fig. 7.

The same holds if we break the bar into any number of pieces; and, quite generally, if we remove any piece, however small, from a magnet, this piece will be found to be magnetic, the direction of its axis usually bearing a distinct and easily recognizable relation to the direction of the axis of the whole magnet. We are therefore driven to the conclusion that the magnetic quality of a body is related to its ultimate structure, and not simply to its mass as a whole, or to its surface alone; and this conclusion is not to be invalidated by the fact that we can in general, as will afterwards appear, represent the action of the magnet at external points by means of a proper distribution of centres of attractive and repulsive forces upon its surface merely.

Temporary Magnetism of Soft Iron and Steel in the Magnetic Field.—Bodies which possess permanent magnetic

[1] The first verification was by Hudson, who, in 1608, found the dip in 75° 22′ N. lat. to be 89° 30′. Gilbert found 72° at London in 1600. The place of vertical dip in the northern hemisphere was first reached by Sir James Ross in 1831. It was found about 70° 5′ 17″ N. lat. and 96° 45′ 48″ W. long.

[2] See Gilbert, *De Magnete*, lib. i. cap. i.

[3] Hartmann (see his letter above cited) was in error on this subject. He describes a somewhat similar experiment, and distinctly states that the needle has a motion of translation. "Schwimmt mit dem Ort welcher ist mitternächtlich am Stein, bis er kam an den Port der Schüssel, da das Wasser in war."

[4] *Cf.* Gilbert, *De Magnete*, lib. i. cap. v.

Magnetic induction.

properties, not depending on the circumstances in which they are placed, we shall henceforth call "permanent magnets." The law of the action of one permanent magnet upon another, as we have seen, is that like poles repel and unlike poles attract each other. The action of a permanent magnet on pieces of soft iron is, at first sight, different, for either pole attracts them alike.

Experiments illustrating induction.

To fix our ideas let us take a small thin bar of soft iron or of steel, and test it with a delicate magnetic needle. It will usually be found, more particularly if a steel bar is taken, that one end of the bar will *repel* one or other of the poles of the needle. This is a sure sign of permanent magnetism. If, however, we heat the bar to whiteness and allow it to cool in a position perpendicular to the earth's magnetic force, all permanent magnetism will be found to have disappeared. If we now place the bar in a horizontal plane (fig. 8) with its axis perpendicular to the axis of the needle, and one of its ends A, B near either pole of the needle, that pole will be attracted, no matter whether it be the north pole or the south pole of the needle, or which end of the bar be used.

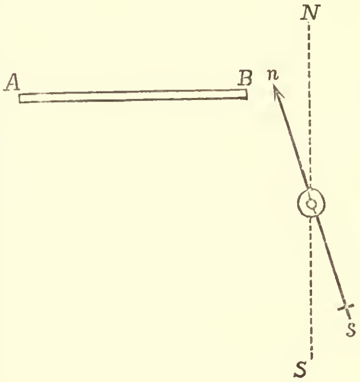

Fig. 8.

Care must be taken in this experiment to avoid using a too strongly magnetized needle, and to keep the needle from touching the bar, otherwise the bar may receive traces of permanent magnetism which will disturb the result. It is very easy, by repeating the above experiment with an unmagnetized needle, to show that the power that the bar acquires of attracting the poles of the needle is temporary and depends on the presence of a magnetized body.

Keeping to our principle that a magnetic cause is to be sought for every magnetic action, we are led to explain the above experiment by saying that in the magnetic field a bar of soft iron or of unmagnetized steel becomes magnetic in such a way that its north pole points as nearly as may be in the positive direction of the lines of force passing in its neighbourhood (or, in other words, in the direction, as nearly as may be, in which a magnetic needle would point if placed in its neighbourhood). A body which becomes magnetic in this way by the magnetic action of another body is said to be "magnetized" by "induction." We shall suppose, in the meantime, that it loses all the magnetism thus acquired when the inducing action is withdrawn; although this is not necessarily, and in fact not generally, the case, as we shall see by and by. The reason why soft iron is attracted by a permanent magnet is therefore now said to be that the iron becomes magnetic by induction, and is then acted upon by the magnet like any other magnet similarly placed. The accuracy of this analysis of the phenomenon may be confirmed by many simple but striking experiments, such as the following.

In the experiment above described, instead of placing the non-magnetic bar in a horizontal plane, place it in the plane of the magnetic meridian with its axis in the direction of the earth's force (*i.e.*, parallel to the line of dip). The lower end of the bar will then be found to repel and the upper end to attract the north pole of the needle (figs. 9, 10). This is at once explained on the above hypothesis; for the bar will be magnetized inductively by the earth's force, so that its lower end becomes a north pole, and its upper end a south pole.

Let NS (fig. 11) be a bar magnet placed horizontally so that its axis produced passes through O, the centre of suspension of the needle *sn*, then the needle will be deflected

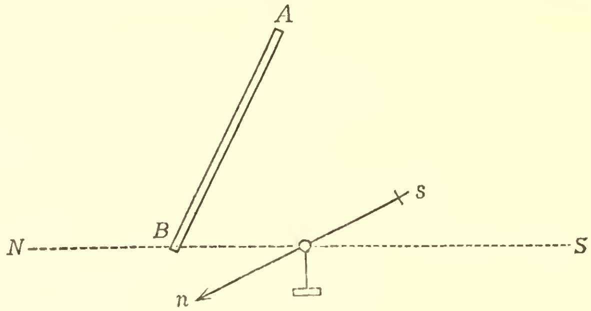

Fig. 9.

in the direction of the arrow. If now we place between S and O a small sphere of soft iron, this deflexion will be

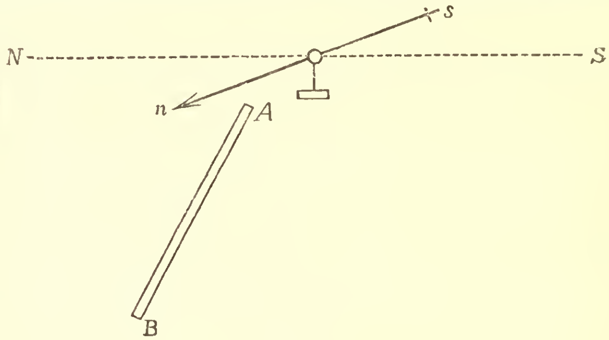

Fig. 10.

increased, the reason being that the sphere is magnetized by induction, having a south pole towards O and a north pole

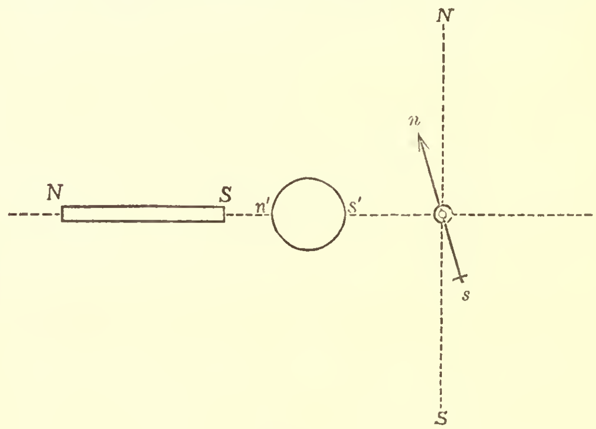

Fig. 11.

towards S, and the action of these is added to that of NS.

Let NS (fig. 12) be a magnet placed in the magnetic meridian, *n's'* a small magnetic needle in the same horizontal plane, with its centre in the line bisecting NS at right angles. When acted on by NS alone, *n's'* will place itself parallel to NS, with its north pole pointing in the direction NS

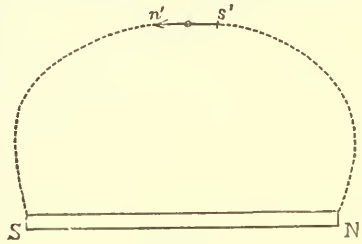

Fig. 12.

Let the dotted line represent a line of force. If we move a small piece of soft iron *ns* along this line in the direction from N towards S, it will first deflect the needle as in fig. 13, and finally as in fig. 14, and in each position reversing it end for end will not alter the effect. All this is at once explained by the above hypothesis.

A variation of the last experiment may be made thus. Place a magnet vertically, in the neighbourhood of a magnetic needle; by moving it up and down a position will be found in which the action of the magnet on the needle is wholly vertical, so that the needle is not deflected from the magnetic meridian. Now take a small piece of soft iron and move it along a line of force passing near the needle, proceeding from the north to the south pole of the vertical magnet. It will then be found, in accordance with our hypothesis, that the north pole of the needle is first repelled, and finally attracted by the soft iron.

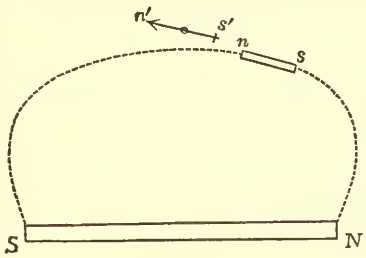

Fig. 13.

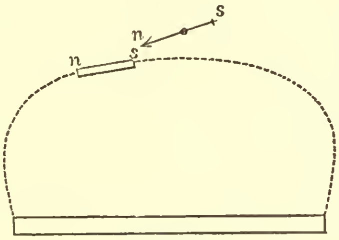

Fig. 14.

[Gilbert's experiment.] If we hang two short pieces of iron wire alongside of each other by parallel threads, they will be found to repel one another, and to hang separated by a considerable interval when a magnet is brought under them (see figs. 15 and 16). This experiment is due to Gilbert, who rightly explains it by saying that the two ends nearer the magnetic pole S become like poles of opposite kind to S, while the two farther ends are like poles of the same kind as S. The experiment may be varied by placing some little distance below the pole of a magnet S a piece of mica or thin cardboard M, and placing below that a short piece of soft iron wire; it will remain adhering to the mica, and so long as it is alone will hang more or less nearly vertical, but when another is placed alongside of it the two will diverge as in fig. 17.

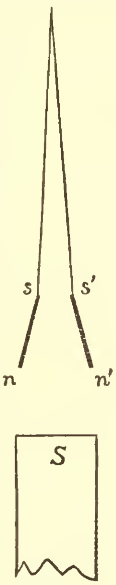

Fig. 15.

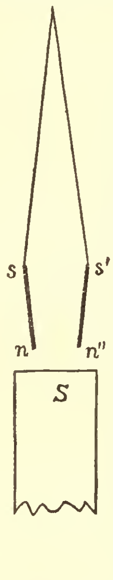

Fig. 16.

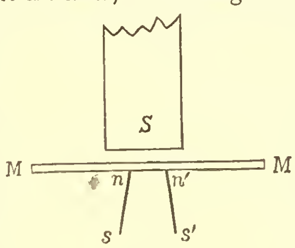

Fig. 17.

[Experiments with iron filings.] One of the most interesting examples of magnetic induction is furnished by the action of a magnet on iron filings. If we plunge a magnet into a quantity of iron filings and then remove it, we find it thickly fringed around the poles, where the filings adhere to the magnet and to one another so as to form short bushy filaments; the thickness of the fringe diminishes very rapidly towards the middle of the magnet, where very few adhere at all. These filaments are composed of magnetized particles of iron adhering by their unlike poles.

If we place a small bar magnet under a piece of moderately rough drawing paper, strewn as uniformly as possible with fine iron filings, and then tap the paper very gently so as to relieve the friction, and allow each filing to follow the magnetic action, then the filings will be seen to arrange themselves in a series of lines, passing, roughly speaking, from pole to pole, as in fig. 4 (p. 222). The explanation of this phenomenon is simply that each filing becomes magnetized by induction, and, if it were quite free to move about its centre, it would not be in equilibrium until it set its longest dimension along the line of force through its centre. The roughness of the paper effectually prevents translation, but does not hinder rotation, especially when the friction is relieved by tapping; hence every filing does actually set as if it were a little magnetic needle, subject of course to some slight disturbance from the neighbouring filings. The whole therefore assumes a grained structure, and the graining runs in the direction of the lines of force. We have thus an extremely convenient way of representing these lines to the eye, which lends itself in a variety of ways to the illustration of magnetic phenomena. In fig. 5 are shown the lines formed in the field near two like magnetic poles. These magnetic figures may be fixed in a great variety of ways, and projected on a screen so as to be visible to a large audience, but it is scarcely necessary to dwell here upon details of this kind.

These magnetic curves seem to have fixed the attention of natural philosophers at a very early period. They were originally called the magnetic currents, from an idea that they represented the stream lines of magnetic matter, which explained the magnetic action according to the theory then in vogue. La Hire mentions them, *Mém. de l'Acad.*, 1717. Bazin gives an elaborate account of them in his *Description des Courans Magnétiques dessinés d'après Nature*, Strasburg, 1753. Musschenbroek seems to have been the first to give the correct explanation depending on magnetic induction, *Diss. de Magnete*, 1729.

Lucretius's experiment. If the filings be laid very thickly on the paper, and one pole of the magnet be brought under them at a short distance off, they will arrange themselves in a pattern, and at the same time bristle up so as to stand more or less erect, according as they are nearer or farther from the magnet. They have thus the appearance of being *repelled* from the magnet. It was, in all probability, this phenomenon that was observed by Lucretius when he says (vi. 1042):—

> "Exultare etiam Samothracia ferrea vidi,
> Ac ramenta simul ferri furere intus ahenis
> In scaphiis, lapis hic Magnes cum subditus esset."

His conclusion, therefore, that iron sometimes flies and sometimes follows the magnet, was scarcely justified by his experimental facts, and it is a mistake to suppose, as some have done, that he was aware of the polarity of *permanent* magnets.

Magnetic paradox. If we tap the card in the last experiment a curious result may sometimes be observed.[1] The lines of filings will be seen to *recede* from the point of the card immediately over the pole of the magnet. If, however, the magnet be held over, instead of under, the card, tapping will cause the filings to approach the point under the pole of the magnet. The most probable explanation[2] of this is to be found in the fact that the erected filings stand in the

[1] Æpinus, *Tentamen Theoriæ Electricitatis et Magnetismi*, 1759; Cavallo, *Treatise on Magnetism*, 1787.
[2] Roget, *Library of Useful Knowledge*, 1832.

former case as shown in fig. 18, and in the latter as shown in fig. 19; that is, in both cases, owing to the action of gravity, they are more acutely inclined to the card than

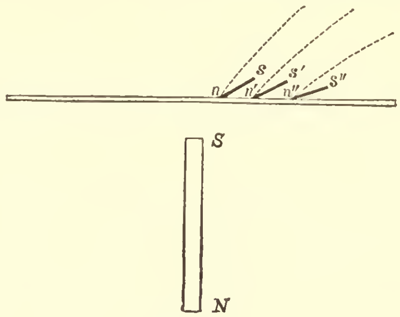

Fig. 18.

the lines of force (represented by dotted lines in the figure). Consequently, when the filing springs up into the air, and is thus free to follow the magnetic couple, it turns more

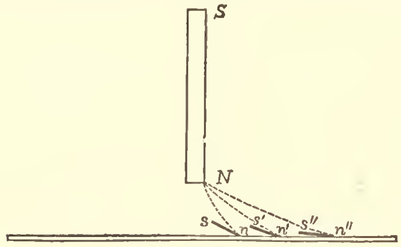

Fig. 19.

into the direction of the line of force; the effect of this is to carry its lower end each time a little farther from the axis of the magnet in the one case, and a little nearer to it in the other.

Electro-magnets.

By far the most important case of magnetic induction is the electromagnet. Whenever an electric current flows in a closed circuit, the surrounding space becomes a field of magnetic force, and any piece of iron in it will be inductively magnetized. Such an arrangement of an electric circuit and iron is called an electromagnet. The variety of form and of application of such instruments in modern science is endless. A few of the more important modifications will be considered below.

Induced and permanent magnetism in the same body.

Co-existence of Induced and Permanent Magnetism.—The fact that a body is already a permanent magnet does not prevent its being susceptible to magnetic induction. If we take any piece of iron at random, the chances are that one end or other of it will repel the north pole of a magnetic needle,—in other words, it will be to some extent permanently magnetic; but if we bring it slowly nearer and nearer to the pole of the needle, provided its magnetism be not *too* strong, it will by and by attract the pole which it at first repelled. Again, if we take two steel magnets, which may be as powerful as we please, provided at all events that they are unequally powerful, and bring two *like* poles together, these poles will at first repel each other in accordance with the fundamental law of permanent magnets; but, when the distance is less than a certain amount, the repulsion passes into an attraction, and when the poles are in contact this attraction may be very considerable. These phenomena are at once explained by the law of induction. The induced or temporary magnetism is superposed on the permanent magnetism, and, when the poles are near enough, the opposite magnetism induced by the pole attracts it more than the permanent like magnetism repels it; and this happens even with steel, whose susceptibility for magnetic induction is considerably less than that of iron. This phenomenon was observed pretty early in the history of magnetism, but was not fully explained until the idea of magnetic induction was fully developed. Michell, in his *Treatise of Artificial Magnets*,[1] gives a tolerably clear account of it. Musschenbroek mentions it,[2] along with the fact that a magnet attracts iron more than it does another magnet, but offers no explanation of either fact. The latter result, so far as it is true, can of course be explained by the smaller susceptibility of steel, particularly of hard steel, to magnetic induction, which is the main factor in attraction at small distances. Poggendorff[3] and others have experimented on the subject in later times. The reader should notice the close analogy between these phenomena and the repulsion and attraction at different distances between two similarly electrified conductors. See article ELECTRICITY, vol. viii. p. 33.

Induction of Permanent Magnetism.—The case above supposed, in which the induced magnetism is wholly temporary, although it can be easily realized with small magnetizing forces, is not the general one, but in fact the exception. Usually a certain proportion of the magnetism remains after the inducing force is removed. This happens even with the softest iron, when the inducing force is very great. Just as bodies differ very much in their susceptibility for induced magnetism, so they differ greatly in their power of retaining this magnetism when the inducing force ceases, or, as the phrase is, in "coercive force." Thus, while the inductive susceptibility of steel is less than that of iron, it retains much more of the magnetism imparted to it, and is therefore said to have much greater coercive force; and the coercive force is greater the harder the steel is tempered.

Coercive force.

It is obvious, therefore, that the principle of "induction," along with the idea of "retaining power" or "coercive force," furnishes us with the key to the explanation of the communication of permanent magnetism, whether by means of natural magnets or of artificial magnets, or of the electric current. In particular, we see at once the reason why the end of a needle which has been touched by the north pole of another magnet becomes a south pole, and *vice versa*,—a fact which greatly puzzled the earlier magnetic experimenters, and indeed all who were inclined to think that, in the process of magnetization, something was communicated from the one magnet to the other.

Mathematical Theory of the Action of Permanently Magnetized Bodies.

In this section we shall suppose the bodies considered to be rigidly magnetized; *i.e.*, we shall suppose that magnetic action exerted on any body produces no change in its magnetization. It is further to be observed that we are merely establishing a compendious representation of observed facts, and foreclosing nothing as to their physical theory or ultimate cause. Our method is therefore to some extent tentative, and its success is to be judged by the agreement of the results with experiment.

There are two main facts to be borne in mind:—(1) that a magnet is polarized, and (2) that the properties of its smallest parts are similar to those of the whole. Adopting the mathematical fiction of action at a distance, we may represent the action of such a body by a proper distribution of imaginary *positive* and *negative* attracting matter throughout its mass. This imaginary matter, following Sir W. Thomson, we shall call "magnetism," as we thus avoid suggesting other properties of matter than attraction, of which in the present case experience has given no evidence. We assume that *magnetism of any sign repels magnetism*

Positive and negative magnetism.

[1] Cambridge, 1750.

[2] *Philosophia Naturalis*, §§ 953, 954, 1762.

[3] *Pogg. Ann.*, xlv. p. 375, 1838.

of the same sign and attracts magnetism of the opposite sign. Magnetism is supposed to be so associated with the matter of the body that magnetic force exerted on the magnetism is ponderomotive force exerted on the matter. On the other hand, magnetic force is always supposed to be exerted by magnetism upon magnetism, and never directly by or upon matter. Into the nature of this association of magnetism with matter there is no pretence, indeed no need, to enter.

Elementary law of action at a distance.

The elementary law of action assumed is that *the attraction or repulsion (as the case may be) between two quantities m and m′ of magnetism supposed concentrated in two points at a distance r apart is* $\frac{mm'}{r^2}$, *and is in the line joining the two points.*

Unit of magnetism.

This supposes that the unit quantity of magnetism is so chosen that two units of positive magnetism at unit distance apart repel each other with unit force. This definition, which is fundamental in the electromagnetic system of units, gives for the dimensions of a quantity of magnetism $[L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}]$. If the electrostatic system be adopted the result would of course be different.

Strength of magnetic field. Resultant magnetic force.

An accurate meaning can now be given to the phrase "strength of a magnetic field," or its equivalent "resultant magnetic force at a point in the field;" it is defined to be *the force exerted upon a unit of positive magnetism supposed concentrated at the point.* The force exerted on a unit of negative magnetism would of course be equal in magnitude, but oppositely directed; and in general, if R denote the resultant magnetic force at the point, the magnetic force exerted on a quantity κ of magnetism concentrated there is κR.

Volume and surface density of magnetism.

We may, as in the corresponding theory of electricity, introduce the ideas of volume density (ρ) and surface density (σ),—so that ρdv and σdS denote the quantities of magnetism in an element of volume and on an element of surface respectively; ρ and σ may of course be positive or negative according to circumstances.

It will now be seen that, mathematically speaking, the theories of action at a distance for electricity and magnetism are identical, and every conclusion drawn will have, so far as the physical diversity of the two cases may allow, a double application.[1] In particular it will be found that the theory of magnetism, when properly interpreted, gives the theory of dielectrics polarized in the way imagined by Faraday.

Total magnetism zero.

The fact of magnetic polarity requires the conception of negative as well as positive magnetism; the fact that the properties of the smallest parts of a magnet are similar to those of the whole requires that in every element of the body there shall be both negative and positive magnetism. From the fact that in a *uniform field, i.e.,* one in which the resultant magnetic force has at every point the same magnitude and direction, the force of translation upon a magnet is nil, it follows that the algebraic sum of all the magnetism in any magnet must be zero; for, if R denote the strength of the field, by the theory of parallel forces the whole force on the magnet will be $\Sigma(\kappa R), = R\Sigma\kappa$; hence $\Sigma\kappa = 0$. In other words, *in every magnet there must be as much negative as positive magnetism*; and this conclusion also must be extended to the smallest parts of every magnet, so long as we do not go behind the mere facts of observation. The positive and negative magnetism cannot be coincident throughout, otherwise there would be no external magnetic action, but the separation is in the elements of the body. Thus, although there is no force of translation in a uniform field, there will in general be a couple. Consider the positive and negative magnetism separately, and let κ denote any element of the former and κ' any element of the latter. Let N be the centre of mass of the positive, S the centre of mass of the negative magnetism; so that, if the magnet be referred to a set of rectangular axes, the coordinates of N and S are

$$\left.\begin{array}{c} \frac{\Sigma\kappa x}{\Sigma\kappa}, \quad \frac{\Sigma\kappa y}{\Sigma\kappa}, \quad \frac{\Sigma\kappa z}{\Sigma\kappa} \\ \text{and} \\ \frac{\Sigma\kappa' x'}{\Sigma\kappa'}, \quad \frac{\Sigma\kappa' y'}{\Sigma\kappa'}, \quad \frac{\Sigma\kappa' z'}{\Sigma\kappa'} \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad (1).$$

Magnetic moment.

Let the distance NS $= l$, and let $K = l\Sigma\kappa, = -l\Sigma\kappa'$; this quantity K is called the "magnetic moment." By the theory of parallel forces, if we suspend the magnet in a uniform field of strength R, the action upon it reduces to two forces $R\Sigma\kappa$ and $-R\Sigma\kappa$, each parallel to the direction of the field, acting respectively at N and S, in other words to a couple whose moment is $R\Sigma\kappa l \sin\chi$ or $KR\sin\chi$, where χ is the angle between $\overrightarrow{SN}$ and the direction of the field.

Magnetic couple in uniform field.

Hence, if the magnet be perfectly free to follow the magnetic action of the field, it will set so that the line $\overrightarrow{SN}$ or the line $\overrightarrow{NS}$ is parallel to the direction of the field, the equilibrium being stable in the former case, but unstable in the latter. The line NS is therefore parallel to what we have already defined on experimental grounds as the axial direction in the magnet. N, S, and NS are sometimes called *par excellence* the poles and the axis of the magnet; we have adopted the looser definition given above because it is more convenient and nearer the popular usage.

Theory of dipping needle.

The above results may be applied to some cases very important in practice. Let the magnet whose centres of positive and negative magnetism are N and S be suspended by the middle point of NS, which, for simplicity, may be assumed to be also its centre of gravity. Let OX (fig. 20) be a horizontal line drawn northwards, OZ

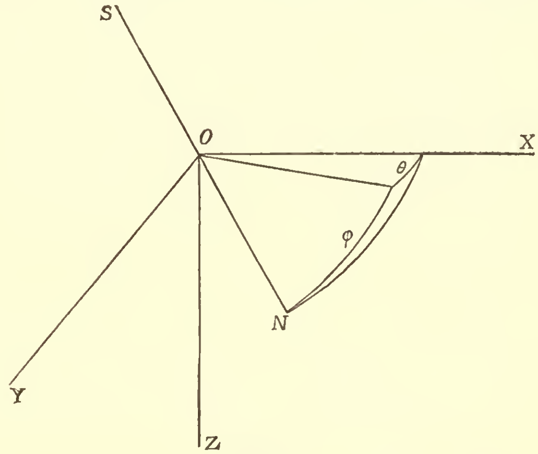

Fig. 20.

a vertical drawn downwards, both in the magnetic meridian. Let the vertical plane through NS make an angle θ with the magnetic meridian, and let ON make an angle ϕ with the horizon. If R be the strength of the earth's magnetic field, and ι the angle of dip, then the horizontal and vertical components of the earth's force are $H = R\cos\iota$ and $Z = R\sin\iota$.

First, suppose the angle ϕ fixed, and the magnet free to rotate about OZ only; then the couple tending to diminish the angle θ is

$$2 \cdot \Sigma\kappa \cdot R\cos\iota\frac{l}{2}\cos\phi\sin\theta, \text{ or } KR\cos\iota\cos\phi\sin\theta.$$

In other words the directive couple varies as the sine of the angle of deviation from the magnetic meridian. This conclusion was verified experimentally by Lambert, and also by Coulomb[2] by means of his torsion balance. It will be seen that, *cæteris paribus*, the directive couple is greatest when the magnetic axis is horizontal.

[1] To prevent needless repetition, we shall adopt henceforth, without further explanation, the definitions, terminology, and results given in the article ELECTRICITY, vol. viii. p. 24 *sq.*

[2] *Mém. de l'Acad.*, 1785.

Next suppose the angle θ fixed, and the magnet free to rotate about a horizontal axis inclined at an angle $90^\circ - \theta$ to OX. The couple tending to diminish the angle ϕ is $\mathrm{KR}(\cos\iota\cos\theta\sin\phi - \sin\iota\cos\phi)$. The position of equilibrium is given by the equation $\tan\phi = \sec\theta\tan\iota$.

The angle at which the axis is depressed below the horizon is therefore least when $\theta = 0$, and greatest when $\theta = 90^\circ$, its value being ι in the former case, and 90° in the latter, as stated above, p. 221.

In general, if λ', μ', ν' and λ, μ, ν be the direction cosines of the direction of the field and of the axis of the magnet respectively, then, resolving the forces acting at N and S, we see at once that the three components of the magnetic couple are

$$\mathrm{KR}(\nu'\mu - \mu'\nu),\ \mathrm{KR}(\lambda'\nu - \nu'\lambda),\ \mathrm{KR}(\mu'\lambda - \lambda'\mu) \quad . \quad . \quad . \quad (2).$$

Magnetic moment resolved as a vector.

These are clearly the same as the components of the couple on a system of three magnets whose axes are parallel to OX, OY, OZ, and whose magnetic moments are $\mathrm{K}\lambda$, $\mathrm{K}\mu$, $\mathrm{K}\nu$. Hence, so far as the action of a uniform field is concerned, we may resolve the magnetic moment like a vector, and replace a given magnet by others the resultant of whose moments is the moment of the given magnet.

It appears therefore that in a uniform field every magnet behaves as if it were made up of a certain quantity of positive magnetism and an equal quantity of negative magnetism placed at such a distance apart on a line parallel to the magnetic axis that the product of the quantity of magnetism into that distance has a value equal to the magnetic moment of the magnet. It is very important to observe that the magnetic moment alone appears in the above formulæ for the magnetic action. We cannot therefore separately determine from observations in a uniform field either the quantity of positive or negative magnetism in a magnet or the distance between the magnetic centres of mass.

Finite magnet replaced by an infinite number of infinitely small magnets.

Let M be any magnet, and P a point whose distance from any point of M is infinitely great compared with the linear dimensions of M. Then, since all the lines drawn from P to different points of M are sensibly parallel and equal in length, we may suppose the positive and negative magnetism of M to be collected at their mass centres, *i.e.*, M to be replaced by an ideal magnet. It is also obvious that, throughout a region around P whose linear dimensions are of the same order as those of M, the field due to M may be regarded as uniform. Hence we conclude that in calculating the mutual action of two magnets M and M′ we may replace each of them by an ideal magnet, provided the distance between them be infinitely great compared with the linear dimensions of either. This condition may be satisfied either by making the distance between the magnets very great if their dimensions be finite, or by making their dimensions infinitely small if the distance between them be finite. The second alternative suggests at once a method for representing the magnetic action of magnetized bodies at finite distances. We may divide up the body into portions whose linear dimensions are infinitely small compared with their distance from any point at which their action is to be considered; each of these portions is itself a magnet, and may be replaced by an ideal magnet having the same axis and moment. The whole magnetic action is obtained by integrating the action of all the ideal magnets of which the body is thus supposed to be composed.

Intensity of magnetization.

Let λ, μ, ν be the direction cosines of the magnetic axis of any element dv of a magnet, and I such that $\mathrm{I}dv$ is the magnetic moment of the element, and let $\mathrm{I}\lambda = \mathrm{A}$, $\mathrm{I}\mu = \mathrm{B}$, $\mathrm{I}\nu = \mathrm{C}$; then I is called the "intensity of magnetization" at the point where the element is taken. I may be regarded as a vector which specifies the magnetization of the body; in general it varies continuously from point to point; if it has the same value and direction at every point, the body is said to be uniformly magnetized. A line drawn so that the direction of I at every point of it is tangential to it is called a "line of magnetization." It is clear from what has already been shown that we may if we choose replace the element dv by three ideal magnets whose axes are parallel to the coordinate axes, and whose moments are $\mathrm{A}dv$, $\mathrm{B}dv$, $\mathrm{C}dv$ respectively.

Line of magnetization.

Resultant magnetic moment and axis.

If then K be the magnetic moment of the whole magnet, $\delta\mathrm{K}$ the moment of any element δv, and p, q, r the direction cosines of the axis of the whole magnet, we have $\mathrm{K} = l\Sigma\kappa, = -l\Sigma\kappa'$; and, remembering that $\kappa' = -\kappa$ for every element,

$$p = \left(\frac{\Sigma\kappa x}{\Sigma\kappa} - \frac{\Sigma\kappa' x'}{\Sigma\kappa'}\right)\frac{1}{l} = \frac{\Sigma\left(l\kappa\,.\,\frac{x - x'}{l}\right)}{l\Sigma\kappa} = \frac{\Sigma(\delta\mathrm{K}\lambda)}{\mathrm{K}} = \frac{\Sigma\mathrm{I}\lambda\delta v}{\mathrm{K}} = \frac{\Sigma\mathrm{A}\delta v}{\mathrm{K}}.$$

We may therefore write, replacing summation by integration,

$$\mathrm{K}p = \iiint \mathrm{A}dv,\quad \mathrm{K}q = \iiint \mathrm{B}dv \quad \mathrm{K}q = \iiint \mathrm{C}dv \quad . \quad . \quad (3).$$

Potential of infinitely small magnet.

Let SN be an ideal magnet of infinitely small length l, let m be its magnetic moment, and $m = \kappa l$. Let Q be its middle point, and the angle $\mathrm{PQN} = \theta$, N being the positive or north-seeking pole; and let $\mathrm{QP} = \mathrm{D}$. Then the potential at P due to this magnet is

$$\kappa\left\{\mathrm{D}^2 - \mathrm{D}l\cos\theta + \tfrac{1}{4}l^2\right\}^{-\frac{1}{2}} - \kappa\left\{\mathrm{D}^2 + \mathrm{D}l\cos\theta + \tfrac{1}{4}l^2\right\}^{-\frac{1}{2}}.$$

Expanding and neglecting powers of $\frac{l}{\mathrm{D}}$ above the first, we get for the potential

$$\frac{m\cos\theta}{\mathrm{D}^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4).$$

Potential of finite magnet.

Hence the potential at P (ξ, η, ζ) of an infinitely small magnet $\mathrm{A}dv$ at (x, y, z), having its axis parallel to the axis of x, is $\mathrm{A}(\xi - x)/\mathrm{D}^3$, and similarly for the other two. We therefore obtain for the potential of the whole magnet

$$\left.\begin{aligned} \mathrm{V} &= \iiint\left\{\mathrm{A}(\xi - x) + \mathrm{B}(\eta - y) + \mathrm{C}(\zeta - z)\right\}\frac{1}{\mathrm{D}^3}dv \\ &= \iiint\left\{\mathrm{A}\frac{d\left(\frac{1}{\mathrm{D}}\right)}{dx} + \mathrm{B}\frac{d\left(\frac{1}{\mathrm{D}}\right)}{dy} + \mathrm{C}\frac{d\left(\frac{1}{\mathrm{D}}\right)}{dz}\right\}dv \\ &= \iiint \mathrm{I}\left\{\lambda\frac{d}{dx} + \mu\frac{d}{dy} + \nu\frac{d}{dz}\right\}\frac{1}{\mathrm{D}}dv \end{aligned}\right\} \quad . \quad (5).$$

Taking the second of these expressions and integrating by parts in the usual way, we get

$$\left.\begin{aligned} \mathrm{V} &= \iint\frac{\sigma}{\mathrm{D}}d\mathrm{S} + \iiint\frac{\rho}{\mathrm{D}}dv\,; \\ \text{where}\quad \sigma &= l\mathrm{A} + m\mathrm{B} + n\mathrm{C} = \mathrm{I}\cos\theta \\ \rho &= -\left(\frac{d\mathrm{A}}{dx} + \frac{d\mathrm{B}}{dy} + \frac{d\mathrm{C}}{dz}\right) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (6),$$

l, m, n being the direction cosines of the outward normal to any element $d\mathrm{S}$ of the surface of the magnet, and θ the angle between the normal and the direction of magnetization at $d\mathrm{S}$.

Poisson's distribution.

Hence the action of any magnet may be represented by means of a certain volume distribution (ρ) and a certain surface distribution (σ) of free magnetism. This important proposition is due to Poisson.[1]

The fact, in itself obvious, that the sum of all the magnetism of Poisson's distribution must be zero, gives the theorem

$$\left.\begin{aligned} \iiint\left(\frac{d\mathrm{A}}{dx} + \frac{d\mathrm{B}}{dy} + \frac{d\mathrm{C}}{dz}\right)dv &= \iint(l\mathrm{A} + m\mathrm{B} + n\mathrm{C})d\mathrm{S} \\ &= \iint \mathrm{I}\cos\theta d\mathrm{S} \end{aligned}\right\} \quad . \quad (7),$$

which admits of course of direct analytical proof.

Gaussian distribution.

The magnet may also be replaced, so far as its external action is concerned, by a distribution wholly on its surface, as was shown by Gauss.[2] This will be seen at once if we replace the positive and negative magnetism throughout the body by positive and negative electricity, and suppose the surface of the magnet covered with a conducting layer in connexion with the earth. The surface will thus become charged with a distribution of positive and negative electricity whose total sum is zero, such that the potential of the surface is zero, and hence the potential at every external point zero. The potential of this surface layer

[1] *Mém. de l'Institut*, tom. v., 1821.

[2] *Intensitas Vis*, § 2 (1832), and *Allgemeine Lehrsätze*, § 36 (1839).

at every point external to the body is therefore equal and opposite to that of the internal electricity. If, therefore, we change the sign of the surface density at every point, we obtain a surface distribution whose potential at every external point is the same as that of the body. There is of course only one such distribution: we may call it Gauss's distribution.

Case of solenoidal magnetization.

Poisson's distribution will coincide with that of Gauss provided the magnetization be such that

$$\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8);$$

when this condition is satisfied at every point of the body, A is said to be "solenoidally" magnetized; a particular case is that of uniform magnetization.

Resultant force inside a magnetized body.

So long as the point considered is external to the magnet there is no difficulty in attaching a definite meaning to the resultant magnetic force ($\mathfrak{H}$) at a point; its components are given by

$$\alpha=-\frac{dV}{dx}, \quad \beta=-\frac{dV}{dy}, \quad \gamma=-\frac{dV}{dz} \quad . \quad . \quad . \quad (9);$$

and the values obtained will be the same whether V be calculated by means of Poisson's or of Gauss's distribution. Inside the body the result is otherwise, for reasons that are not difficult to understand, when we examine the nature of our fundamental assumptions. It is therefore necessary to be careful to define what we mean by resultant magnetic force in the interior of a magnet. It is defined by the above equation (9) on the understanding that V is calculated from Poisson's distribution. We can show that $\mathfrak{H}$ thus defined is the resultant force in an infinitely small cylindrical cavity within the magnet, whose axis is parallel to the line of magnetization, and whose radius a is infinitely small compared with its axis $2b$.

The removal of the matter filling such a cavity will affect Poisson's volume distribution to an infinitely small extent; the alteration of the force if any, will therefore arise simply from the surface distribution which we must place on the walls of the cavity in order to make up the complete representation of the action of the magnet in the cavity. This distribution reduces to two circular disks of radius a at the two ends, the densities of the magnetism on which are $-I$ and $+I$ respectively. The action due to these is a force $4\pi I(1-b/\sqrt{a^2+b^2})$ in the direction of magnetization. If a be infinitely small compared with b, this force becomes zero, which proves our proposition.

Magnetic induction.

If, on the other hand, the cavity in the magnet be disk-shaped—say a narrow crevasse perpendicular to the line of magnetization—then the force due to the distribution on its walls becomes $4\pi I$, and the resultant force in the cavity is no longer $\mathfrak{H}$, but a force $\mathfrak{B}$, whose components are

$$a=\alpha+4\pi A, \quad b=\beta+4\pi B, \quad c=\gamma+4\pi C \quad . \quad . \quad (10).$$

$\mathfrak{B}$ is called the "magnetic induction" at the point (x, y, z).

From the definition of $\mathfrak{H}$ it follows that outside the magnet

$$\frac{d\alpha}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11).$$

Inside

$$\left.\begin{aligned}\frac{d\alpha}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}&=4\pi\rho\\ &=-4\pi\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)\end{aligned}\right\} \quad . \quad . \quad (12).$$

Continuity and discontinuity of $\mathfrak{H}$ and $\mathfrak{B}$.

At the surface of a magnetized body the tangential component of $\mathfrak{H}$ is continuous, but the normal component increases abruptly by $4\pi I\cos\theta$ in passing from the inside to the outside of the surface.

Outside magnetized matter the magnetic force and the magnetic induction are coincident. Inside we have

$$\frac{da}{dx}+\frac{db}{dy}+\frac{dc}{dz}=\frac{d\alpha}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}+4\pi\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)=0. \quad (13).$$

Hence the magnetic induction satisfies the solenoidal condition both inside and outside magnetized matter. It has normal continuity, and, in general, tangential discontinuity, at the surface of a magnetized body.

For if ν, τ and n, t be the normal and tangential components of $\mathfrak{H}$ and $\mathfrak{B}$ just inside, and ν', τ' and n', t' the corresponding components just outside the surface near any point, we have $n=\nu+4\pi I\cos\theta$, and $n'=\nu'$; but $\nu'=\nu+4\pi I\cos\theta$, therefore $n=n'$. On the other hand $\tau'=t'$, whereas τ is the resultant of t and $4\pi I\sin\theta$, which is parallel to the surface, but otherwise may have any direction according to circumstances; hence, since $t'=t$, in general τ' is not equal to τ.

In fact there will be tangential discontinuity of the magnetic induction unless the line of magnetization be perpendicular to the surface of the magnet; in this case there is complete continuity of the magnetic induction. When the magnetization at the surface is tangential, there is, on the other hand, complete continuity of the magnetic force.

Surface integral of magnetic induction is zero.

It follows from the above that the surface integral of the magnetic induction taken over any closed surface S vanishes.

First, let the surface be wholly within or wholly without continuously magnetized matter. We have, integrating all over S and all over the space enclosed by S, the analytical theorem

$$\iint(la+mb+nc)dS=\iiint\left(\frac{da}{dx}+\frac{db}{dy}+\frac{dc}{dz}\right)dv \quad . \quad . \quad (14);$$

hence the result follows, for every element of the right-hand integral vanishes. Next, suppose S to be partly within and partly without a magnetized body. Divide it into two parts by a double partition one of whose walls runs outside the surface of the body and infinitely near it, the other inside and infinitely near it; then, on account of the normal continuity of $\mathfrak{B}$, the surface integral will be the same in absolute value over each of these walls. Hence the integral over the whole of S differs infinitely little from the sum of the integrals over the two surfaces into which it is broken up by the double partition, each of which vanishes by the former case. Hence the theorem holds in this case also.

We may therefore apply to lines and tubes of magnetic induction without restriction all the theorems proved for lines and tubes of electric force in space free from electrified bodies. We may speak of the number of lines of magnetic induction instead of the surface integral if we choose. And we have this important theorem:—

The number of lines of magnetic induction that pass through an unclosed surface depends merely on its boundary.

Vector potential.

There must therefore be a vector $\mathfrak{A}$, whose line integral round the boundary is equal to the surface integral of $\mathfrak{B}$ over the surface.

The components F, G, H of $\mathfrak{A}$ are connected with those of $\mathfrak{B}$ by the equations

$$a=\frac{dH}{dy}-\frac{dG}{dz}, \quad b=\frac{dF}{dz}-\frac{dH}{dx}, \quad c=\frac{dG}{dx}-\frac{dF}{dy} \quad . \quad . \quad (15),$$

as has been shown in the article ELECTRICITY, vol. viii. p. 69.

Mutual potential energy of two magnets.

Mutual potential energy and mutual action of two magnetic systems.—The potential energy of a small magnet is $\kappa(V_2-V_1)$, where V_1 and V_2 are the values of V at its negative and positive poles. If the magnet be infinitely small, of length ds say, the direction cosines of ds being λ, μ, ν, this may be written $\kappa ds dV/ds$, *i.e.*, $m dV/ds$, or, if we are considering a magnetized element of volume dv,

$$I\left(\lambda\frac{dV}{dx}+\mu\frac{dV}{dy}+\nu\frac{dV}{dz}\right)dv \quad . \quad . \quad . \quad . \quad . \quad (16).$$

Hence the potential energy of the whole magnetic system in a field whose potential is given by V is

$$\left.\begin{aligned}W&=\iiint\left(A\frac{dV}{dx}+B\frac{dV}{dy}+C\frac{dV}{dz}\right)dv\\ &=-\iiint(A\alpha+B\beta+C\gamma)dv\end{aligned}\right\} \quad . \quad . \quad . \quad (17),$$

the integration being extended all over the magnetized masses supposed to be acted upon. Integrating by parts, we get at once

$$W=\iint V\sigma dS+\iiint V\rho dv \quad . \quad . \quad . \quad . \quad . \quad (18),$$

σ and ρ being the surface and volume densities of Poisson's distribution, a result that might have been expected. W may also be expressed as a sextuple integral; for, if I', λ', μ', ν', x', y', z' refer to the acting system, then

$$V=\iiint I'\left(\lambda'\frac{d}{dx'}+\mu'\frac{d}{dy'}+\nu'\frac{d}{dz'}\right)\frac{1}{D}dx'dy'dz'.$$

Whence

$$W = \iiiiiint dx\,dy\,dz\,dx'\,dy'\,dz'\,\Pi'\left(\lambda\frac{d}{dx}+\mu\frac{d}{dy}+\nu\frac{d}{dz}\right) \times\left(\lambda'\frac{d}{dx'}+\mu'\frac{d}{dy'}+\nu'\frac{d}{dz'}\right)\frac{1}{D} \quad (19).$$

A remarkable expression for W may be obtained by supposing the integration in (17) extended throughout the whole of space, on the understanding that A, B, C are zero where there is no magnetized matter, and then integrating by parts. We get, since the surface integral at infinity may be shown to vanish,

$$\begin{aligned} W &= \iiint_{-\infty}^{\infty}\left(A\frac{dV}{dx}+B\frac{dV}{dy}+C\frac{dV}{dz}\right)dv \\ &= -\iiint_{-\infty}^{\infty}V\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)dv \end{aligned} \quad . \quad . \quad (20),$$

where it must be understood that A, B, C vary continuously, however rapidly. In point of fact, where, as at the surface of a magnetized body, there is discontinuity, a finite portion of the integral will arise from an infinitely thin stratum near the surface. The proper representation of this part will be a surface integral, as may be seen by referring to (18), from which we might have started.

If now V′ be the potential of the magnet acted upon, then

$$\frac{d^2V'}{dx^2}+\frac{d^2V'}{dy^2}+\frac{d^2V'}{dz^2}=4\pi\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right);$$

whence

$$\begin{aligned} W &= -\frac{1}{4\pi}\iiint_{-\infty}^{\infty}V\left(\frac{d^2V'}{dx^2}+\frac{d^2V'}{dy^2}+\frac{d^2V'}{dz^2}\right)dv \\ &= +\frac{1}{4\pi}\iiint_{-\infty}^{\infty}\left(\frac{dV}{dx}\frac{dV'}{dx}+\frac{dV}{dy}\frac{dV'}{dy}+\frac{dV}{dz}\frac{dV'}{dz}\right)dv \\ &= +\frac{1}{4\pi}\iiint_{-\infty}^{\infty}RR'\cos\theta\,dv \text{ [1]} \end{aligned} \quad (21),$$

where R and R′ are the resultant forces at any point of space due to the acting and acted-upon systems respectively, and θ the angle between their directions.

Force and couple on a magnet in given field.

In practice W is expressed as a function of the variables (equal in number to the degrees of freedom) that determine the relative position of the two systems; differentiation with respect to any one of these then gives the generalized force component tending to decrease that variable.

We may also calculate the forces directly. For, the components of force on the element dv, being the differences of the forces acting on the two poles of the element, are

$$\left(A\frac{d\alpha}{dx}+B\frac{d\alpha}{dy}+C\frac{d\alpha}{dz}\right)dv, \text{ \&c.};$$

and the components of couple, in calculating which the field may be supposed uniform, are (see above, p. 228)

$$(\gamma B - \beta C)dv, \text{ \&c.}$$

Hence, integrating, we get, with the chosen origin, for the components of the whole force and couple,

$$\begin{aligned} \mathfrak{X} &= \iiint\left(A\frac{d\alpha}{dx}+B\frac{d\alpha}{dy}+C\frac{d\alpha}{dz}\right)dv, \\ &\text{and similarly for } \mathfrak{Y} \text{ and } \mathfrak{Z}. \\ \mathfrak{L} &= \iiint\left\{\gamma B-\beta C+y\left(A\frac{d\gamma}{dx}+B\frac{d\gamma}{dy}+C\frac{d\gamma}{dz}\right)\right. \\ &\quad \left.-z\left(A\frac{d\beta}{dx}+B\frac{d\beta}{dy}+C\frac{d\beta}{dz}\right)\right\}dv, \\ &\text{and similarly for } \mathfrak{M} \text{ and } \mathfrak{N}. \end{aligned} \quad . \quad (22).$$

In the important case of a uniform field whose components are α, β, γ, we have

$$W = -K(l\alpha+m\beta+n\gamma) \quad . \quad . \quad . \quad . \quad . \quad (23),$$

K being the moment of the magnet, and l, m, n the direction cosines of its axis. From this formula the results given above (p. 227) can be deduced with great ease.

Examples.—Some examples of the application of the foregoing theory are here given, partly on account of their intrinsic value as types enabling us to conceive the different varieties of magnetic action, partly for the sake of the light they throw on the theory itself. The reader who desires more such should consult Maxwell's *Electricity and Magnetism*, or Mascart and Joubert, *Leçons sur l'Électricité et le Magnétisme.*

Solenoidal magnetization.

Solenoidal Magnets have already been defined as such that the vector I satisfies the solenoidal condition

$$\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}=0.$$

The lines of magnetization, therefore, have all the properties of lines of magnetic induction or electric force. In particular, if we consider a portion of the magnet enclosed by a tube of the lines of magnetization, the product of the intensity of magnetization by the section at each point is the same. Such a portion of magnetized matter taken by itself is called a "magnetic solenoid," and the product mentioned is called its "strength." It is clear (from the general definition, or it may be proved directly from the secondary property just mentioned) that the action of the solenoid may be represented by the distribution of a certain quantity ωI of positive magnetism on the one end and an equal quantity of negative magnetism on the other, I being the intensity of magnetization, ω the normal section at the end. The action therefore depends merely on the strength of the solenoid and on the position of its ends. The shape

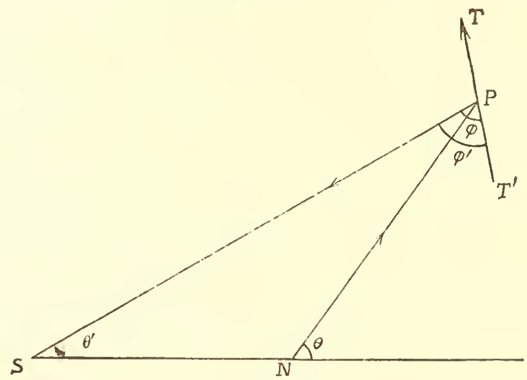

Fig. 21.

of the intervening portion is immaterial. If we suppose it straight, and if the section be infinitely small so that the magnetism at the ends may be regarded as condensed at two points, we have an ideal magnet of finite length. The equipotential lines of such a magnet in any plane through its axis are of course given by the equation

Equipotential lines and lines of force.

$$\frac{1}{r}-\frac{1}{r'}=\text{const.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24),$$

where r and r' are the distances of any point P on the line from the poles.

Ideal bar magnet.

The equation to the lines of force is easily obtained;[2] for, if NP and SP (fig. 21) make angles θ and θ' with the axis of the magnet, and ϕ and ϕ' with the line of force, we must have

$$\sin\phi/r^2 - \sin\phi'/r'^2 = 0;$$

hence, since

$$\sin\phi = r\,d\theta/ds, \quad \sin\phi' = r'd\theta'/ds,$$

we get

$$d\theta/r - d\theta'/r' = 0; \quad i.e., \sin\theta\,d\theta - \sin\theta'd\theta' = 0;$$

which gives for the equation to a line of force

$$\cos\theta - \cos\theta' = \text{const.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25).$$

Two like poles.

We may imagine a magnet of this kind so long that the action of one of its poles may be altogether neglected at points which are at a finite distance from the other. We thus *effectively* realize what never occurs in nature, viz., a magnet with one pole only. If we place the like poles of two such magnets near each other, we get a field the equipotential lines and lines of force in any axial plane of which are given by the equations

$$\frac{1}{r}+\frac{1}{r'}=\text{const.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26).$$

$$\cos\theta + \cos\theta' = \text{const.} \quad . \quad . \quad . \quad . \quad . \quad . \quad (27).$$

The lines of force given by equations (25) and (27) may be traced in a diagram by means of the following simple and elegant construction[3] Draw two circles A and B, having equal radii and N and S respectively for centres; produce the line NS both ways, and, starting from the centre, divide it into any number of equal parts; through these draw perpendiculars to meet the circles A and B;

[1] See Thomson, *Reprint of Papers on Electricity and Magnetism*, p. 433.

[2] The first mathematical investigations of the equation to the lines of force of an ideal magnet appear to have been made by Playfair at the request of Robison, and by Leslie, *Geom. Analysis*, 1821. They had previously been very carefully considered from an experimental point of view by Lambert, *Mém. de l'Acad. de Berlin*, 1766.

[3] Roget, *Jour. Roy. Inst.*, 1831.

from N draw a series of lines to the points of division on B, and from S a similar series to the points of division on A. These lines will form a network of lozenges the loci of the vertices of which will be lines of force, corresponding to (25) or (27) according as we

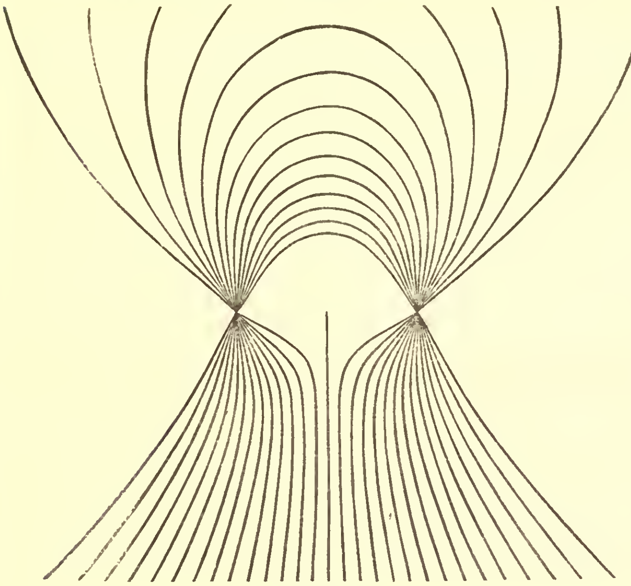

Fig. 22.

pass from point to point along one set of lozenge diagonals or along the other. Fig. 22 will give the reader an idea of the general appearance of the two sets of lines. He may compare the ideal with the actual cases by referring to figs. 4 and 5, p. 222.

Infinitely small magnet.

In the case of an infinitely small magnet, the equipotential lines are of course given by the polar equation $r^2 = c^2 \cos\theta$, c being a variable parameter. It is easily shown that the lines of force, which are necessarily orthogonal to these, have for their equation $r = c \sin^2\theta$.[1] If ϕ be the angle between r and the tangent of the line of force, we have $\tan\phi = rd\theta/dr = \frac{1}{2}\tan\theta$; hence the following construction for the direction of the line of force at P due to a small magnet at O:—let K be the point of trisection of OP nearest O, and let KT, perpendicular to OP, cut the axis of the magnet in T; then TP is the tangent to the line of force at P. This construction in a slightly different form was given by Hansteen[2] and by Gauss[3]; the latter adds that the resultant force at P is given by $M.PT/OT.OP^3$ where M is the magnetic moment of the magnet, a proposition which the reader will easily verify. These propositions are of considerable use in rough magnetic calculations. As this is an important case we give a diagram of the equipotential lines and lines of force in fig. 23.

We may, if we choose, consider a filament of matter magnetized longitudinally at every point, but so that the strength ωI ($=J$, say) is variable. Such a filament is called a complex solenoid. It may clearly be supposed made up of a bundle of simple solenoids whose ends are not all coincident with the ends of the filament. If ds be an element of such a filament, the potential is given by

$$V = \int dsJ \frac{d\left(\frac{1}{D}\right)}{ds} = \frac{J_1}{D_1} - \frac{J_2}{D_2} - \int ds \frac{1}{D}\frac{dJ}{ds} \quad . \quad . \quad . \quad (28).$$

That is, its action may be represented by two particles of magnetism J_1 and J_2 at its two ends, and by a continuous distribution of free magnetism along its length whose density is $-dJ/ds$. This is of course merely a particular case of Poisson's distribution.

When a body is solenoidally magnetized, the magnetic force 𝔜 both external and internal depends solely on the surface distribution, *i.e.*, merely on the ends of the solenoids of which the body is composed. We may therefore suppose the two ends of any solenoid joined by a solenoid of equal strength lying in the surface of the body. Proceeding thus, we may in an infinite number of ways construct a surface layer of *tangentially* magnetized matter which will represent the magnetic action of a solenoidally magnetized body. Thomson has shown by means of a highly interesting piece of analysis how to find the components of this tangential magnetization. See *Reprint of Papers on Electricity and Magnetism*, p. 401.

The magnetic theorems just stated will suggest at once to the mind of the reader acquainted with the analysis employed in hydro kinetical problems the close analogy that subsists between the two methods. In fact, by proper arrangement, every problem in the one subject can be converted into a problem in the other. For details we refer the reader to Thomson, who was, so far as we know, the first to work out this matter fully; in the present connexion he should consult more particularly §§ 573 *sq.* of the *Reprint*.

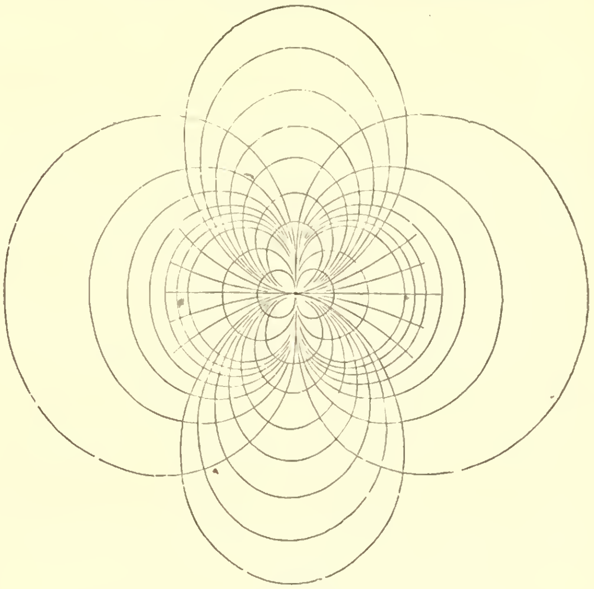

Fig. 23.

Potential of uniformly magnetized bodies.

Uniformly Magnetized Bodies constitute in practice the most important case of solenoidal magnets. In the first place it is obvious that the whole magnetic moment of such a body is simply its volume multiplied by the intensity of magnetization, and that the axis of the whole is parallel to the axis of each of its infinitely small parts. The method usually applied to calculate the potential in this case may be presented in two ways. The potential is calculated according to Poisson's method in this case merely from a surface distribution of varying density $I\cos\theta$. We may replace this by a layer of uniform density ρ and varying normal thickness. Let the thickness at any point measured parallel to the magnetic axis be t; then the normal thickness is $t\cos\theta$; hence $\rho t\cos\theta = I\cos\theta$, and $\rho t = I$; *i.e.*, t is constant. We may therefore suppose the magnet replaced by itself (fig. 24) with a uniform volume distribution ρ of positive magnetism, and itself displaced through a distance t in a direction opposite to that of magnetization with a uniform volume distribution $-\rho$; or, which comes to the same thing, the potential of the magnet at P is $\rho(U - U')$, where U is the potential at P of a uniform volume distribution of density $+1$ throughout the magnet, and U′ the potential of the same at a point P′ displaced through a distance t in the direction of magnetization.

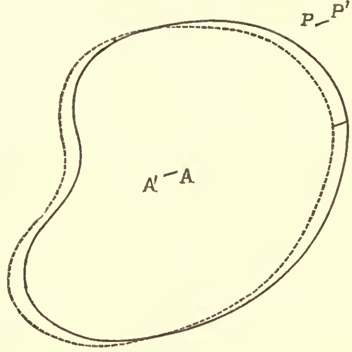

Fig. 24.

If l, m, n be the direction cosines of the magnetic axis, this gives at once

$$\left.\begin{aligned} V &= -\rho\left(\frac{dU}{dx}tl + \frac{dU}{dy}tm + \frac{dU}{dz}tn\right) \\ &= -I\left(l\frac{dU}{dx} + m\frac{dU}{dy} + n\frac{dU}{dz}\right) \\ &= AX + BY + CZ \end{aligned}\right\} \quad . \quad . \quad . \quad (29);$$

where X, Y, Z are the components of the resultant force due to volume distribution $\rho = +1$ throughout the body, and A, B, C the components of the magnetization.

The same result may also be arrived at thus. The part of the potential due to the element dv is $Idv\cos\theta/r^2$, but this is the component parallel to the direction of I of the resultant force at P of a volume distribution whose density in dv is I; hence, since the

[1] Hansteen, *Magnetismus der Erde*, p. 208 (1819).
[2] *Magnetismus der Erde*, p. 209.
[3] *Resultate d. Mag. Vereins*, 1837 and 1840.

direction of I is everywhere the same, the whole potential is the component parallel to the magnetic axis of the body of the resultant force at P of a volume distribution $\rho = 1$ throughout its whole extent. This gives at once the expression of (29) for V.

Sphere.

In the case of a uniformly magnetized sphere of radius a, the axis being parallel to the axis of x, and the centre at the origin, we get, if r be the distance of P from the origin, for external points,

$$V = \tfrac{4}{3}\pi I a^3 x / r^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30);$$

in other words, the external action is that of a magnet of infinitely small dimensions, having the same moment and axis, placed at the centre.

For internal points

$$V = \tfrac{4}{3}\pi I x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31);$$

whence it appears that the magnetic force inside the sphere is constant in magnitude and in direction, being opposite to the uniform magnetization, and equal to $-\tfrac{4}{3}\pi I$.

Ellipsoid.

The potential of a uniformly magnetized ellipsoid may be similarly treated. Let the origin be at the centre, and the axes along the principal diameters of the ellipsoid, whose lengths are $2a$, $2b$, $2c$, and let l, m, n be the direction cosines of its magnetic axis. Consider first an external point. Then,[1] if

$$L = 2\pi abc \int_\alpha^\infty \frac{d\phi}{\sqrt{(a^2+\phi)^3(b^2+\phi)(c^2+\phi)}}, \quad M = \&c., \quad N = \&c. \quad (32),$$

where α is the positive root of

$$\frac{x^2}{a^2+\phi} + \frac{y^2}{b^2+\phi} + \frac{z^2}{c^2+\phi} = 1,$$

we have

$$X = Lx, \quad Y = My, \quad Z = Nz,$$

and

$$V = ALx + BMy + CNz \quad . \quad . \quad . \quad . \quad . \quad (33),$$

where it must be remembered that L, M, N are functions of x, y, z, inasmuch as α is so.

If (x, y, z) be an internal point, X, Y, Z are the components of the force due to a similar and similarly situated ellipsoid through (x, y, z). Let its axes be pa, pb, pc; we now have

$$X = Lx, \quad Y = My, \quad Z = Nz,$$

where

$$L = 2\pi papbpc \int_0^\infty \frac{d\phi}{\sqrt{(p^2a^2+\phi)^3(p^2b^2+\phi)(p^2c^2+\phi)}};$$

or, writing $\phi = p^2\psi$,

$$L = 2\pi abc \int_0^\infty \frac{d\psi}{\sqrt{(a^2+\psi)^3(b^2+\psi)(c^2+\psi)}}, \quad M = \&c., \quad N = \&c. \quad (34).$$

We thus obtain for V,

$$V = ALx + BMy + CNz, \quad . \quad . \quad . \quad . \quad . \quad . \quad (35),$$

where L, M, N are now constants, which remain the same so long as the ratios of the axes remain unaltered. The components of the force inside the ellipsoid are

$$\alpha = -AL, \quad \beta = -BM, \quad \gamma = -CN \quad . \quad . \quad . \quad (36).$$

The force is therefore uniform; but its direction does not coincide with that of the magnetization, unless the latter be parallel to one of the principal diameters, and then the force is opposite in direction to the magnetization. It will be observed that the force inside similar ellipsoids similarly magnetized to the same intensity is always the same.

For an oblate ellipsoid of revolution, in which $b = c = a/\sqrt{1-e^2}$,

$$L = 4\pi\left(\frac{1}{e^2} - \frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e\right), \quad M = N = 2\pi\left(\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e - \frac{1-e^2}{e^2}\right).$$

For a very flat oblate ellipsoid of revolution $L = 4\pi$, $M = N = \pi^2 a/c$. For a prolate or ovary ellipsoid of revolution, in which

$$a = b = c\sqrt{1-e^2},$$

$$L = M = 2\pi\left(\frac{1}{e^2} - \frac{1-e^2}{2e^3}\log\frac{1+e}{1-e}\right),$$

$$N = 4\pi\left(\frac{1}{e^2} - 1\right)\left(\frac{1}{2e}\log\frac{1+e}{1-e} - 1\right).$$

From the formulæ for an ellipsoid we could easily deduce those for an infinitely long elliptic or circular cylinder; we have merely to make one of the axes infinite. We find in this way, for instance, that the force inside a circular cylinder of infinite length magnetized transversely is $-2\pi I$.

The reader will find it interesting to examine the values of the magnetic induction in the foregoing cases, and to verify its normal continuity at the surface of the magnet.

Lamellar Magnets form another very important class. In them the components of magnetization are derivable by differentiation

Lamellar magnetization.

from a function $\phi(x, y, z)$, which is sometimes called the "potential of magnetization,"[2] so that

$$A = \frac{d\phi}{dx}, \quad B = \frac{d\phi}{dy}, \quad C = \frac{d\phi}{dz} \quad . \quad . \quad . \quad . \quad . \quad (37).$$

It is obvious at once that the family of surfaces $\phi(x, y, z) = \text{const.}$ cut the lines of magnetization at right angles; for, if dx, dy, dz be the projections of the element of any line on the surface, we have by differentiation

$$\frac{d\phi}{dx}dx + \frac{d\phi}{dy}dy + \frac{d\phi}{dz}dz = 0,$$

$$i.e., \quad A\,dx + B\,dy + C\,dz = 0,$$

which is the analytical expression of the property in question.

Magnetic shells.

We may therefore suppose a lamellar magnet divided up by these surfaces of magnetization into an infinite number of infinitely thin normally magnetized shells or lamellæ. It can be shown that the product of the intensity of magnetization by the thickness at each point of any such shell is the same; for, if $\phi(x, y, z) = c$ and $\phi(x, y, z) = c + \delta c$ be the equations to the two surfaces bounding the shell, $\delta\nu$ the normal distance between them at any point, we have

$$\frac{d\phi}{dx}\delta x + \frac{d\phi}{dy}\delta y + \frac{d\phi}{dz}\delta z = \delta c,$$

hence

$$\left(\frac{d\phi}{dx}\frac{dx}{d\nu} + \frac{d\phi}{dy}\frac{dy}{d\nu} + \frac{d\phi}{dz}\frac{dz}{d\nu}\right)\delta\nu = \delta c,$$

i.e., $I\delta\nu = \delta c = \text{constant}$ for the same shell, which was to be proved. This product is called the strength of the shell.

A shell, which is everywhere normally magnetized, but whose strength is not constant, is called a "complex shell"; a magnet made up of such shells is called a "complex lamellar magnet." The condition to be satisfied by A, B, C in this case is simply that the lines of magnetization must be orthogonal to a family of surfaces, *i.e.*, $A\,dx + B\,dy + C\,dz$ must be convertible into a perfect differential by multiplication by a factor; otherwise that

$$A\left(\frac{dB}{dz} - \frac{dC}{dy}\right) + B\left(\frac{dC}{dx} - \frac{dA}{dz}\right) + C\left(\frac{dA}{dy} - \frac{dB}{dx}\right) = 0.$$

The potential at P of a simple magnetic shell of strength i is given by the formula

$$V = \iint \frac{i\cos\theta\, dS}{D^2} = i\iint \frac{dS\cos\theta}{D^2} = i\omega \quad . \quad . \quad . \quad (38),$$

where ω is the solid angle subtended at the point P.[3] There is a convention here as to sign, viz., that side of the shell is positive towards which the lines of magnetization pass, and the solid angle subtended at points infinitely near that side is positive, while that subtended at points infinitely near the other side is negative. If we cause P to move from the positive side away to infinity, then back from infinity to the negative side, or to move anyhow from infinitely near the positive side to a point infinitely near the negative side without cutting through the shell, it will decrease continuously by $4\pi i$; if we pass *through* the shell from a point infinitely near on the negative side to a point infinitely near on the positive side, there will be a sudden increase of $4\pi i$; tangentially to the shell there is continuity. The potential of a closed shell is evidently zero for any external point, $\pm 4\pi i$ for an internal point according as the positive or negative side is innermost. It appears also that the potential of a simple magnetic shell depends merely on its strength and on its boundary, just as that of a magnetic solenoid depends merely on its strength and the position of its ends.

Potential of lamellar magnet.

A lamellar magnet will in general be made up partly of closed shells, and partly of shells whose boundaries lie on the surface; only the latter of course can influence the potential at external points. The general expression for the potential at any point $P(\xi, \eta, \zeta)$ is

$$\left.\begin{aligned} V &= \iiint\left(\frac{d\phi}{dx}\frac{d\left(\frac{1}{D}\right)}{dx} + \frac{d\phi}{dy}\frac{d\left(\frac{1}{D}\right)}{dy} + \frac{d\phi}{dz}\frac{d\left(\frac{1}{D}\right)}{dz}\right)dv \\ &= \iint\phi\left(l\frac{d\left(\frac{1}{D}\right)}{dx} + m\frac{d\left(\frac{1}{D}\right)}{dy} + n\frac{d\left(\frac{1}{D}\right)}{dz}\right)dS - \iiint\phi\nabla^2\left(\frac{1}{D}\right)dv \\ &= \iint\frac{\phi\cos\theta}{D^2}dS + 4\pi\phi' \end{aligned}\right\} (39),$$

where θ is the angle between D and the outward normal to dS, and ϕ' the value of ϕ at the point ξ, η, ζ (zero of course if ξ, η, ζ be outside the magnet). The value of V thus found is not discontinuous at the surface as might be supposed, for both the surface integral and

[1] See Thomson and Tait, *Natural Philosophy*, vol. i. § 522.

[2] To be distinguished of course from the magnetic potential.

[3] Gauss, *Allgemeine Theorie des Erdmagnetismus*, § 38.

$4\pi\phi'$ have discontinuities there, and they are equal in amount and of opposite sign.

For an external point the potential is

$$\iint \frac{\phi\cos\theta}{D^2}dS\,.$$

The immediate interpretation of this is that the potential is the same as that due to a normally magnetized layer on the surface of the body whose strength at dS is ϕ; in other words, *qua* external action, every lamellar magnet may be replaced by a complex shell on its surface.

There is, however, another way of looking at the result. Since A, B, C are derivable from a potential ϕ, the difference between the values of ϕ at any two points is simply the value of the line integral $\int(Adx+Bdy+Cdz)$ along any path between those points. Hence if the tangential component of magnetization be given in direction and magnitude all over any surface, the value of ϕ, *à constant près*, is given all over that surface. We conclude therefore that, if a body be lamellarly magnetized, and we know the tangential component of its magnetization all over its surface, its external action is determined;[1] for a constant c added to ϕ will simply add to the surface integral

$$c\iint\frac{\cos\theta\,dS}{D^2}\,,$$

which, being c times the whole solid angle subtended by the surface at any external point, vanishes. For another very interesting proof of this result, see Thomson, *Reprint*, p. 398 *sq.*

Vector potential of lamellar magnet.

The vector potential of a lamellar magnet may be expressed by means of the formulæ

$$\left.\begin{aligned} F&=\iiint\left(\frac{d\phi}{dy}\frac{d\left(\frac{1}{D}\right)}{dz}-\frac{d\phi}{dz}\frac{d\left(\frac{1}{D}\right)}{dy}\right)dv\\ &=\iint\phi\left(m\frac{d\left(\frac{1}{D}\right)}{dz}-n\frac{d\left(\frac{1}{D}\right)}{dy}\right)dS'\\ &=-\iint\frac{1}{D}\left(m\frac{d\phi}{dz}-n\frac{d\phi}{dy}\right)dS'\,;\ G=\&c.\,;\ H=\&c. \end{aligned}\right\}\quad(40).$$

These formulæ furnish an immediate proof of the theorems of Thomson above stated.

Potential energy of magnetic shell, &c.

By means of the last of them, it has been shown in the article ELECTRICITY[2] that the vector potential of a simple magnetic shell can, as might be expected, be expressed by means of a line integral taken round its boundary; in the same place it has also been shown that the potential energy of such a shell in a magnetic field reduces to a similar line integral; and that the mutual potential energy of two such shells reduces to a double line integral taken round their boundaries.

Approximate expression for magnetic potential.

An important approximate expression for the potential of a magnet at a point P, whose distance r from some chosen point in the magnet is great compared with the greatest linear dimension of the magnet, may be obtained as follows. Let the coordinates of P with respect to the chosen point and any axes through it be $\xi,\ \eta,\ \zeta$; and let the coordinates of any point in the body referred to the same axes be $x,\ y,\ z$. Also let $D=\left\{(\xi-x)^2+(\eta-y)^2+(\zeta-z)^2\right\}^{\frac{1}{2}}$, and let $r=(\xi^2+\eta^2+\zeta^2)^{\frac{1}{2}}$, $s=(x^2+y^2+z^2)^{\frac{1}{2}}$, $t=\xi x+\eta y+\zeta z$. Then the potential U at $(x,\ y,\ z)$ of a unit pole placed at $(\xi,\ \eta,\ \zeta)$ is given by

$$\begin{aligned} U=\frac{1}{D}&=\frac{1}{r}+\frac{t}{r^3}+\frac{3t^2-r^2s^2}{2r^5}+\frac{5t^3-3tr^2s^2}{2r^7}+\&c.\\ &=\frac{1}{r}+U_1+U_2+U_3+\&c., \end{aligned}$$

by a well-known theorem, where $U_1,\ U_2,\ U_3$, &c., are spherical harmonics of degrees 1, 2, 3, &c., in $x,\ y,\ z$, and $-2,\ -3,\ -4$, &c., in $\xi,\ \eta,\ \zeta$. Now, by the theorem of mutual potential energy, the potential V of the magnet at $(\xi,\ \eta,\ \zeta)$ is the potential energy of the magnet in the field due to a unit pole at $(\xi,\ \eta,\ \zeta)$; hence by (17)

$$\left.\begin{aligned} V&=\iiint\left(A\frac{dU}{dx}+B\frac{dU}{dy}+C\frac{dU}{dz}\right)dv\\ &=V_1+V_2+V_3+\&c. \end{aligned}\right\}\quad .\ .\ .\quad(41),$$

where V_1 arises from U_1, V_2 from U_2, and so on. $V_1,\ V_2,\ V_3$, &c., will be spherical harmonics in $\xi,\ \eta,\ \zeta$ of the most general kind, involving essentially 3, 5, 7, . . . $2i+1$ constants respectively, their degrees being $-2,\ -3,\ .\ .\ .\ -i$ respectively. These constants will, however, depend in each case on a larger number of integrals taken throughout the magnetized body, thus the constants in V_i will depend upon $\frac{3}{2}(i+1)(i+2)$ integrals.[3] There is no difficulty in writing down these terms except the length of the formulæ. Putting

$$\left.\begin{aligned} &\iiint A\,dv=Kl,\quad \iiint B\,dv=Km,\quad \iiint C\,dv=Kn\\ &L=\iiint Ax\,dv,\quad M=\iiint By\,dv,\quad N=\iiint Cz\,dv\\ &P=\iiint(Bz+Cy)dv,\quad Q=\&c.,\quad R=\&c. \end{aligned}\right\}\ .\quad(42),$$

we get

$$V=K\frac{l\xi+m\eta+n\zeta}{r^3}+\frac{(2L-M-N)\xi^2+\&c.+3P\eta\zeta+\&c.}{r^5}+\&c.\qquad(43).$$

It may be shown[4] that, in the most general case, if we take the axis of x parallel to the magnetic axis, and the origin at the point

$$\left\{(2L-M-N)/2K,\ \ R/K,\ \ Q/K\right\},^5$$

and turn the axes about an angle $\tan^{-1}P/(M-N)$, the above reduces to

$$V=\frac{K\xi}{r^3}+\frac{3}{2}\frac{(M-N)(\eta^2-\zeta^2)}{r^5}+\&c.\quad .\ .\ .\quad(44).$$

An interesting particular case is that in which the magnet is symmetrical with respect to the three coordinate planes. If we take its axis to be in the axis of x, then, since all the integrals L, M, N, P, Q, R vanish, V_2 disappears, of the next set only

$$A_1=\iiint Ax^2dv,\quad A_2=\iiint Ay^2dv,\quad A_3=\iiint Az^2dv\quad .\quad(45)$$

remain, and we get

$$V=\frac{K\xi}{r^3}+\frac{3\left\{A_1(2\xi^2-3\eta^2-3\zeta^2)+A_2(4\eta^2-\zeta^2-\xi^2)+A_3(4\zeta^2-\xi^2-\eta^2)\right\}\xi}{2r^7}\quad(46).$$

The potential to the same degree of approximation of a positive and negative pole of strength μ, placed on the magnetic axis at distances $+L$ and $-L$ from the origin (centre of symmetry), is

$$V'=\frac{2\mu L\xi}{r^3}+\frac{2\mu L^3\xi(2\xi^2-3\eta^2-3\zeta^2)}{2r^7}.$$

Ideal representative magnet.

If we attempt now to find μ and L, so that the two magnetic systems may be equivalent, we find different values for L for different positions of the external point. If, however, the magnet be symmetrical *about its axis*, so that $A_2=A_3$, then the expression for V reduces to

$$V=\frac{K\xi}{r^3}+\frac{3(A_1-A_2)\xi(2\xi^2-3\eta^2-3\zeta^2)}{2r^7}\quad .\ .\ .\quad(47),$$

we then get $2\mu L=K$, and $2\mu L^3=3(A_1-A_2)$, whence $L^2=3(A_1-A_2)/K$. In other words, in the case of a magnet which is symmetrical about its axis and also about an equatorial plane, we can represent the external action by means of a fixed ideal magnet, provided higher powers of the ratio of the greatest linear dimension of the magnet to the distance of the point considered than the fourth can be neglected. It is to be observed, however, that if $A_1<A_2$ the length of the ideal representative magnet will be imaginary.[6]

Series for potential energy.

A convergent series for the mutual potential energy of two magnets M and M′ may be obtained from the sextuple integral of mutual (19). Let the origin be a fixed point O in M, and let the coordinates of a fixed point O′ in M′ with reference to a set of axes fixed in O be $\xi,\ \eta,\ \zeta$; further, let $x,\ y,\ z$ and $x',\ y',\ z'$ be the coordinates of any elements dv and dv' in M and M′, the axes being in the former case the system already indicated, in the latter a parallel system through O′; then, if r denote $(\xi^2+\eta^2+\zeta^2)^{\frac{1}{2}}$, and $\delta_1,\ \delta_2,\ \delta_3$ stand for $\frac{d}{d\xi},\ \frac{d}{d\eta},\ \frac{d}{d\zeta}$, we have

$$W=-\int dv\int dv'(A\delta_1+B\delta_2+C\delta_3)(A'\delta_1+B'\delta_2+C'\delta_3)\left(\frac{1}{r}+\Sigma u_n\right),$$

where $$u_n=\frac{1}{n!}\left\{(x'-x)\delta_1+(y'-y)\delta_2+(z'-z)\delta_3\right\}^n\frac{1}{r}\,;$$

or

$$W=W_1+W_2+W_3+\quad .\ .\ .\ .\ .\ .\ .\ .\ .\ .\quad(48),$$

where $W_1,\ W_2,\ W_3$, are spherical harmonics in $\xi,\ \eta,\ \zeta$ of degrees $-2,\ -3,\ -4$, &c.

If we neglect all the terms except those of the first order, which amounts to supposing M and M′ infinitely small, we get

$$W=-KK'\left\{ll'\delta_1^2+\ .\ .\ .\ +(mn'+m'n)\delta_2\delta_3+\ .\ .\ .\right\}\frac{1}{r}\,.$$

If $\theta_1,\ \theta_2$ be the angles between the axes of M and M′ and the line

[1] Sir W. Thomson, *Reprint of Papers on Electricity and Magnetism*, p. 392.

[2] Vol. viii. p. 60.

[3] This fact is a further proof, if that were wanted, that the magnetization of a body cannot be determined from its external action.

[4] See Sir W. Thomson, *Reprint*, p. 368.

[5] This point is sometimes called the centre of the magnet, and the new axes of Y and Z its secondary axes. It should be observed, however, that this "centre" is not necessarily the middle point of the line joining the mass centres of the positive and negative magnetism. On this subject see a paper by Beltrami, "Sul Potenziale Magnetico," *Ann. d. Matem.*, 1882.

[6] *Cf.* Riecke in *Pogg. Ann.*, p. 149, 1873; and *Wied. Ann.*, p. 8, 1879.

from the centre of M to the centre of M′, and θ_{12} the angle between the axes, this reduces to

$$W=\frac{KK'}{r^3}(\cos\theta_{12}-3\cos\theta_1\cos\theta_2)\quad . \quad . \quad . \quad . \quad . \quad (49).$$

Action between two infinitely small magnets.

From this formula we can derive at once by differentiation the force of translation and the couple about the centre of M′, which represent the action of M upon it. An elegant synthesis of this action has been given for the most general case by Tait.[1] It will be sufficient to confine ourselves here to the case where the magnetic axes are in one plane. In this case $\theta_{12}=\theta_1-\theta_2$, and W becomes $KK'(\sin\theta_1\sin\theta_2-2\cos\theta_1\cos\theta_2)/r^3$. Denoting by X, Y, L the forces of translation parallel to $\overrightarrow{MM'}$ and perpendicular to MM′ (so as to decrease θ_1) and the couple tending to decrease θ_2, we have

$$\left.\begin{aligned}X&=-\frac{dW}{dr}=\frac{3KK'}{r^4}(\sin\theta_1\sin\theta_2-2\cos\theta_1\cos\theta_2)\\ Y&=\frac{dW}{rd\theta_1}+\frac{dW}{rd\theta_2}=\frac{3KK'}{r^4}\sin(\theta_1+\theta_2)\\ L&=\frac{dW}{d\theta_2}=\frac{KK'}{r^3}(\sin\theta_1\cos\theta_2+2\cos\theta_1\sin\theta_2)\end{aligned}\right\}\quad . \quad (50).$$

Force of translation ∝ (dist)$^{-4}$. Couple ∝ (dist)$^{-3}$.

One most important conclusion follows at once from these formulæ, viz., that the translatory forces vary inversely as the fourth power of the distance, whereas the directive couple varies only inversely as the third power. Hence the couple may be quite sensible at distances for which the force of translation is inappreciably small. These conclusions apply of course equally to any pair of magnetized bodies, provided the distance between them be sufficiently great as compared with their linear dimensions. This, applied to the case of the earth, at once explains the phenomena that puzzled Norman and the earlier magnetic philosophers so greatly. The following particular cases are important (fig. 25):—

(A) $\theta_1=\theta_2=0,\ X=-\frac{6KK'}{r^4},\ Y=0,\ L=0.$

(B) $\theta_1=\theta_2=\frac{\pi}{2},\ X=\frac{3KK'}{r^4},\ Y=0,\ L=0.$

(C) $\theta_1=0,\ \theta_2=\frac{\pi}{2},\ X=0,\ Y=\frac{3KK'}{r^4},\ L=\frac{2KK'}{r^3}.$

(D) $\theta_1=\frac{\pi}{2},\ \theta_2=0,\ X=0,\ Y=\frac{3KK'}{r^4},\ L=\frac{KK'}{r^3}.$

Deflecting magnet "end on" and "broadside on."

The last two cases are especially important: the position of the deflecting magnet in (C) is described as "end on" (erster Hauptlage), in (D) as "broadside on" (zweiter Hauptlage); it will be noticed that the couple in the former case is double that in the latter.

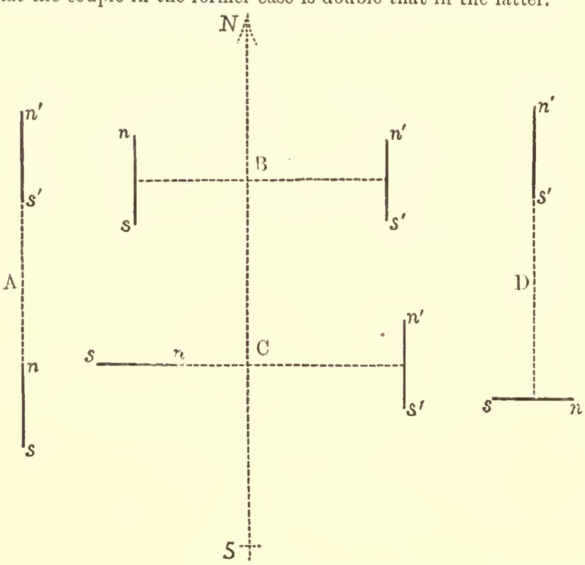

Fig. 25.

Closer approximation for deflecting couple end on and broadside on.

If the terms of the second and third order be taken into account, and the magnet $n's'$ be deflected through an angle ϕ from its original position by a deflecting magnet (I.) originally end on and (II.) originally broadside on, we get for the couples

$$\left.\begin{aligned}&\text{I.}\quad \cos\phi\left[\frac{2KK'}{r^3}-\frac{T_1}{r^4}+\frac{T_2}{r^5}+\ .\ .\ .\ \right]\\ &\text{II.}\quad \cos\phi\left[\frac{KK'}{r^3}+\frac{T'_1}{r^4}+\frac{T'_2}{r^5}+\ .\ .\ .\ \right]\end{aligned}\right\}\quad . \quad . \quad (51),$$

where T_1 and T'_1 are odd functions of the relative position of M and M′, but T_2 and T'_2 are even. In the case where M and M′ are symmetrical about three orthogonal planes, O and O′ being the centres of symmetry, T_1 and T'_1 vanish, and the writer has obtained for the values of T_2 and T'_2

$$\left.\begin{aligned}T_2&=-6\{K(3A'_1-4A'_2+A'_3)-K'(2A_1-A_2-A_3)\}\\ T'_2&=-\tfrac{3}{2}\{K(12A'_1-11A'_2-A'_3)-K'(3A_1-4A_2+A_3)\}\end{aligned}\right\}\quad (52),$$

where A_1, A_2, &c., have the meanings above assigned in (45).[2]

Gauss's theory of terrestrial magnetism.

Sphere Magnetized in any Manner.—This is the most interesting of all the cases that fall under the present section, both from its being amenable to mathematical treatment and on account of its historical interest. It was first discussed in the beautiful memoir, entitled *Allgemeine Theorie des Erdmagnetismus*,[3] in which Gauss laid the foundation of the rational theory of terrestrial magnetism. The following is a brief account of the theory, which has not been greatly added to since he left it.

Let X, Y, Z be the components of the earth's resultant magnetic force at any point on its surface, in the directions of geographical north, geographical west, and vertically upwards respectively. The force is completely known when these are given, since it depends on three elements only. If H, δ, ι have the meanings formerly assigned (p. 220, 221, 227), we have of course

$$H=\sqrt{X^2+Y^2},\ \tan\delta=Y/X,\ \tan\iota=Z/\sqrt{X^2+Y^2}.$$

Again, if V be the magnetic potential of the earth, l the latitude, and λ the longitude of any point on its surface, then, supposing the earth to be a sphere of radius a, we have

$$X=-\frac{1}{a}\frac{dV}{dl},\ Y=-\frac{1}{a\cos l}\frac{dV}{d\lambda},\ Z=-\frac{dV}{dr},\quad . \quad (53),$$

r denoting the distance of any point from the centre of the earth. When V is known, therefore, the force is completely determined.

If now we suppose all the magnetized matter (or its equivalent—say, electric currents) to be within the earth, it follows, from the theory of spherical harmonics, that we can write down a convergent series for its potential at all external points, when the potential at every point of its surface is given.[4] In fact, if the expansion of this surface potential in terms of surface harmonics be

$$S_1+S_2+\ .\ .\ .\ +S_i+\ .\ .\ .\ ,$$

we have for all external points

$$V=S_1\left(\frac{a}{r}\right)^2+S_2\left(\frac{a}{r}\right)^3+\ .\ .\ .\ +S_i\left(\frac{a}{r}\right)^{i+1}+\ .\ .\ .\quad (54).^{5}$$

The number of terms of this series that must be retained in order to obtain a sufficiently accurate representation of the phenomena will of course depend on circumstances, and can only be ascertained by trial. $S_1, S_2, \ldots S_i$ are functions of known form, containing respectively 3, 5, . . . $2i+1$ constants; hence, if terms beyond the i^{th} order may be neglected, the expression for V will contain i^2+2i arbitrary constants. These must be determined by observation, and then the magnetic action at all points on the surface or outside the earth is known irrespective of the internal distribution of the magnetic causes.

Data sufficient to determine the earth's magnetic action.

If we look at the matter from the general point of view that V is determined when its surface value is known, we have the following propositions.

I. V is determined when the vertical force is known at every point of the earth's surface.

For, let the surface value of Z be expanded in a series of surface harmonics of which the i^{th} is Z_i; then, equating this to the i^{th} harmonic in the surface value of $Z=-dV/dr$ derived from (54), we have $(i+1)S_i=aZ_i$, which determines S_i. Thus the proposition is proved.

[1] *Quart. Jour. Math.*, 1860; and *Quaternions*, § 414.

[2] *Cf.* Riecke, *l.c.*

[3] *Res. d. Mag. Vereins*, 1838.

[4] See Thomson and Tait, vol. i. chap. 1, App. A and B.

[5] The term S_0 of course vanishes, since the sum of the positive and negative magnetism within the earth is zero.

II. The surface value of V, and hence its general value for external points, is determined if the northward component of the magnetic force be known at every point of the earth's surface.

This follows at once from the fact that the difference of the values of V at any two places is the line integral of the magnetic force along *any* line joining them; thus, if V_0 be the value of V at the geographical north pole, we have

$$V = -a\int_{\frac{\pi}{2}}^{l} Xdl + V_0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (55).$$

But the constant V_0 does not affect the general value of V; hence the proposition is established.

III. The same conclusion follows if the westward horizontal component be known all over the earth's surface and the northward component along any one meridian.

In fact, if V be the potential at any place whose latitude is l and longitude λ, then

$$V = -a\int_{\frac{\pi}{2}}^{l} Xdl - a\int_{\lambda_0}^{\lambda} Y \cos l d\lambda + V_0 \,,$$

the first integration being performed along the given meridian, the second along the parallel of latitude corresponding to the place.

From I., II., and III. we have the remarkable conclusion that, if the vertical component be given all over the earth, or the northward component, or the westward component and the northward along one parallel, then in each case the other two elements are determined.

Approximation by means of the line integral of magnetic force.

Gauss gives another interesting application of the line integral of magnetic force. If this integral be taken all round any closed curve or polygon, the result is zero. Let us express this for any geodesic triangle ABC, at whose vertices the horizontal force has the values H_1, H_2, H_3. If the inclinations of H to $\overrightarrow{BC}$ at B and C be α and α', to $\overrightarrow{CA}$ at C and A β and β', to $\overrightarrow{AB}$ at A and B γ and γ', then, if the arcs BC, CA, AB be not too long, we may replace the component along BC at every point by the average of its values at B and C, and so on. We thus get

$$\tfrac{1}{2}BC\,(H_2\cos\alpha + H_3\cos\alpha') + \tfrac{1}{2}CA\,(H_3\cos\beta + H_1\cos\beta') + \tfrac{1}{2}AB\,(H_1\cos\gamma + H_2\cos\gamma') = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (56).$$

If we suppose the values of H at B and C to be known, and the values of the declination to be known at all three places, the above equation determines the value of H at A. Calculating in this way from observed values at Göttingen, Milan, and Paris, Gauss found for H at Paris 0·51696, the observed value being 0·51804.

External and internal causes of earth's magnetic action.

It has been supposed hitherto that the magnetic causes are entirely internal to the earth. The foregoing theory enables us to test how far this assumption is correct.

If we suppose that there are external causes, then the potential at internal points due to these will be

$$T_0 + T_1\frac{r}{a} + T_2\left(\frac{r}{a}\right)^2 + \; . \; . \; . \; T_i\left(\frac{r}{a}\right)^i + \; . \; . \; . \; ,$$

$T_0, T_1, T_2 \ldots T_i$ being the different harmonics in the surface value of the part of the potential due to external causes. Suppose now the whole vertical force deduced from observation for all parts of the earth's surface, and expanded in a series of surface harmonics, the i^{th} of which is Z_i; then, since this is the sum of the i^{th} harmonics in the parts due to internal and to external causes, we have

$$-(i+1)S_i + iT_i = aZ_i \,. \quad . \quad . \quad . \quad . \quad . \quad (57).$$

Further, suppose the surface value of V determined from observations of horizontal force, and let the i^{th} harmonic in it be V_i, then we have

$$S_i + T_i = V_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (58).$$

From equations (57) and (58) we can determine S_i and T_i, and thus settle how much is due to external and how much to internal causes. It does not appear from observation that any sensible part of the *mean* value of V arises from causes external to the earth.

Gaussian distribution for a sphere.

We have seen already that the action of any body can be represented at external points by an ideal layer of positive and negative magnetism. Gauss finds for the surface density of the layer in the case of a spherical body like the earth, the expression $(V/a - 2Z)/4\pi$, which may be deduced immediately from the formulæ already given.

If we draw a series of equipotential surfaces corresponding to small equidifferent values of V, these will cut the earth's surface in a series of equipotential lines, which are called the "magnetic parallels." These lines obviously have the following properties. The horizontal force is everywhere perpendicular to them, and is at any point inversely proportional to the distance between two consecutive lines there. So that, if these lines were drawn upon a terrestrial globe, their crowding would indicate increase of horizontal force. The lines of horizontal force, or "magnetic meridians," the tangent at every point of which is parallel to the horizontal component, are everywhere orthogonal to the magnetic parallels, and their positive direction is from parallels of greater potential to parallels of less potential. If, as has been tacitly assumed hitherto in accordance with the results of observation, the potential on the earth's surface have but one maximum and one minimum, then the parallels will be closed curves expanding successively from the maximum point and then closing again round the minimum point, and the magnetic meridians will all run between these two points. It is clear that at each of these points the equipotential surface and the earth's surface touch; at the minimum point the line of total resultant force will pass *to* the earth, at the maximum point *from* it; at the former, therefore, the *north* end of a freely suspended needle will dip vertically downwards, at the latter the *south* end will do the same. This is the simplest possible case for a magnetized sphere. It is easy to see that, if we define a north pole[1] as a point on the earth's surface at which the horizontal intensity vanishes, and the dip is 90°, there might be more than one such point. Consider the series of equipotential surfaces 1, 2, 3, 4, 5, 6 in fig. 26,[2] each of which has two eminences with a depression

Magnetic parallels and meridians.

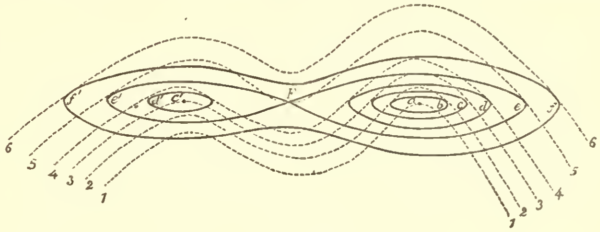

Fig. 26.

between them. The lines a, b, c, d, e, f are the sections of these by the earth's surface. 1 just touches the surface in a; and, if the potential increase in the order in which the surfaces are numbered, a will be a north pole. The section by 2 is the single oval b. 3 touches the surface in c', which is clearly another north pole, and also meets the surface in a single oval c equipotential with c'. The section by 4 is the double oval d, d'. The depression on 5 touches the surface at F, and meets it in a figure of 8, e, e', on which F is the double point. F is therefore yet another north pole according to our definition; it differs, however, from an ordinary north pole in one important respect; for the law that the north end of the compass points from parallel of greater to parallel of less potential shows at once that near F and *inside* the 8-shaped parallel the south end will point to F, whereas at a neighbouring point *outside* the north end will point to F. Such a point is called a false north pole, and we see that the existence of two true north poles necessitates the existence of a false north pole; and in general it may be established[3] that,

False poles.

[1] Of course pole as thus defined has nothing to do with pole in any of the former senses, *e.g.*, the line joining its N and S poles is not parallel to the earth's magnetic axis.

[2] Gauss, *l.c.*, § 12. *Cf.* Mascart and Joubert, *Leçons sur l'Électricité et sur le Magnétisme*, tom. i. § 436, 1882.

[3] See Gauss, *All. Theorie des Erdmagnetismus*, § 12; Maxwell, vol. i. § 113, vol. ii. § 468.

however many poles of the same kind there may be, true and false, the whole number must be odd. This of course disposes of the notion formerly held by some physicists that the earth actually had *two* north poles. As already indicated, Gauss concluded from his reduction of the magnetic observations at his disposal that, apart from purely local disturbances, the earth has, as a matter of fact, only one north and one south pole.

Local disturbances of magnetic parallels.

The effect of a deposit of magnetic ore, or other cause of the kind, might of course produce a disturbance, within a limited area, of the equipotential lines. It may assist the practical magnetist to indicate the nature of this disturbance in a particular case. Let us suppose that a magnet is placed some distance underground, vertical, with its north pole uppermost. Then, if its moment be sufficiently great, the equipotential lines will be as in fig. 27.[1] The upper side of the figure is supposed to be magnetic north, and it is supposed that the undisturbed

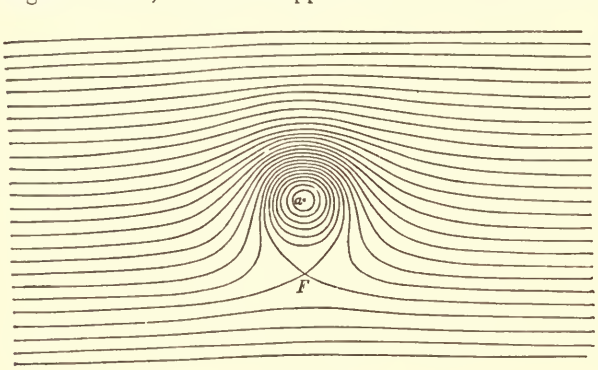

Fig. 27.

parallels would be straight lines running magnetic east and west, which is sufficiently near the truth in most cases. It should be observed that fig. 27 is in reality a transformation of figure 26, one of the poles being projected to infinity. The reader should notice that the double point F, due south of the point *a* vertically over the disturbing magnet, is a point of equilibrium at which the horizontal components of the forces of the earth and the magnet destroy each other; it will be a false pole, south or north according as the magnet or the earth prevails.

Experimental Foundation for the Law of the Inverse Square.

Difficulties of the question as to the elementary law.

From what has already been laid down, it will be seen that the determination of the elementary law of magnetic action is a very complex problem. The action between two magnets depends, not only on their distance apart, but also on their relative angular position. Then we have to distinguish force of translation, which varies inversely as the fourth power of the distance, and directive couple, which varies inversely as the third power. It must also be remembered that the elementary law results in part from an hypothesis as to the nature and distribution of the cause of the magnetic action, for, until some such hypothesis is made, no clear conception is possible of what is to be understood by elementary action. Lastly, we have the disturbance which arises from magnetic induction, the consequence of which is that magnetically speaking two magnets are not the same at different distances apart. When all these circumstances are considered, it is not surprising to find considerable uncertainty and difference of opinion among the earlier magnetic philosophers. The truth is that the law as now established owes quite as much to the development of magnetic theory as to the work of magnetic experimenters.

Huygens, Hooke, Newton.

The question attracted the notice of Huygens and Hooke, but Newton seems to have been one of the first who propounded any law on the subject. He says (*Principia*, lib. iii. prop. 6, cor. 5) that some rough experiments had led him to the conclusion that the magnetic force (vis magnetica) decreases according to the law of the inverse cube of the distance. No account of the experiments is extant, and it does not appear what he means exactly by vis magnetica. If the directive couple is meant, and the action of the *entire* magnet is intended, then, as we have seen, this is in agreement with modern theory. In a remarkable note in the annotated edition of the *Principia* by Le Sueur and Jacquier (assisted by Calandrini?) (1742) on the passage in question, a series of deflexion experiments are described, and an accurate discussion is given, from which results the law of the inverse cube for the deflecting couple. Hawksbee[2] made experiments with a view to determine the law of magnetic action, in which a deflecting magnet was moved at various distances round a compass, and the corresponding deflexions noted. A few years later Brook Taylor[3] and the same experimenter made a series of observations in which the "end on" method of deflexion still in use was adopted. But in neither case was any definite result arrived at. A similar uncertainty appeared in the experiments of Whiston, who indicates the inverse $\frac{3}{2}$th power of the distance as the law of decrease. Musschenbroek's experiments, which were extensive, also led to no final result. He used the method of Hooke, in which the attraction of a vertical bar magnet upon another suspended from one arm of a delicate balance is balanced by weights attached to the other arm. From some of his experiments he deduces as low a power as the inverse 1st, from others the $\frac{3}{2}$th, and so on; but no attempt is made to analyse the phenomena. Michell, in his treatise on artificial magnets (1750), however, deduces the law of the inverse square from Musschenbroek's results. Although Æpinus does not arrive at any definite result as to the elementary law, there can be no doubt that his *Tentamen Theoriæ Electricitatis et Magnetismi* (1759) contributed powerfully towards the solution of the question. Tobias Mayer seems to have been the first to publish the law of the inverse square as the actual result of an experimental investigation. His paper was read before the Royal Society of Göttingen, and was referred to in the *Göttinger Gelehrter Anzeiger* for 1760, but never fully published; it is best known from the criticism of Æpinus, "Examen Theoriæ Magneticæ a Tob. Mayero propositæ" (*Nov. Comm. Acad. Petrop.*, 1768).[4] The most important of the earlier contributions was undoubtedly that of Lambert.[5] He seems to have been the first to analyse the physical circumstances of the problem in a thorough manner, and to point out the various elements of disturbance to be provided for. We regret that we are unable to devote space to an exhaustive account of his memoirs,[6] which are most instructive reading even now. He showed that the effect of an oblique magnetic force on the needle varies as the sine of the inclination; and, making allowances for this, he deduced the law of the inverse square from deflexion experiments made at different distances. He also described the method of oscillations, but found difficulties in its practical application. It is upon his theoretical work, however, rather than upon his experiments, that his claim to be remembered rests. About the same time as Lambert,

Le Sueur and Jacquier. Hawksbee and Taylor. Whiston. Musschenbroek. Tobias Mayer. Lambert.

[1] Gauss, *l.c.*, § 13.

[2] *Phil. Trans.*, 1712.
[3] *Phil. Trans.*, 1715 and 1721.
[4] Comp. Hansteen, *Mag. d. Erde*, p. 283, 1819.
[5] *Hist. d. l'Acad. Roy. d. Sc. Berlin*, 1766.
[6] An excellent one will be found in Hansteen, *Magnetismus der Erde*, pp. 295 *sq.*

Dalla Bella and Robison. we have Dalla Bella[1] and Robison,[2] the well-known professor of natural philosophy in the university of Edinburgh, working at the same subject. The former used the method of Hooke and Musschenbroek, but discussed more carefully the exact nature of the resultant action. His results indicated the law of the inverse square. Robison used both the method of deflexion and the method of oscillation, the peculiarity in his apparatus being the movable magnet, which was composed of two magnetized spheres connected by a slender rod, and suspended either in the field of the earth alone, or at different distances from a large magnet. He made several independent investigations, and seems to have arrived in each case at the law of the inverse square as his final result.

Coulomb. The researches of Coulomb,[3] from which many date the commencement of the modern theory, present many features of great interest. He used the improved form of Michell's torsion balance, which had served him so well in his electrical experiments. In order to realize as nearly as possible the ideal case of a linear solenoid, whose action can be represented by positive and negative magnetism concentrated at its ends, he worked with magnets made of thin steel wire magnetized longitudinally. The circumstances of the experiment are thus considerably simplified, for the acting magnet may be so arranged that the action of one of the poles may be neglected, or, failing that, the action of both can be easily calculated.

In one of his experiments he took a magnetized steel wire 25 inches long, and $1\frac{1}{3}$ lines thick, and placed it vertically in the magnetic meridian before a horizontal magnetic needle some 3 inches long, delicately suspended by a silk fibre. The rod was raised and lowered at a given distance from the needle until the attraction on the near pole of the needle, as tested by the rapidity of the vibrations, was a maximum; it was then found that the lower end of the bar was about 1 inch below the needle. Again, the rod being placed horizontal and perpendicular to the magnetic meridian on a level with the needle, it was displaced until the needle returned to the magnetic meridian; it was then found that the needle was directed to a point about 1 inch from the end of the bar. Both these experiments thus indicate that the magnetism at one end may be supposed concentrated at a point about an inch from the end of the bar. It is clear that, in these experiments, provided the rod is sufficiently long or the distance between it and the needle not too great, the action of the distant pole may be neglected, for the double reason that the pole is more distant and that the force exerted by it is nearly perpendicular to the direction in which it can be effective. Making this assumption, Coulomb observed the number of vibrations, when the vertical rod was absent, and when it was placed at various distances.

The forces thence deduced were found to vary very nearly as the inverse square of the distance. Statical experiments with the torsion balance led to a like result.

Later researches. Hansteen. Later than Coulomb we have the experiments of Bidone,[4] Hansteen,[5] Steinhauser,[6] and Scoresby.[7] By far the most important among these is Hansteen, whose methods were a great step towards the more complete treatment finally adopted by Gauss. He uses Taylor's "end on" method of deflexion, and also the method of Hooke and Musschenbroek. The acting magnet was a bar magnet, the action of which he represents by a distribution of positive and negative magnetism on its two halves whose density at a distance x from the centre is λx^r. The force at distance D due to an element $d\mu$ of positive magnetism he assumes to be $d\mu/D^n$. He finds that in all his experiments the value $n=2$ best represents the results obtained; but that various values of r may be adopted with almost equal advantage; he inclines, however, to the value $r=2$.

[1] *Mem. d. Acad. Real d. Sc. d. Lisboa.*
[2] See *Ency. Brit.*, supplement to 3d ed., 1801.
[3] *Mém. de l'Inst.*, 1785, 1788.
[4] Gren's *Journal*, 1811; *Gilb. Ann.*, 1820.
[5] *Magnetismus der Erde*, 1819.
[6] *De Magnetismo Telluris*, 1806–10.
[7] Jamieson's *New Edinburgh Journal*, 1831.

Gauss. In his classical memoir on the absolute measurement of the earth's magnetic force, Gauss took up the question in the most general manner yet attempted. Assuming that the force due to an element of positive magnetism varies as the inverse nth power of the distance, he showed that, when the distance between the magnets is sufficiently great compared with the greatest linear dimensions of either (more than four times as great in his own experiments), the deflexions ϕ and ϕ' for the "end on" and "broadside on" positions of the deflecting magnet are given by

$$\tan\phi = L_1 r^{-(n+1)} + L_3 r^{-(n+2)} + \text{\&c.},$$
$$\tan\phi' = L_1' r^{-(n+1)} + L_3' r^{-(n+2)} + \text{\&c.};$$

where $L_1/L'_1 = n$. He made a series of deflexion experiments, and found that his results could be represented with sufficient accuracy by the formulæ[8]

$$\tan\phi = 0{\cdot}086870 r^{-3} - 0{\cdot}002185 r^{-5},$$
$$\tan\phi' = 0{\cdot}043435 r^{-3} + 0{\cdot}002449 r^{-5}.$$

The following table shows the closeness of the agreement between theory and experiment (r is measured in metres; Φ and Φ' denote observed and ϕ and ϕ' calculated values):—

r	Φ	$\Phi-\phi$	Φ'	$\Phi'-\phi'$
	° ′ ″	″	° ′ ″	″
1·1			1 57 24·8	+2·8
1·2			1 29 40·5	−6·0
1·3	2 13 51·2	+ 0·8	1 10 19·3	+6·0
1·4	1 47 28·6	+ 4·5	0 55 58·9	+0·2
1·5	1 27 19·1	− 9·6	0 45 14·3	−6·6
1·6	1 12 7·6	− 3·3	0 37 12·2	−3·2
1·7	1 0 9·9	− 5·0	0 30 57·9	−1·2
1·8	0 50 52·5	+ 4·2	0 25 59·5	−3·4
1·9	0 43 21·8	+ 7·8	0 22 9·2	+2·6
2·0	0 37 16·2	+10·6	0 19 1·6	+5·9
2·1	0 32 4·6	+ 0·9	0 16 24·7	+4·9
2·5	0 18 51·9	−10·2	0 9 36·1	−2·5
3·0	0 11 0·7	− 1·1	0 5 33·7	−0·2
3·5	0 6 56·9	− 0·2	0 3 28·9	−1·0
4·0	0 4 35·9	− 3·7	0 2 22·2	+1·7

We have here a double proof of the law of the inverse square,—first, in the fact that $\tan\phi$ and $\tan\phi'$ can be expressed so accurately by two terms of a series, the first of which contains r^{-3}; second, in the fact that the coefficient of the first term in $\tan\phi$ is exactly double that in $\tan\phi'$. These researches of Gauss are remarkable, not only for the great generality of the theory, but also for the novelty of the experimental method, and the exceeding accuracy and refinement of the observations. The law of the inverse square has in fact been regarded as settled ever since they were made. They are important from another point of view, to which we shall return presently.

Magnetic Measurements, Relative and Absolute.

Chief magnetic measurements. he mos. important magnetic determinations that have to be made are the direction of the axis of a magnet relatively to its mass, the magnetic moment of a magnet, the direction of a magnetic field, and the strength of a magnetic field, or its component in any given direction. In most of these cases the measurement may be either relative or absolute. For example, we may determine the moment of a magnet either relatively, in terms of the moment of some other magnet arbitrarily chosen, or absolutely, in terms of the fundamental units of space, mass, and time. The complete theory of measurements of the latter kind is due to Gauss, and the carrying of them into practice to him in conjunction with Weber and the *Magnetischer Verein*, of which these two German philosophers were the leading spirits. We shall discuss the

[8] *Intensitas Vis Magneticæ*, &c., § 21, 1833.

matter here only in so far as it concerns the work of a physical laboratory, the rest belonging more properly to the subject of Terrestrial Magnetism (see METEOROLOGY).

Determination of magnetic axis, and of the magnetic declination.

Axial Direction and Magnetic Declination.—The magnet is suspended, usually by means of one or more fibres of unspun silk, so as to be free to move about a vertical axis. We shall suppose, for simplicity, that the magnetic axis is in a horizontal plane. If this is not so, instead of determining the axial direction, we determine a vertical plane through it. In order to obtain a fixed line of reference in the magnet, two marks may be made on it as nearly in the direction of the axis as can be guessed to begin with ; this arrangement is used with dipping needles and also for horizontal needles when no great accuracy is required. For declination needles two contrivances of greater refinement are used.

Mirror method.

1. A mirror is rigidly attached to the magnet, so that the normal to its surface is nearly parallel to the magnetic axis. The image of a fixed horizontal scale in this mirror is observed by means of a fixed telescope, and the angular motion of the magnet deduced from the motion of the scale divisions over the wires of the telescope. This is called the mirror method.[1]

Collimator magnet.

2. A more compact arrangement is to attach to the magnet a small photographic scale and a lens, the former being placed at the principal focus of the latter, so that the line joining the middle division of the scale to the optical centre of the lens is nearly parallel to the axis of the magnet. The scale is viewed through the lens by means of a fixed telescope, and it is clear that the line just mentioned gives us a fixed direction in the magnet, and that the motion of the magnet can be followed by observing the apparent motion of the scale across the wires of the telescope. This may be called the collimator method.[2]

Unifilar magnetometer.

The apparatus usually employed in the United Kingdom for observing the magnetic declination,[3] and also for other absolute magnetic measurements, is the portable unifilar magnetometer, the upper part of which is shown in figs. 28, 29. The lower part consists simply of a tripod stand supporting three V-shaped groves, into which the points of the levelling screws attached to the fixed limb of the instrument are set. In making an observation of the declination the instrument is arranged as in fig. 28. The declination collimator magnet is suspended in the box A (the sides of which are removed to allow the interior to be seen) by means of the suspension fibre D, attached to the torsion head PH. The scale of the magnet is observed through the small telescope QBG. The first step is to remove the torsion as far as possible from the suspension fibre by hanging to it a brass plummet E of the same weight as the declination magnet. After this weight has come to rest, it is replaced by the declination magnet, so that the latter shall rest as nearly as possible in the magnetic meridian without introducing torsion of the fibre. The movable limb is now turned till some division of the magnet scale is on the cross wires of the telescope. It is then clamped. The magnet is now inverted, and the number of the scale division on the wires again read. The mean of these readings gives the point of the scale the line from which to the centre of the collimating lens is parallel to the axis of the magnet. This point of the scale (axial point) will remain the same so long as the magnetism of the magnet does not alter, or the adjustment of the scale and collimating lens is not interfered with. The tangent screw is now worked until the cross wires of the telescope are on the axial point of the scale. The verniers of the limb are then read. The next step is to observe the azimuth of the sun or of some other heavenly body, by means of which we can refer the azimuth of the magnetic meridian to the true north. For this purpose the instrument is provided with a small transit mirror NO, which has a motion in altitude so as to bring any object into the field of the telescope. To use it, the limb is unclamped, and it and the mirror moved until the sun or star comes into the field of the telescope ; the limb is then clamped and the time noted at which the heavenly body passes the intersection of the cross wires. The verniers are again read. The differences of the readings, added to the azimuth of the heavenly body found by means of the time from the *Nautical Almanac*, gives the declination at the time and place of observation.

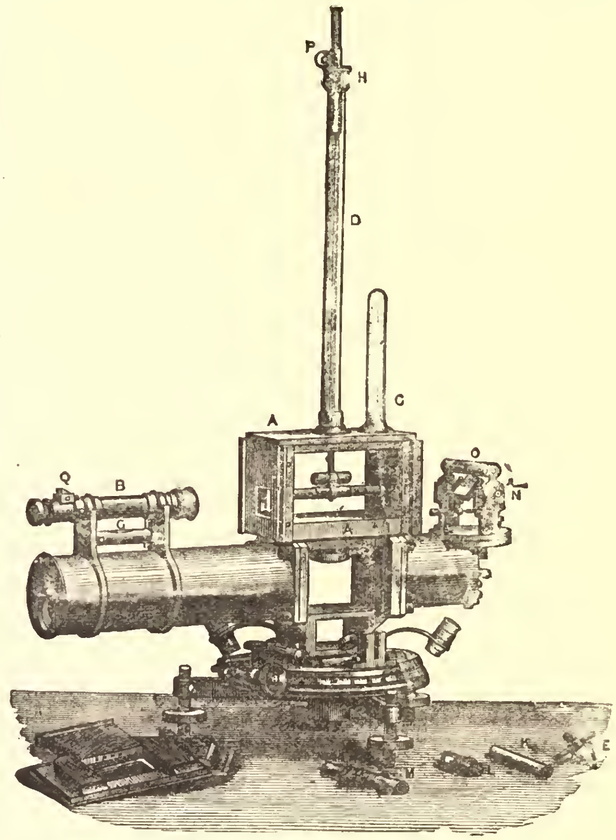

FIG. 28.—Unifilar Magnetometer, arranged to indicate declination.

There are several causes of error to be guarded against. (1) Torsion is reduced within as small limits as possible to begin with, and if there is reason to suspect any residual error we may test the apparatus by turning the torsion head of the suspension tube first 90° one way and then 90° the other. If the deflexion of the magnet is exactly the same and oppositely directed in the two cases, then we may conclude that the torsion is zero in the azimuth of equilibrium. If not, then we may turn the torsion head so as to reduce the error still further; or we may calculate its amount (assuming torsion to be proportional to twist) from the two observations, and allow for it. (2) If the axis of the magnet is not very nearly parallel to the line of collimation of the telescope to begin with, and consequently the two scale readings far apart, an error may arise[4] from the vertical axis of suspension not being exactly reversed by the inversion. This error is reduced by repeating the observation, after adjusting the axis of the magnet and telescope so as to be more nearly parallel. (3) If mean declination for a given day be desired, correction must be made for the diurnal variation, and under certain circumstances this variation may even produce disturbances in the course of a single observation.

Magnetic moment and horizontal intensity.

Magnetic Moment, Horizontal Intensity of the Earth's Force.—If merely relative measurements of the magnetic moment K of a given magnet, or of the horizontal intensity H of the earth's force, are desired, there are two methods of obtaining them. The first is the method of vibrations. Having found the moment of inertia A of the magnet M about its vertical axis of suspension, and the

[1] The mirror method was first suggested by Poggendorff (*Pogg. Ann.*, vii., 1826). It was carried out in practice by Gauss.

[2] There seems to be some doubt to whom the collimator method is due. Airy, Lloyd, Lamont, and Weber all did something for it. See Lamont, *Handb. d. Magnetismus*, p. 154.

[3] Want of space compels us to omit all but the leading points. Readers in search of full practical details must be referred to *The Admiralty Manual of Scientific Enquiry*, pp. 84 *sq.*; Maxwell, *Electricity and Magnetism*, §§ 449 *sq.* ; Lamont, *Handbuch der Magnetismus*, and *Erd-Magnetismus*, where references to all the authorities up to his time will be found. They should also study the classical memoirs of Gauss to be found in the fifth volume of his collected works.

[4] See Swan, *Trans. Roy. Soc. Edin.*, vol. xxi., 1855.

time T of its vibration under the earth's force, we obtain the product $KH, = p$, say. Secondly, by the method of deflexion, of which two varieties, tangent deflexion and sine deflexion, are in use, the value of the quotient $K/H, = q$, say, is found. In this method K is used as the *deflecting* magnet, and the moment K′ of the *deflected* magnet does not appear in the result.[1] It is obvious that, if we know the value of H, or may assume it constant, either of these methods will enable us to express the moment of any magnet in terms of that of another arbitrarily chosen as unit; and, reciprocally, if we operate with a magnet of known or of constant moment, we can determine the values of H at different times and places in terms of its value at an arbitrarily chosen time and place.

By combining two observations, in one of which a magnet K is the vibrating and in the other the deflecting magnet, we can obtain both K and H in absolute measure, for we have two equations $KH = p$, and $K/H = q$, which give

$$K = \sqrt{pq}\,, \quad \text{and } H = \sqrt{p/q}\,.$$

Unifilar magnetometer: vibration experiments.

Vibration Experiments.—If θ be the angle between the axis of the magnet and H at time t, γ the angle between the axis and H in the position of no torsion, τKH the coefficient of torsion, then the equation of motion of the magnet, when the arc of oscillation is very small, may be written

$$A\ddot{\theta} + KH\theta + \tau KH(\theta - \gamma) = 0 \quad . \quad . \quad . \quad . \quad . \quad (59).$$

This gives for the period of a complete vibration

$$T^2 = 4\pi^2 A/KH(1+\tau) \quad . \quad . \quad . \quad . \quad . \quad . \quad (60).$$

The observations are made with the magnetometer arranged as for the declination experiment. The swinging magnet is brought to rest, and the circle so clamped that the axial point of the magnet scale is on the cross wire of the telescope; the magnet is then slightly disturbed so as to oscillate through a small arc (16′ or so). The time of vibration is found first roughly, by taking the time of a single vibration, then more accurately by counting a large number of vibrations and timing the end of the last as accurately as possible. τ is found by observing the deflexion θ' and θ'' caused by turning the torsion head through an angle β in one direction and then through an angle β in the opposite direction; we thus get from equation (59)

$$KH\theta' + \tau KH(\theta' - \gamma - \beta) = 0\,,$$
$$KH\theta'' + \tau KH(\theta'' - \gamma + \beta) = 0\,;$$

and $\tau = (\theta' - \theta'')/(2\beta - \theta' + \theta'')$. From the same equation we may also determine γ when necessary.

The most troublesome part of the whole process still remains, viz., the determination of A. This is effected by attaching to the magnet a body whose moment of inertia B can be calculated from its dimensions. For this purpose Gauss fixed a cross bar of wood to the magnet, and attached to it at known equal distances from the axis of suspension two cylindrical weights of known mass and dimension. Sometimes a cylinder of gun metal is slung below the magnet by means of two loops. Perhaps the best method is to use a ring of gun metal attached to the magnet so that its plane is horizontal and its centre as nearly as possible in the line of suspension. The new time of vibration being T_1, and the new coefficient of torsion (if different) τ', we have the new equation

$$T_1^2 = 4\pi^2(A+B)/KH(1+\tau')\,.$$

From this and (60) we get

$$A = B\Big/\left(\frac{1+\tau}{1+\tau'}\cdot\frac{T_1^2}{T^2} - 1\right).$$

[1] This important fact was first noticed by Lambert.

There are several corrections which, although in general negligible, may sometimes require to be considered. (1) H may vary so much during the experiment as to cause a sensible error; (2) if the arc of vibration be too large, it may be necessary to apply the reduction to infinitely small arcs; (3) if the amplitude of the vibrations decrease too rapidly, account must be taken of the resistance to the motion arising from the viscosity of the air, &c.;[2] (4) a correction has to be made for the alteration of the moment of the magnet by the earth's induction,[3] and (5) a temperature correction for the magnetic moment and the moment of inertia.

Deflexion experiments with unifilar magnetometer.

Deflexion Experiments.—In Gauss's arrangement the deflecting magnet was placed in an east-west direction, *i.e.*, end on to the original position of the deflected magnet. The equation of equilibrium in this case is [see equation (51)]

$$K'H(1+\tau)\sin\theta = \cos\theta\left(\frac{2KK'}{r^3} - \frac{T_1}{r^4} + \frac{T_2}{r^5} + \ . \ . \ . \right)$$

or

$$r^3\frac{H(1+\tau)}{2K}\tan\theta = 1 - \frac{P_1}{r} + \frac{P_2}{r^2} + \ . \ . \ . \ . \ . \ . \ . \quad (61).$$

where $P_1 = T_1/2K'K$, $P_2 = T_2/2K'K$, &c.

In the method of sines the deflecting magnet is turned until it is perpendicular to the axis of the deflected magnet in its final position of equilibrium; the equation of equilibrium in this case is

$$\frac{r^3 H}{2K}\sin\theta = 1 - \frac{P_1}{r} + \frac{P_2}{r^2} + \&c. \quad . \quad . \quad . \quad . \quad . \quad (62).$$

The advantage of the method of tangents is that the moment of the deflector is not affected inductively by the earth's force. In the method of sines a correction has on this account to be made; but, on the other hand, there is no torsion, and, from the symmetry of the position of the two magnets, the approximate formulæ have a more exact application.

The new pattern of the unifilar magnetometer is adapted for the method of sines. The instrument arranged as in fig. 29 is first carefully levelled, and fitted with the graduated cross bar D, which is so set in its sockets as to be perpendicular to the line of collimation of the telescope A. The box is opened, and the torsion removed from the suspending fibre by means of a plummet as already explained. The deflected magnet is then suspended so as to be at the same height as the deflecting magnet when the latter is placed in its carriage on the cross bar. The sides of the box are now closed, and the circle of the instrument turned until the middle division of the scale B, seen by reflexion from a mirror attached to the deflected magnet, is on the cross wires of the telescope A; the circle is then clamped, and the verniers read. The deflecting magnet K (the same as that used in the vibration experiments) is next placed in its carriage L on the cross bar at a distance r_1 (30 cm. or so) east; the circle is then turned until the middle division of the scale is again on the cross wires; the verniers are read once more. The difference between the two readings being θ_1, we have

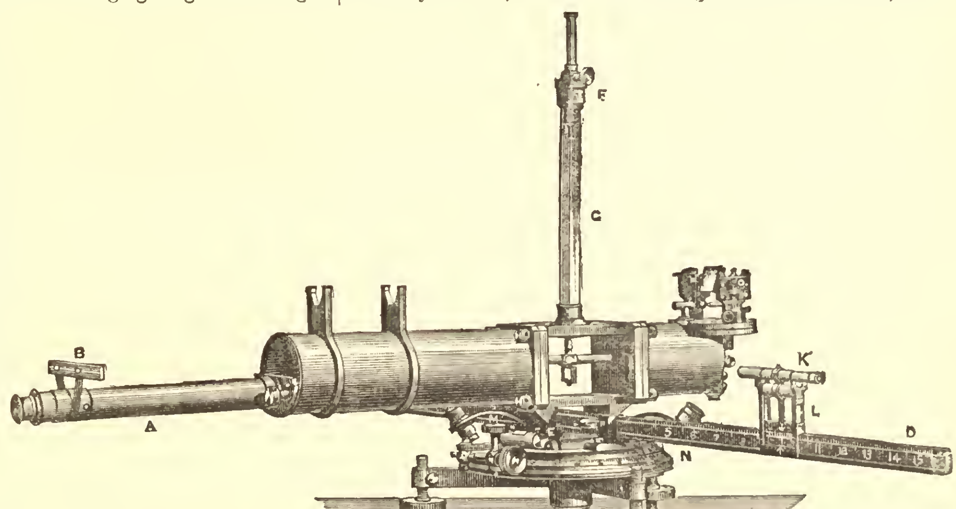

Fig. 29.—Unifilar Magnetometer, arranged to show deflexion.

[2] In this connexion see more especially Lamont. *Handb. d. Magnetismus*, pp. 282 *sq.*

[3] See Lamont, *Handb.*, p. 371; Maxwell, vol. iii. § 457.

$$\frac{r_1^3 H \sin\theta_1}{2K} = 1 - \frac{P_1}{r_1} + \frac{P_2}{r_1^2} + \ldots \quad (63).$$

The deflecting magnet is reversed in its carriage, and the whole operation repeated. If the deflexion now be θ_2, irrespective of sign, then

$$\frac{r_1^3 H}{2K} \sin\theta_2 = 1 + \frac{P_1}{r_1} + \frac{P_2}{r_1^2} + \ldots \quad (64).$$

The mean of these gives

$$\frac{r_1^3 H}{4K}(\sin\theta_1 + \sin\theta_2) = 1 + \frac{P_2}{r_1^2} + \ldots \quad (65).$$

The magnet is finally removed to a distance r_1 west, and the previous observations repeated; we thus get

$$\frac{r_1^3 H}{4K}(\sin\theta_3 + \sin\theta_4) = 1 + \frac{P_2}{r_1^2} + \ldots \quad (66).$$

The mean of (65) and (66) is then taken, and we get

$$\frac{r_1^3 H}{2K} S_1 = 1 + \frac{P_2}{r_1^2} \quad \ldots \quad (67),$$

where $S_1 = \frac{1}{4}(\sin\theta_1 + \sin\theta_2 + \sin\theta_3 + \sin\theta_4)$, or, what is practically the same, the sine of the mean of θ_1, θ_2, θ_3, and θ_4. The object in taking the mean of (65) and (66) is to eliminate any error arising from the non-coincidence of the middle point of the cross bar with the axis of suspension.

In order to eliminate P_2, another set of observations are made with a new distance r_2 (26 cm. or so), giving the equation

$$\frac{r_2^3 H}{2K} S_2 = 1 + \frac{P_2}{r_2^2} \quad \ldots \quad (68).$$

From (67) and (68) we have finally

$$\frac{K}{H} = \frac{r_1^5 S_1 - r_2^5 S_2}{2(r_1^2 - r_2^2)};$$

$$P_2 = \frac{r_1^2 r_2^2 (r_2^3 S_2 - r_1^3 S_1)}{r_1^5 S_1 - r_2^5 S_2}.$$

When great accuracy is required, several corrections have to be applied:—(1) the moment of the deflector must be corrected for induction; (2) the moment of the deflector must be corrected for temperature; (3) the lengths r_1 and r_2 on the cross bar must be corrected for temperature.

Statical instruments.

Statical Method.—There is another method by which we may determine the product KH, viz., we may oppose a statical couple to the couple exerted by the earth on the magnet in a given position, so that there may be equilibrium; the statical couple, which may arise from the torsion of a fibre, from a bifilar suspension, or other gravitational force, thus becomes the measure of the magnetic couple; and hence KH can be determined in absolute measure. Coulomb's torsion balance experiments are an example of this method. It finds numerous applications in the variation instruments of fixed magnetical observatories, and also in instruments for magnetic observations at sea, but it is very little used in the ordinary work of a physical laboratory.

Measurements by electromagnetic induction.

Magnetic Measurement by Electromagnetic Induction.—It has been explained in the article ELECTRICITY that, if, either owing to the variation of the magnetic field, or owing to the motion of a closed linear conductor in it, the number of lines of magnetic force N passing in the positive direction through the conductor vary, this variation will cause an electromotive force $-dN/dt$ in the positive direction round the circuit. Let us suppose, to take a simple case, that we have a coil of wire made up of a number of parallel plane circular windings, and that the sum of all the areas of the separate windings is A. If we place this in a field of uniform intensity R, so that the normal to the windings makes an angle θ with R, the number of lines of force passing through the coil will be $N_1 = AR\cos\theta$. If we now suddenly reverse the coil, by turning it through 180° about an axis perpendicular to its normal, the value of N in the new position is $N_2 = -AR\cos\theta$. Hence the *integral* electromotive force during the motion is $-\int dt dN/dt = N_2 - N_1 = -2AR\cos\theta$, and the whole quantity Q of electricity which passes will be $Q = -2AR\cos\theta/S$, where S is the resistance of the coil. If Q be found in absolute measure,[1] and A and S be known, we thus obtain the value of $R\cos\theta$. This is the principle of Weber's "earth inductor,"[2] by means of which the horizontal and vertical components of the earth's force can be measured, and in consequence the declination and inclination determined.

Weber's earth inductor.

Verdet's exploring coil.

If the test coil be made very small, so that the portion of the field which it occupies may be supposed uniform, this method may be applied to measure the intensity at different parts of a non-uniform field.[3] The small coil is placed with its windings perpendicular to the lines of force, and then suddenly reversed, or, if that be impossible, suddenly removed to a part of the field where the number of lines of force passing through it is zero. The integral electromotive force is of course in the latter case only half what it is in the former. This method is often of use where, owing to the great strength of the field and the consequent disturbances arising from induction, any other method would be utterly useless.

Magnetic moment determined by electro-magnetic induction.

The method of electromagnetic induction may also be applied to measure the component of the magnetic moment of any body parallel to a given line.

Let $aa'bb'$ (fig. 30) be the section of a uniform cylindrical coil of length $2l$, made up of a single layer of flat circular windings of radius b, n to the centimetre. Let the axis of the coil be taken for x-axis, and let K be any magnet within the coil, placed with

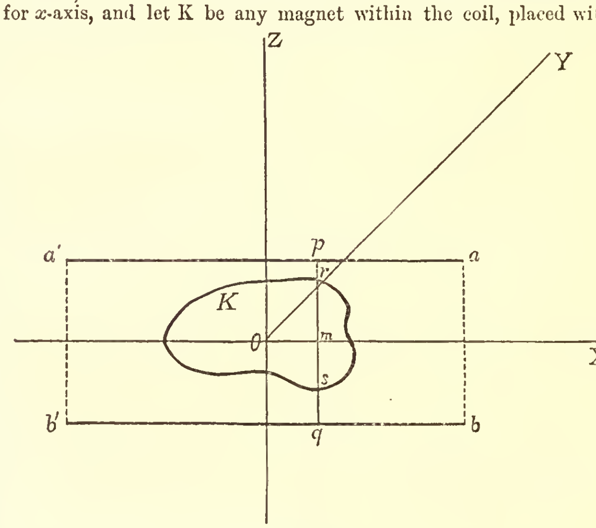

Fig. 30.

the given line parallel to the axis of the coil. Let pq be any single winding of the coil, then the surface integral of the magnetic induction for pq is given by $\iint a\,dydz$; hence the whole number of lines of force through the coil is given by

$$N = \int n dx \iint a\,dydz,$$

$$= n\iiint a\,dxdydz,$$

the integration being extended all over the cylindrical space $abb'a'$. Now, since $a = \alpha + 4\pi A = -dV/dx + 4\pi A$, we get

$$\left.\begin{aligned} N &= -n\iiint \frac{dV}{dx}dxdydz + 4\pi n\iiint A\,dxdydz, \\ &= -n\left(\iint V dydz - \iint V' dydz\right) + 4\pi n K, \\ &= +4\pi n K - n(S - S') \end{aligned}\right\} \quad (69),$$

where K is the component parallel to the axis of the coil of the moment of the magnet, and S and S′ the values of the surface integral of the potential of the magnet (derived from Poisson's distribution) over the two ends of the coil. When there are more layers than one, we must of course sum the different parts of N arising from the different layers.

The formulæ are quite general, and some applications will be given later. Meantime we see that, if the coil be

[1] See arts. ELECTRICITY and GALVANOMETER.
[2] *Pogg. Ann.*, xc., 1853.
[3] *Cf.* Verdet, *Ann. d. Chim. et d. Phys.*, xli., 1854.

so long that the magnetic potential of the body at its two ends may be neglected, then the integral electromotive force caused by the sudden removal of the body, or by the sudden destruction of its magnetism, is $4\pi n$ times the component of the magnetic moment parallel to the axis of the coil, n being the number of windings per unit of length of the coil.

[Early vibration observations.] *Historical Remarks on the Progress of Magnetic Measurements.*—The method of vibrations came very early into use in magnetic measurements. Whiston and Graham made vibration observations with a dipping needle. Musschenbrock and Mallet also used a horizontal needle. Lambert appears, however, to have been the first to thoroughly understand and appreciate the method. For long it was the only accurate process in use for obtaining relative measures of the earth's force. It was so used by Rossel, D'Entrecasteaux, and Humboldt. Coulomb, Hansteen, and Poisson, all contributed more or less to its improvement; and it finally reached perfection in the hands of Gauss,[1] who gave the experimental process for obtaining the moment of inertia, investigated the correction for resistance, and, by the introduction of the mirror and scale method, imparted astronomical accuracy to the determination of the period of vibration.

The method of deflexion, in one form or another, is very old. Its existence as a thoroughly scientific method, however, dates from Hansteen. The essential improvement of eliminating the constants depending on the magnetic distribution by observations at different distances is due to Gauss. The advantages of the sine method were first pointed out by Lamont in 1841.[2]

[Poisson first suggests absolute magnetic measurements.] Poisson seems to have been the first to conceive the idea of absolute magnetic measurement. In a short but luminous article at the end of the *Connaissance des Temps* for 1828, he describes a method for obtaining the value of H in absolute measure. Horizontal vibration experiments are to be made with two magnets A and A′, whose moments of inertia A and A′ are known. The times of vibration t and t' of A and A′, each suspended alone, are to be observed. Then both are to be placed in the magnetic meridian at a distance r apart in the same horizontal line, and the periods θ and θ' observed, of A when A′ is fixed, and of A′ when A is fixed. If r be very great compared with the linear dimensions of A and A′, then

$$H^2 = \frac{8\pi^2\theta\theta'\sqrt{AA'}}{r^3tt'\sqrt{(t^2-\theta^2)(t'^2-\theta'^2)}}.$$

He recommends, however, that comparatively small values of r be taken, and the constants of distribution eliminated by experimenting at different distances. His fundamental units are the gramme, metre, and second.

Nothing came of Poisson's proposal until Gauss took up the subject, both theoretically and experimentally, as above described. The first absolute measure of the earth's horizontal force was made by him at Göttingen on the 18th September 1832; the value found was 1·782[3] in millimetre milligramme second units. The magnet he used (about a foot long and weighing about 1 lb) had for its moment 100877000[4] in the same units.

[Determination of magnetic distribution.] *The determination of the distribution of magnetism within a body*, in other words, the determination of the magnetic moments of its individual elements, by observations of magnetic force at external points, is, as we have seen, an indeterminate problem. Nevertheless, a considerable part of the literature of magnetic science relates to it; and we must give some account of what has been done, although the results obtained are of comparatively slight physical interest, and of small practical value.

["Free magnetism," different uses of the phrase.] Experimenters have been somewhat slow in recognizing the essential indeterminateness of the problem. This no doubt has arisen from their imperfect analysis of the phenomena. Thus, although we cannot determine the actual internal distribution, yet the problem to determine the Gaussian surface distribution which will represent the magnetic action at all external points, however difficult, is quite determinate. This surface distribution has been called by some the "free magnetism" of the body; and some, all the powerful contrary evidence notwithstanding, have imagined that this distribution has a physical existence, and have even spoken of the depth to which the free magnetism penetrates into the magnet. Others have confounded the free magnetism of Gauss's distribution with that of Poisson's; and in many cases it is impossible to gather what the experimenter meant to indicate exactly by the phrase.

The case in which, from the circumstances, the variation of the internal distribution is confined within the narrowest limits is that of bar magnets, whose length considerably exceeds their lateral dimensions; and this is practically the only case that has been much studied. The most natural way of attempting to represent the action of such a magnet would be to suppose it replaceable by a fixed ideal magnet, and then to determine by experiment the strength and position of the poles of this magnet. The earliest notion was that the poles were situated exactly at the ends of the bar. It was soon found, however, that, if the poles did exist, they were not in general exactly at the ends. Lambert and Kupfer[5] concluded from their experiments that in many cases the poles lay outside the bar, while in weak magnets they lay inside. Coulomb, as we have seen, and also Dalla Bella, inferred from their results that the poles fell within. Recent experiments have been made by Pouillet,[6] by Benoit,[7] by Petruscheffsky,[8] and by others on the same subject; but it is needless to describe them here.

["Poles," different meanings of.] The word "pole," like the phrase "free magnetism," has been used by different writers in very different senses. Some have applied that name to the mass centres of the positive and negative magnetism of the actual molecules. But, although as a matter of convenience we have used these points in our theoretical development, they have, as far as physical observations are concerned, no existence. Others have defined the poles to be the mass centres of the positive and negative parts of Gauss's surface distribution. These might of course be determined, although the process would be extremely troublesome, and the result of no practical value whatever. In point of fact, if the magnet be in a uniform field, *i.e.*, at a very great distance from the system that acts on it, the action depends solely on the magnetic moment, and the magnetic distribution has nothing to do with it; the poles in this case are physically indeterminate. If, on the other hand, two magnets are within a moderate distance of each other, we may set to ourselves the problem to find two points in each of them such that the mutual action will be represented by quantities of positive and negative magnetism concentrated there. Then, in general, such points may or may not exist. Riecke has shown (see above, p. 233) that, if the distance between the magnets exceed a certain limit, then, as a matter of approximation, these equivalent poles, as he calls them, do exist. Except, however, in the case of magnets symmetrical about an axis, and also about an equatorial plane, they are not fixed in the magnets, but

[1] See his memoir, "Anleitung zur Bestimmung der Schwingungsdauer einer Magnetnadel," in *Res. d. Mag. Ver.*, 1837.
[2] *Handb. d. Magnetismus*, p. 309.
[3] ·17821, *C. G. S.*
[4] 10087·7, *C. G. S.*
[5] See Lamont, *Handb. d. Magnetismus*, p. 294 *sq.*
[6] *Comptes Rend.*, 1868.
[7] *Comptes Rend.*, 1875.
[8] *Pogg. Ann.*, clii., 1874, and clx., 1877.

depend upon their relative position. Although his results are extremely interesting from a mathematical and theoretical point of view, we do not see that much practical advantage would attend the use of these equivalent poles; and we are inclined to think that, except in the popular usage for distinguishing one end of a magnet from the other, and in the case of ideal magnets, the word pole had better be abandoned altogether.

Distribution in a linear magnet.

The idea of representing the action of a linear magnet by a continuous distribution of free magnetism, positive in one half and negative in the other, is very old. It appears in Bazin's work on the magnetic curves published in 1753; and Tobias Mayer, in his memoir above quoted, assumes that the density of the distribution is proportional to the distance from the middle of the bar. Four distinct methods have been used in attempting to determine the law of distribution.

1. The deflexions of a small needle in different positions near the magnet have been observed, and by means of these the constants in some formula assumed for the distribution have been calculated. This was the process adopted by Lambert and Hansteen, and, in some of his experiments, by Lamont.[1]

2. Instead of measuring deflexion, we may count the oscillations of the needle, and proceed as before. This method was used by Coulomb, Becquerel, and Kupfer, but it led to no satisfactory results, partly owing to the disturbances arising from induction and the force of translation upon the needle, partly owing to the difficulty of putting a satisfactory theoretical interpretation upon the results.

Different methods employed.

3. Some observers have measured the force required to detach a small armature of soft iron or steel from different parts of the bar, thinking thereby to obtain a direct measure of the free magnetism. It is not very easy to say what is measured by this process, but it is obvious, on a little consideration, that the effect is complex, depending greatly on the nature and extent of the surfaces in contact, and also upon the mutual induction between the magnet and the armature. Experiments of this kind have been made by Dub, Lamont, and others.

4. Another method frequently employed is to slide along the bar a small ring-shaped coil embracing it as closely as possible, and to measure the induction currents for a given displacement. The assumption usually made is that the integral electromotive force is proportional to the free magnetism on the portion of the bar passed over, or, what amounts to the same thing, to the difference between the magnetic moments per unit of length of the sections of the bar on which the coil rests at the beginning and end of the motion. This is, however, only an approximation to the truth, and the accuracy of this approximation is very difficult to estimate in the practical case where the lateral dimensions of the bar are finite. The following investigation will show the nature of the difficulty.

The integral electromotive force is $-(N_1 - N_2)$, where N_1 and N_2 are the surface integrals of magnetic induction taken over the coil in its initial and final positions. Let us take first a linear solenoid SN (fig. 31) of length l, and magnetic moment m, and a coil of a single winding PQ, which moves so that its centre R is always in the line SN, and its plane always perpendicular to SN; then

$$N = \iint a\,dydz = \iint \alpha\,dydz + 4\pi\iint A\,dydz ,$$

the former integral extending all over PQ, the latter over the infinitely small section of the solenoid at R, α being the force due to the end distribution at N and S. We thus get

$$N = \frac{2\pi m}{l}(\cos\theta - \cos\theta') \quad . \quad . \quad . \quad . \quad . \quad (70),$$

where θ and θ' are the angles PSX and PNX. This shows, in the first place (see equation (25) above), that if the coil PQ were to expand and contract as it moves, so as always to remain a section of the same tube of force, there would be no variation of N, and no electromotive force, which is as it should be. If we were at liberty to suppose PQ infinitely small, then, when R is between S and N, $\cos\theta - \cos\theta'$ would be the sum of two unities, and, when R is outside, the difference. In such a case, so long as PQ moved on the magnet, there would be no electromotive force, but if we suddenly move it over the end, there would be an electromotive force

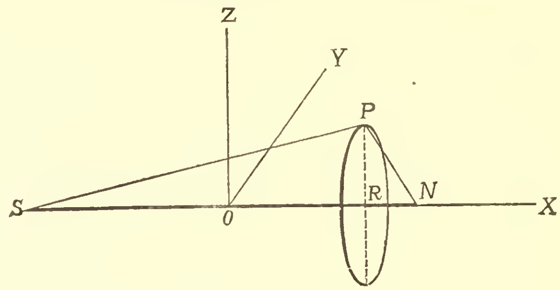

Fig. 31.

$-4\pi m/l$, which is proportional to the moment of the bar. When PQ is not infinitely small, there is a variable part of N, depending on the dimensions of PQ, which will give rise to an electromotive force, even when the coil is moved along a uniformly magnetized bar, where there is no free magnetism except at the ends.

It is now easy to form a conception of what happens in the case of an ordinary complex solenoidal bar. We may suppose such a bar made up of a number of simple linear solenoids. A certain number of these, corresponding to the end parts of Poisson's distribution, will have the same length as the bar; the others, corresponding to the lateral surface and volume parts of the distribution, will be of continuously diminishing lengths. If we were at liberty to suppose the lateral dimensions of the bar and the radius of the coil to be infinitely small, then, as the coil moves along the bar, we should have an electromotive force due to passage over the ends of the short solenoids, and, as it moves over the end, an electromotive force due to passage over the ends of the long solenoids. We might in this way by a sufficient number of observations determine the distribution of the free magnetism throughout the bar and at its ends; and in this case no distinction would be necessary between the volume and the surface distribution in any section.

If, however, the dimensions of the section of the bar, and consequently of the coil, be finite, a correction would have to be applied, depending, not only on the dimensions of the bar and coil, but also on the magnetic distribution. All that we can then do is to assume a formula for Gauss's surface distribution and determine its constants. We thus get Gauss's distribution, and a formula that will account for the electrical observations; *but we obtain no information as to the actual internal distribution of the magnetism in the bar.*

Lenz and Jacobi[2] appear to have been the first to apply the method of induction currents to the measurement of the magnetic distribution in bar magnets. They attempted no theoretical analysis of their results, although they assigned a law of distribution. Van Rees,[3] who questioned their conclusions, gave an imperfect theory, and made some careful researches of his own. Rothlauf[4] made further experiments, and entered more fully into the theory, though still with insufficient generality. The most recent experiments of the kind we are aware of are those of Schaper,[5] who discusses the theory with complete generality, taking account of the ends of the bar.

Different laws assigned.

After what has been said, the reader will scarcely be surprised to find that the different experimenters assigned very different formulæ for the distribution in bar magnets. Lambert deduces from his experiments a distribution whose density is Ax,—A being a constant, and x the distance from the ends of the bar. Brugmans, V. Swinden, and Lenz and Jacobi adopt the law Ax^2; Hansteen, as we have seen, the law Ax^r, where $r = 2$ or 3. Biot deduced from Coulomb's experiments the law $A(\mu^x - \mu^{-x})$ for the density of the free magnetism, which would give for the moment per unit of length of the bar the law $a - b(\mu^x + \mu^{-x})$, see above, p. 231. Becquerel,

[1] See also Airy and Stuart, *Phil. Mag.*, 1873.

[2] *Pogg. Ann.*, lxi., 1844.

[3] *Over de Verdeeling van het Magnetismus in Magneten*, Amst., 1847.

[4] *Pogg. Ann.*, cxvi., 1862.

[5] *Wied. Ann.*, ix., 1880.

Van Rees, Lamont, and Rothlauf favour this last formula; but none of these experimenters give any proper account of the ends, which must be specially represented in all but those cases where the magnetic moment is zero there. Schaper finds that the results of experiment can be adequately represented by means of end distributions, and a lateral surface distribution following the law $Ax+Bx^3$. See his paper above quoted, p. 242.[1]

[Theory of carrying power; experiments on it.] *Carrying Power of a Magnet.*—It is obvious that the magnetization of a piece of iron must affect its force of cohesion. The most familiar case is that of a magnet to which an armature is fitted. If the surfaces of the pole and armature be carefully ground flat, so as to fit, we may regard the magnet and the armature as continuations of each other. The force of cohesion here is mainly due to the magnetism; and the force required to separate the two is called the "carrying power" of the magnet. To simplify the question, let us consider a cylindrical bar of section ω, uniformly magnetized in the direction of its length with intensity I. Suppose the bar cut so that the normal to the plane of section makes an angle θ with I, and let the surfaces of section be separated infinitely little, then the surface density of Poisson's distribution will be $I\cos\theta$ on each surface. Assuming that the cohesion is caused solely by the attraction of these surface layers, we get for the carrying power $P=2\pi I\cos\theta\times I\cos\theta\,\omega\sec\theta$, *i.e.*, $P=2\pi I^2\omega\cos\theta$. The carrying power is therefore greatest, viz., $2\pi\omega I^2$, when the surface of the pole is perpendicular to the lines of magnetization.

A great variety of experiments have been made on this subject by Joule, Dub, Tyndall, Lamont, and others, mostly, however, under circumstances that do not admit of the application of the above theory. For an account of what has been done, the reader should consult Wiedemann's *Galvanismus*, ii. § 425 *sq.* The most recent investigations on the subject will be found in the papers of Rowland, quoted below, p. 255, and in papers by Stefan and Wassmuth in the *Monatsberichte der Weiner Akademie* for 1880 and 1882.[2] The facts are not so simple as the above theory would indicate; but Wassmuth finds a modified form of it to agree sufficiently well with observation.

Mathematical Theory of Magnetic Induction.

[Axioms of magnetic induction.] The two fundamental axioms of this theory are the following:—

1. The induced magnetism in any element of a body depends merely on the magnitude and direction of the resultant magnetic force ($\mathfrak{H}$) at the element.

2. The magnetic moment induced by any force $\mathfrak{H}$ is the resultant of the magnetic moments induced separately by any forces of which $\mathfrak{H}$ is the resultant.

With reference to axiom 1 it is to be remarked that account must be taken of the physical condition of the body as to temperature, and so forth; but it is implied that no account is to be taken of its magnetic state, except in so far as that affects the resultant magnetic force. In other words, it is asserted that the moment induced by any force does not depend upon any pre-existing magnetic moment in the element, and is the same whatever forces may have acted on the element previously. The full significance of these statements will be better appreciated when we come to consider the exceptions to them in case of strongly magnetic bodies. It should also be noticed that it is supposed that the body has reached a state of magnetic equilibrium, and that by whole resultant magnetic force is understood, not only that arising from the given inducing system, including pre-existing magnetism in the body itself, but also that arising from induced magnetism.

In the mathematical theory no distinction is drawn between the part of the induced magnetism which disappears when the inducing force is removed, and that which remains. If anywhere we contemplate what happens after the removal of the force, it is assumed that *all* the induced magnetism disappears. This important restriction must be borne in mind in applying the results in practice.

Axiom 2 enables us to assign at once the law connecting the components of induced magnetization A_1, B_1, C_1 with the components α, β, γ of the resultant force. If r_1, q_3, p_2 be the components parallel to the three coordinate axes of the induced magnetization caused by a unit resultant force parallel to the axis of x, then, by the axiom, the components of magnetization induced by a force α in the same direction will be $r_1\alpha$, $q_3\alpha$, $p_2\alpha$; similarly, if p_3, r_2, q_1 be the components due to unit force parallel to the y axis, then the components due to β will be $p_3\beta$, $r_2\beta$, $q_1\beta$; and finally, if q_2, p_1, r_3 be components due to unit force parallel to z axis, the components due to γ will be $q_2\gamma$, $p_1\gamma$, $r_3\gamma$. Compounding all these, according to the axiom, we get

[General law of induction.]

$$\left.\begin{aligned}A_1&=r_1\alpha+p_3\beta+q_2\gamma\\B_1&=q_3\alpha+r_2\beta+p_1\gamma\\C_1&=p_2\alpha+q_1\beta+r_3\gamma\end{aligned}\right\}\quad\quad(71).$$

Hence the most general expressions for the components of magnetization compatible with our axioms are three linear functions of the components of the resultant force.

Here it is necessary to introduce a classification of bodies according to their magnetic properties.

[Homogeneity and heterogeneity.] If equal, similar, and *similarly situated* elements cut from different parts of a body have identical magnetic properties, it is said to be "magnetically homogeneous," if not, "heterogeneous."

[Isotropy and æolotropy.] If equal and similar elements cut around the same point *in different directions* be identical in their magnetic properties, the body is said to be magnetically "isotropic"; if not, "æolotropic."

These are not cross classifications; for a body (*e.g.*, Iceland spar) may be æolotropic and yet homogeneous, and it might be heterogeneous and yet isotropic. We must regard the coefficients p, q, r of (71) as belonging to a point of the body; and we see that in a homogeneous body they will be the same for all points, whereas in a heterogeneous body they will vary from point to point, *i.e.*, they will be functions continuous or discontinuous of the position of the point.

[Law of induction for isotropics.] In the case of an isotropic body it is obvious *a priori* that the induced magnetization must be coincident in direction with the resultant force; the conditions for this are that the coefficients p and q should all vanish, and that $r_1=r_2=r_3=\kappa$. The equations (71) thus reduce to

$$A_1=\kappa\alpha\,,\ B_1=\kappa\beta\,,\ C_1=\kappa\gamma\quad\quad(72).$$

In an æolotropic body, on the other hand, the coefficients may be all different from zero and from one another; but, as we shall see, at all events in the ideal case contemplated by the mathematical theory, the conservation of energy reduces the number of independent constants by three; while a proper choice of axes reduces it by three more; so that the magnetic properties of any element of an æolotropic body depend virtually on three independent constants.

The theory here given is the generalization of Poisson's theory due to Sir William Thomson. It aims at giving the simplest possible exposition of the results of experiment with the fewest assumptions as to the molecular structure of bodies. We first discuss specially a few of the cases

[1] Various experimenters have attempted to determine the "indifference zone" of magnets under different circumstances, *i.e.*, the line separating the positive and negative parts of the surface distribution. For information as to this and other matters under the present head omitted for want of space, see Wiedemann, *Galvanismus*, ii. §§ 277, 356, 396, 401; and Lamont, *Handbuch*, §§ 6, 27, 63, 64, 65.

[2] Abstracted in *Wied. Beibl.* 1880 and 1882; see also Von Waltenhofen, *Wien. Ber.*, 1870, and Siemens, *Berl. Monatsber.*, 1881.

more important in practice, and then give a brief account of the general theory with a view to establish some general principles to guide us in the subsequent account of the (often very complex) phenomena observed by experimenters.

Synthetic solution for a sphere in uniform field.

Homogeneous Æolotropic Sphere in a Uniform Field of Inductive Force.—We suppose that the sphere, to begin with, is not magnetized. If the sphere were uniformly magnetized,[1] with components A_1, B_1, C_1, then (see above, p. 232) the force inside the sphere due to this magnetization would have for its components

$$\alpha_1 = -\tfrac{4}{3}\pi A_1\,,\ \beta_1 = -\tfrac{4}{3}\pi B_1\,,\ \gamma_1 = -\tfrac{4}{3}\pi C_1\,.$$

This uniform force combined with the given uniform force $(\alpha_0, \beta_0, \gamma_0)$ of the inductive field would result in a uniform force

$$\alpha = \alpha_0 - \tfrac{4}{3}\pi A_1\,,\ \beta = \beta_0 - \tfrac{4}{3}\pi B_1\,,\ \gamma = \gamma_0 - \tfrac{4}{3}\pi C_1 \quad . \quad . \quad (73).$$

It is obvious therefore that the assumption of uniform magnetization will enable us to satisfy the law of induction.

In point of fact, substituting in (71) and transposing, we get three linear equations to determine A_1, B_1, C_1 in terms of α_0, β_0, γ_0, viz.,

$$(1 + \tfrac{4}{3}\pi r_1)A_1 + \tfrac{4}{3}\pi p_3 B_1 + \tfrac{4}{3}\pi q_2 C_1 = r_1\alpha_0 + p_3\beta_0 + q_2\gamma_0\,,\ \&c. \ . \quad (74).$$

Reduction in the number of induction coefficients.

It is easy, by means of these and formulæ given above, to calculate the couple exerted on the inductively magnetized sphere. If we put $\alpha_0 = 0$, $\beta_0 = F\cos\theta$, $\gamma_0 = F\sin\theta$, we can calculate the work done on the sphere in turning through 180° about an axis perpendicular to the direction of the field. This, by the conservation of energy, ought to vanish, and we thus get the conditions $p_1 = q_1$, $p_2 = q_2$, $p_3 = q_3$. The equations (74) therefore reduce to

$$\left.\begin{aligned} A_1 &= r_1\alpha + p_3\beta + p_2\gamma \\ B_1 &= p_3\alpha + r_2\beta + p_1\gamma \\ C_1 &= p_2\alpha + p_1\beta + r_3\gamma \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (75).$$

Hence, if α, β, γ be parallel to a radius of the central quadric

$$r_1x^2 + r_2y^2 + r_3z^2 + 2p_1yz + 2p_2zx + 2p_3xy = 1\,,$$

A_1, B_1, C_1 will be normal to the diametral plane of that radius. We have, therefore, by the theory of surfaces of the second degree, the following conclusions.

Three principal magnetic axes.

1. The induced magnetization is not in general in the direction of the inducing force; but there are in general at every point three directions, called the three principal magnetic axes, mutually at right angles to each other, for which the directions of the induced magnetization and of the inducing force coincide. If the axes of coordinates be parallel to these principal axes, the equations (75) reduce to

$$A_1 = r_1\alpha\,,\ B_1 = r_2\beta\,,\ C_1 = r_3\gamma \quad . \quad . \quad . \quad . \quad (76).$$

Principal magnetic inductive susceptibilities.

The values of r_1, r_2, r_3 in this case are called the "principal magnetic inductive susceptibilities." Bodies for which these coefficients are all positive are called paramagnetic or ferromagnetic. Bodies for which they are all negative are called diamagnetic. No substance is known for which some are positive and others negative, although this is a mathematically possible case. Since intensity of magnetization and resultant magnetic force are of the same dimension $[L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}]$, r_1, r_2, r_3 are pure numbers; for all substances except iron, nickel, and cobalt, they are extremely small. The value of the coefficients r and p for any other axes can be expressed in terms of the three principal susceptibilities by means of simple formulæ which we need not stop to deduce.

A physical meaning can be given to r_1, as follows. Let the body be homogeneous, and let us cut from it a cylindrical piece whose axis is parallel to the principal axis of susceptibility r_1. Place this cylinder in the direction of the lines of force in a uniform field of unit strength, then, provided the cylinder be infinitely thin, and of longitudinal dimensions infinitely great compared with its lateral, the internal force due to the induced magnetization will be zero (see above, p. 229), and it will be magnetized inductively with a uniform intensity r_1. Similarly for r_2, r_3.

Principal permeabilities.

The three coefficients

$$\varpi_1 = 1 + 4\pi r_1\,,\ \varpi_2 = 1 + 4\pi r_2\,,\ \varpi_3 = 1 + 4\pi r_3\,,$$

used later on, are called by Thomson the three principal permeabilities of the body at any point. These are of course pure numbers, and they are positive for all known substances.

2. If the susceptibilities for any two principal axes be equal, then every axis in the plane of these two is a principal axis.

3. If all three principal susceptibilities be equal at any point, then every axis through that point is a principal axis, and the susceptibility for every such axis is the same. The body is therefore isotropic at that point, and the direction of the induced magnetization coincides with the direction of the inductive force for every direction of the latter.

Magnetization and couple for sphere in uniform field.

Returning to the problem of the æolotropic sphere, let us simplify our equations by taking the coordinate axes parallel to the common directions of the principal axes throughout the homogeneous sphere. We then get for the components of magnetization

$$A_1 = \frac{r_1}{1 + \frac{4}{3}\pi r_1}\alpha_0\,,\ B_1 = \frac{r_2}{1 + \frac{4}{3}\pi r_2}\beta_0\,,\ C_1 = \frac{r_3}{1 + \frac{4}{3}\pi r_3}\gamma_0 \quad . \quad (77).$$

Using these formulæ, we get, by means of (22), for the components of the couple acting on the sphere (of volume v),

$$\left.\begin{aligned} \mathfrak{L} &= v\frac{r_2 - r_3}{(1 + \frac{4}{3}\pi r_2)(1 + \frac{4}{3}\pi r_3)}\beta_0\gamma_0 \\ \mathfrak{M} &= v\frac{r_3 - r_1}{(1 + \frac{4}{3}\pi r_3)(1 + \frac{4}{3}\pi r_1)}\gamma_0\alpha_0 \\ \mathfrak{N} &= v\frac{r_1 - r_2}{(1 + \frac{4}{3}\pi r_1)(1 + \frac{4}{3}\pi r_2)}\alpha_0\beta_0 \end{aligned}\right\} \quad . \quad . \quad . \quad (78).$$

There is of course no force of translation. As a special case let us suppose r_1, r_2, and r_3 to be in descending order of algebraical magnitude, and suspend the sphere with the axis of r_1 perpendicular to the lines of force. We may put $\beta_0 = F\cos\theta$, $\gamma_0 = F\sin\theta$, where θ is the angle between the axis of γ (r_2) and the direction of the field, then we have

$$\mathfrak{L} = \tfrac{1}{2}vF^2(r_2 - r_3)\sin 2\theta/(1 + \tfrac{4}{3}\pi r_2)(1 + \tfrac{4}{3}\pi r_3).$$

Hence the sphere tends to turn so as to place the axis of algebraically greatest susceptibility parallel to the lines of force. It will be in equilibrium when either principal axis is parallel to the lines of force; but in stable equilibrium only when the axis of greatest permeability is in that position. It is to be noticed that the couple is proportional to the square of the strength of the field.

There is another way of expressing these results more in accordance with the ideas of Faraday.

If N be the surface integral of magnetic induction taken over the meridian section (ω) of the sphere perpendicular to the direction of the vector $\mathfrak{B}$ inside, or, as we may call it, the number of lines of force that pass through the sphere, then we have

$$N = 3F\omega\left\{\left(\frac{\varpi_2}{\varpi_2 + 2}\right)^2\cos^2\theta + \left(\frac{\varpi_3}{\varpi_3 + 2}\right)^2\sin^2\theta\right\}^{\frac{1}{2}},$$

$$\mathfrak{L} = -\frac{1}{24\pi^2 R}\,\frac{(\varpi_2 + 2)(\varpi_3 + 2)}{\varpi_2 + \varpi_3 + \varpi_2\varpi_3}\,\frac{d(N^2)}{d\theta}\,,$$

R being the radius of the sphere.

Deduction of Faraday's laws.

From these formulæ we can draw the following conclusions:—

1. *The number of lines of force that pass through the sphere is greatest, viz.,* $3F\omega\varpi_2/(\varpi_2 + 2)$, *when the axis of greatest permeability is parallel to the direction of the undisturbed field, and least, viz.,* $3F\omega\varpi_3/(\varpi_3 + 2)$, *when the axis of least permeability is in the same position.*

2. *In any position the number of lines passing through the spherical space is greater for a paramagnetic body, and*

[1] Here and in future the suffix 0 denotes components of magnetizing force, &c., due to given or pre-existent magnetization; while the suffix 1 denotes those due to induced magnetization. Letters without suffixes denote totals; *e.g.*, $\alpha = \alpha_0 + \alpha_1$, $A = A_0 + A_1$, and so on.

less for a diamagnetic body, than it would be if the sphere were absent.

3. *The sphere is in equilibrium when the number of lines of force passing through it is a maximum or a minimum, the equilibrium being stable in the former case, and unstable in the latter.*

duced agnet- ition of otropic here.

Homogeneous Isotropic Sphere in Uniform Field.—This case is obtained by putting $r_1 = r_2 = r_3 = \kappa$ in the above formulæ. The magnetization is parallel to the undisturbed field; and the couple vanishes, so that the sphere is in equilibrium in all positions. If the strength of the field be F, we get for the intensity of magnetization

$$I = \frac{\kappa}{1+\frac{4}{3}\pi\kappa}F = \frac{3}{4}\frac{(\varpi-1)}{\varpi+2}F\ ;$$

also

$$\mathfrak{N} = \frac{3\varpi}{\varpi+2}F\omega .$$

In order to familiarize the reader with this important case, we give two figures of the lines of force from Sir W. Thomson's *Reprint*, pp. 490, 491,—one for a paramagnetic

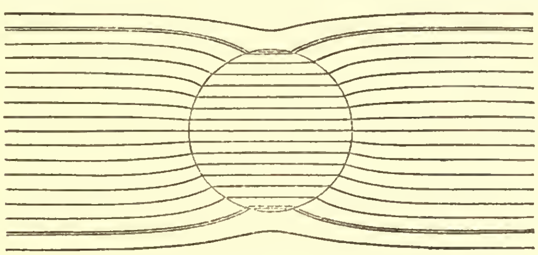

FIG. 32.—Lines of Force for a Paramagnetic Sphere.

(fig. 32) having $\varpi = 2{\cdot}8$, and another for a diamagnetic (fig. 33) having $\varpi = {\cdot}48$. The former represents a paramagnetic whose susceptibility is something like $\frac{1}{440}$th of the maximum observed for the best Norway iron. The latter corresponds to a diamagnetic having a susceptibility some 16,000 times that of bismuth, which is the most powerfully diamagnetic substance known.

The reader should observe that, although the field inside the isotropic sphere is uniform, this is not the case outside,

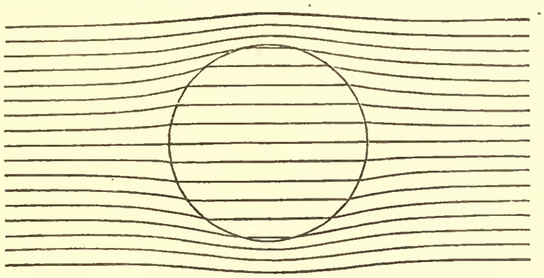

FIG. 33.—Lines of Force for a Diamagnetic Sphere.

a fact sometimes forgotten by experimenters. Of course the disturbance in the case of a bismuth sphere would be infinitesimal.

Eolotro- ic ellip- oid in niform eld.

Homogeneous Æolotropic Ellipsoid in a Uniform Field.—In the case of a sphere the tendency to set in a uniform field is wholly dependent on the æolotropy of the sphere, and is independent of its form. It is important, in order to get a complete picture of the behaviour of inductively magnetized bodies, to obtain a solution for some case where the form has an effect upon the result. A solid bounded by a surface of the second degree affords such a case.

If an ellipsoid be uniformly magnetized so that the components of magnetization parallel to its three principal axes a, b, c be A_1, B_1, C_1, this magnetization gives rise to a force

$$\alpha_1 = -A_1L\,,\quad \beta_1 = -B_1M\,,\quad \gamma_1 = -C_1N\ ;$$

when L, M, N have the values given above, p. 232. If we now place this ellipsoid in a uniform field $(\alpha_0, \beta_0, \gamma_0)$, the force inside will be given by

$$\alpha = \alpha_0 - A_1L\,,\quad \beta = \beta_0 - B_1L\,,\quad \gamma = \gamma_0 - C_1L \quad . \quad . \quad (79).$$

It is obvious, therefore, that the equations (75) of induction can, as in the case of a sphere, be satisfied by the assumption of uniform magnetization.

There is no difficulty in dealing with the general case in which the principal magnetic axes are not parallel to the principal axes of figure; we shall content ourselves, however, with the case in which the principal magnetic axes r_1, r_2, r_3 are parallel respectively to a, b, c. Equations (76) then give at once

$$A_1 = r_1(\alpha_0 - A_1L)\,,\quad B_1 = r_2(\beta_0 - B_1M)\,,\quad C_1 = r_3(\gamma_0 - C_1N) \quad (80);$$

whence

$$A_1 = \frac{r_1\alpha_0}{1+r_1L}\,,\quad B_1 = \frac{r_2\beta_0}{1+r_2M}\,,\quad C_1 = \frac{r_3\gamma_0}{1+r_3N} \quad . \quad . \quad (81).$$

The components of the magnetic moment are of course obtained at once from these by multiplying by the volume.

For the components of couple, $\mathfrak{L}, \mathfrak{M}, \mathfrak{N}$, tending to turn the ellipsoid about the axes a, b, c, we get

$$\left.\begin{array}{l}\mathfrak{L} = \frac{4}{3}\pi abc\,\dfrac{r_2 - r_3 + r_2r_3(N-M)}{(1+r_2M)(1+r_3N)}\beta_0\gamma_0 \\ \mathfrak{M} = \&c., \qquad \mathfrak{N} = \&c.\end{array}\right\} \quad . \quad . \quad . \quad (82).$$

From these equations we can draw the following important conclusions,—first as to the magnetization of the ellipsoid.

1. When r_1, r_2, r_3 are so small that their squares may be neglected, as in fact is the case with all bodies except iron, nickel, and cobalt, the components of magnetization reduce to $r_1\alpha_0$, $r_2\beta_0$, $r_3\gamma_0$. A glance at equations (79) will show that what happens is simply that the part of the internal inducing force which depends on the squares of the susceptibilities is not sensible. In other words, the *form* of the body is without influence on the induced magnetization. Or, what is again equivalent to the same thing, the induced magnetism may be supposed to produce no disturbance in the inducing field. With weakly magnetic substances the form does not affect the induced magnetization.

These conclusions are of course not limited to the ellipsoidal form in particular; but we have the general result that, *if the squares of the susceptibilities are negligible, then the form of the body has no effect on the induced magnetism.*

2. On the other hand, *when the susceptibilities* (and consequently the permeabilities) *are very great*, since $A_1 = \alpha_0/(1/r_1 + L)$, &c., it is clear that *the influence of the form of the body predominates.* The extreme case is that of a body of infinite permeability, in which the induced magnetism is wholly determined by the form. With strongly magnetic bodies the influence of form predominates.

3. If, however, the ellipsoid be very elongated in the direction of a, then L will be very small, and r_1L may be very small, notwithstanding the largeness of r_1. In that case $A_1 = r_1\alpha_0$. Exception.

4. From 1, 2, and 3 we have the following most important results. In experimenting with weakly magnetic bodies in a uniform field—in order, say, to determine their susceptibility—the form of the body is indifferent. On the other hand, with strongly magnetic bodies an elongated form must be used, because in that case only does the induced magnetism depend mainly on the susceptibility of the material. With bodies approaching the spherical form differences in form produce far more effect on the experimental results than differences in the susceptibility of the material, so that in such cases the experimenter really measures the accuracy of his instrument maker [1] more than the magnetic susceptibility of his material. Best form for determination of susceptibility.

5. For a flat disk (infinitely oblate ellipsoid), having its r_1 axis parallel to the lines of force, $L = 4\pi$, and $A_1 = r_1\alpha_0/(1+4\pi r_1) = \alpha_0(\varpi_1 - 1)/4\pi\varpi_1$. If such a body were diamagnetic, and had $r_1 = -1/4\pi$, *i.e.*, had zero Flat disk.

[1] As a matter of history, Riecke did unwittingly obtain in this way a tolerable approximation to the ratio of the circumference of a circle to the diameter. See Stoletow, *Phil. Mag.*, 1874, p. 202.

permeability, the normal magnetization would be infinite for any finite force.

Magnetic couple, two parts of.

Next, we have the following conclusions as to the magnetic couple. Let us suppose the ellipsoid free to move about its a axis, and let the direction of the field be perpendicular to a, so that $\beta_0 = \mathrm{F}\cos\theta$, $\gamma_0 = \mathrm{F}\sin\theta$; the couple tending to turn the b axis parallel to the undisturbed direction of the field is the sum of two parts:—

$$\mathfrak{L}_1 = \tfrac{2}{3}\frac{\pi abc\mathrm{F}^2(r_2 - r_3)}{(1 + r_2\mathrm{M})(1 + r_3\mathrm{N})}\sin 2\theta \quad . \quad . \quad . \quad . \quad (83),$$

and

$$\mathfrak{L}_2 = \tfrac{2}{3}\frac{\pi abcr_2r_3(\mathrm{N} - \mathrm{M})}{(1 + r_2\mathrm{M})(1 + r_3\mathrm{N})}\sin 2\theta \quad . \quad . \quad . \quad . \quad (84).$$

For small susceptibilities the effect of æolotropy predominates.

1. *If the susceptibilities are so small that their squares and products are negligible*, then $\mathfrak{L}$ reduces to

$$\mathfrak{L}_1 = \tfrac{2}{3}\pi abc\mathrm{F}^2(r_2 - r_3)\sin 2\theta.$$

In other words, *the form of the body has no effect*, and it behaves exactly like an æolotropic sphere of the same volume; *i.e.*, it will tend to turn its axis of greatest permeability parallel to the lines of force.

For large susceptibilities the effect of form predominates.

2. *If the susceptibilities be very large*, then the most important part of $\mathfrak{L}$ will be $\mathfrak{L}_2$. Now a glance at the values of M and N (34) shows that N − M has the same sign as $b^2 - c^2$; hence *the ellipsoid will tend to place its longest dimension parallel to the lines of force.*[1] This is the general effect of the influence of *form* in the case of strongly magnetic bodies, or, if we choose to put it so, the effect of the disturbance of the field by the induced magnetism.

3. It is of course possible in the case of strongly magnetic bodies that both parts of $\mathfrak{L}$ may be sensible, so that the resultant action would be affected both by form and by the magnetic structure, either predominating according to circumstances; for by properly shaping the ellipsoid we can give N − M any value positive or negative from 0 to 2π. In this way, given an æolotropic body for which $1/r_3 - 1/r_2$ is not greater than 2π, we might so shape it that it would turn its longest dimensions parallel to the lines of force, or so that it would turn its shortest dimensions parallel to the lines of force, the shortest axis in the second case being the axis of greatest permeability; or we might so shape it that the equilibrium would be neutral.

And, in general, given a body æolotropic within certain limits, we might shape it in such a manner that the effect of its form would exactly neutralize the effect due to its structure, so that, as far as setting in a uniform field is concerned,[2] it would behave like an isotropic sphere.

Isotropic ellipsoid.

Homogeneous Isotropic Ellipsoid in a Uniform Field.—The formulæ for this case are of course at once obtained by putting $r_1 = r_2 = r_3 = \kappa$ in the above formulæ. We thus get

$$\mathrm{A}_1 = \frac{\kappa\alpha_0}{1 + \kappa\mathrm{L}}, \quad \mathrm{B}_1 = \frac{\kappa\beta_0}{1 + \kappa\mathrm{M}}, \quad \mathrm{C}_1 = \frac{\kappa\gamma_0}{1 + \kappa\mathrm{N}} \quad . \quad . \quad . \quad (85);$$

$$\mathfrak{L} = \tfrac{4}{3}\frac{\pi abc\kappa^2(\mathrm{N} - \mathrm{M})\beta_0\gamma_0}{(1 + \kappa\mathrm{M})(1 + \kappa\mathrm{N})}, \quad \mathfrak{M} = \&\mathrm{c.}, \quad \mathfrak{N} = \&\mathrm{c.} \quad (86).$$

The following conclusions are worthy of notice:—

1. *The resultant magnetization will not, as in the case of an isotropic sphere, be parallel to the resultant magnetic force.*

Influence of form the same for a diamagnetic as for a paramagnetic body.

2. *The ellipsoid will tend to set its longest dimension parallel to the lines of force*; and, since κ is involved in the numerator in the form κ^2, *this conclusion is the same for a diamagnetic as for a paramagnetic body.* Of course we exclude the mathematically possible case of one of the factors $1 + \kappa\mathrm{M}$ or $1 + \kappa\mathrm{N}$ vanishing or becoming negative. For all weakly magnetic bodies, however, κ is so small that the tendency of an elongated isotropic body to set in a *uniform* field is insensible.

Tore.

Ring Electromagnet.—A simple case,[3] which has recently acquired practical importance, is that of an electromagnet having a soft iron core shaped like an anchor ring, whose mean diameter is R, and radius of section a, wound uniformly with n turns of a primary coil in which flows a current i. The lines of force and the lines of magnetization will evidently be circles, and, since the Poisson's surface and volume distributions vanish, the whole magnetic force $\mathfrak{H}$ will be simply that due to the current. At a distance ρ from the axis of the ring $\mathfrak{H} = 2ni/\rho$; for the whole work done on a unit pole in passing round any coaxial circle of radius ρ is $\mathfrak{H} \times 2\pi\rho = 4\pi ni$.[4] The intensity of magnetization is, therefore, $\mathrm{I} = 2n\kappa i/\rho$, and $\mathfrak{B} = 2ni(4\pi\kappa + 1)/\rho = 2n\varpi i/\rho$. Hence it appears that the total induction through a secondary coil of n' windings is $2nn'i(4\pi\kappa\int d\mathrm{S}/\rho + \int d\mathrm{S}'/\rho)$, where $\int d\mathrm{S}/\rho$ is taken over the section of the core, and $\int d\mathrm{S}'/\rho$ over the section of the coil. In the case of an anchor ring of circular section, if we neglect the difference between the radius of the primary coil and the radius of the core, the expression for the total induction through the secondary is $4\pi nn'\varpi i(\mathrm{R} - \sqrt{\mathrm{R}^2 - a^2})$.

Small sphere non-uniform field.

In a *non-uniform field* the problem of magnetic induction becomes very difficult for bodies of finite size. If, however, we deal with infinitely small bodies we may suppose the field uniform throughout the body, and apply the results already obtained to find the induced magnetism.

Small Æolotropic Sphere in a Non-uniform Field.—Let $\mathrm{A}_1, \mathrm{B}_1, \mathrm{C}_1$ be the components of the induced magnetization parallel to the principal magnetic axes of the sphere, $\alpha_0, \beta_0, \gamma_0$ the components of the strength of the undisturbed field at the centre of the sphere in the same direction; then, denoting $r_1/(1 + \frac{4}{3}\pi r_1)$ by s_1, and so on, we have $\mathrm{A}_1 = s_1\alpha_0$, $\mathrm{B}_1 = s_2\beta_0$, $\mathrm{C}_1 = s_3\gamma_0$. If the magnetization of the small sphere (of volume v) were rigid, its potential energy W′ would be $\mathrm{W}' = -v(\mathrm{A}_1\alpha_0 + \mathrm{B}_1\beta_0 + \mathrm{C}_1\gamma_0)$. The actual potential energy, W, of the inductively magnetized sphere is different, because its magnetism varies as it passes from one part of the field to another. In any infinitely small displacement, however, we may calculate the work on the supposition that the magnetism is temporarily rigid. In other words, we may put $d\mathrm{W} = d\mathrm{W}'$, where the latter is taken on the supposition that $\mathrm{A}_1, \mathrm{B}_1, \mathrm{C}_1$ do not vary, while on the other hand $\alpha_0, \beta_0, \gamma_0$ do vary, because the resultant force both alters its magnitude and its direction relative to the principal axes of the sphere. We thus get

$$d\mathrm{W} = -v(\mathrm{A}_1 d\alpha_0 + \mathrm{B}_1 d\beta_0 + \mathrm{C}_1 d\gamma_0).$$

In integrating we must take account of the fact that $\mathrm{A}_1, \mathrm{B}_1, \mathrm{C}_1$ are variable. Substituting their values, we get

$$d\mathrm{W} = -v(s_1\alpha_0 d\alpha_0 + s_2\beta_0 d\beta_0 + s_3\gamma_0 d\gamma_0),$$

whence

$$\mathrm{W} = -\frac{v}{2}(s_1\alpha_0^2 + s_2\beta_0^2 + s_3\gamma_0^2) \quad . \quad . \quad . \quad (87).$$

This important formula contains the whole of the theory of the movement of small spherical masses of inductively magnetizable matter in any field of force. We can deduce from it at once the position of equilibrium of an æolotropic sphere suspended in a uniform magnetic field, with freedom to rotate about a given diameter.

Faraday's magnecrystallic law deduced from the principle of least potential energy.

Let λ, μ, ν and l, m, n be the direction cosines of the given diameter and of the direction of the field relative to the principal magnetic axes of the sphere, and R the strength of the field; then $\mathrm{W} = -\frac{1}{2}v\mathrm{R}^2(s_1l^2 + s_2m^2 + s_3n^2)$. For stable equilibrium W must be a minimum, and for unstable equilibrium a maximum, *i.e.*, there is stable or unstable equilibrium according as $s_1l^2 + s_2m^2 + s_3n^2$ is a maximum or a minimum under the given kinematical conditions, which will be expressed by a relation between λ, μ, ν and l, m, n. It is needless to work out the analytical solution; for it leads to results easily obtainable from formulæ already given. It is important, however, to show the identity of this method of treatment

[1] Assuming, as is always the case in nature, that r_2 and r_3 have the same sign.

[2] In other respects it would not in general behave as if it were isotropic.

[3] See art. ELECTRICITY, vol. viii. p. 68.

[4] Kirchhoff, *Pogg. Ann.*, Ergbd. v. 1870. In the same paper he discusses the effect of a rectilinear current in a cylindrical iron wire, and finds that the circular magnetization in a wire of length L gives rise to an apparent increase of the coefficient of self-induction equal to $2\pi\kappa\mathrm{L}$.

with Faraday's view of the matter. If a, b, c be the components of the magnetic induction parallel to the principal axes of the sphere, then we get $a=(1+\frac{8}{3}\pi s_1)Rl$, $b=$&c., $c=$&c. Whence if N denote the total induction through the sphere[1] in the direction of the undisturbed field, we have, ω being the area of its meridian section,

$$N=\omega(al+bm+cn)$$
$$=R+\frac{8}{3}\pi R(s_1l^2+s_2m^2+s_3n^2).$$

N is thus a maximum or a minimum when $s_1l^2+s_2m^2+s_3n^2$ is a maximum or a minimum.

We have therefore established quite generally Faraday's law that *an æolotropic sphere suspended in a uniform field with freedom to rotate about any diameter will be in stable or unstable equilibrium according as the number of lines of force that pass through it is a maximum or a minimum.* A particular case of this theorem has already been proved above (p. 245) for strongly magnetic bodies.

We next apply the formula (87) to deduce the force of *translation* in a heterogeneous field.

1. We see that in a uniform field W is constant so long as there is translation merely without rotation, *i.e.*, there is no tendency in an æolotropic or isotropic sphere to move bodily in a uniform field.

Faraday's law of translational force deduced. Isotropic sphere.

2. If we suppose the sphere isotropic (*i.e.*, $s_1=s_2=s_3=\tau$), then $W=-\frac{1}{2}\tau v(\alpha_0^2+\beta_0^2+\gamma_0^2)=-\frac{1}{2}\tau vR^2$. Hence the force tending to move the sphere in the direction of ds is

$$-\frac{dW}{ds}=\frac{1}{2}\tau v\frac{d(R^2)}{ds}=\tau vR\frac{dR}{ds} \quad . \quad . \quad . \quad (88).$$

In other words, the small sphere is subject to a force of which the scalar potential is $\frac{1}{2}\tau vR^2$. If then we draw the isodynamic surfaces $R^2=$const., the force on an inductively magnetized isotropic sphere will be everywhere at right angles to these; that is, the direction of this force at every point will be tangential to the *lines of slope* of the resultant force, viz., in the direction in which that force varies most rapidly. In the case of paramagnetic bodies, for which τ is positive, *the spheres will tend to move from places of weaker to places of stronger resultant force*; in the case of diamagnetic bodies, for which τ is negative, *from places of stronger to places of weaker force.* This is the famous law found experimentally by Faraday, and afterwards theoretically established by Sir William Thomson.

Isodynamic surfaces and lines of slope.

It must be carefully borne in mind that the lines of slope of the field are not necessarily coincident with the lines of force, *but may cross them at any degree of obliquity.*

As strange mistakes have been made in this matter,[2] it may be well to illustrate this statement by a few examples.

In the case of an isolated north pole the lines of slope coincide with the lines of force, which are straight lines radiating from the pole. In this case a paramagnetic sphere would approach and a diamagnetic sphere recede from the pole *along the lines of force.*

The lines of force for a rectilinear electric current are circles of which it is the axis; the lines of slope are straight lines radiating from the current. A paramagnetic sphere would therefore move towards, a diamagnetic sphere away from the current in a direction *perpendicular to the lines of force.*

In the case of an infinitely small magnet, whose lines of force are given by $r=c\sin^2\theta$, the lines of slope are given by $r=c'\sin^4\theta/\cos\theta$; and the angle between the line of force and the line of slope at the point (r,θ) is $\tan^{-1}\{\tan\theta(1+\cos^2\theta)/(3+5\cos^2\theta)\}$

The theory of isodynamics and lines of slope in the case of plane fields of force, *i.e.*, those for which the potential is given by the equation $d^2V/dx^2+d^2V/dy^2=0$, is remarkably simple. If $\xi=x+iy$, $\eta=x-iy$, we know that $V=\phi(\xi)+\psi(\eta)$, ϕ and ψ being functions depending on the particular case. When these are known the isodynamics are given by

$$\phi'(\xi)\psi'(\eta)=\text{const.}$$

and the lines of slope by

$$\frac{\phi'(\xi)}{\psi'(\eta)}=\text{const.}$$

Æolotropic sphere.

3. Next suppose an æolotropic sphere allowed to move without rotation in any direction ds. Let the direction cosines of the field relative to its principal magnetic axes be l,m,n, then these are constant during the displacement; and, if R be the intensity of the field, $\alpha_0=Rl$, $\beta_0=Rm$, $\gamma_0=Rn$; whence

$$-\frac{dW}{ds}=\frac{1}{2}v(s_1l^2+s_2m^2+s_3n^2)\frac{d(R^2)}{ds} \quad . \quad . \quad . \quad (89).$$

Hence, as before, *the resultant force of translation on the sphere is along the line of slope, in the direction in which the force increases if the body be wholly paramagnetic, in the opposite direction if it be wholly diamagnetic.*

Besides depending on the nature of the field, the force of translation, on account of the factor $s_1l^2+s_2m^2+s_3n^2$, depends on the position of the body relative to the lines of force. Bearing in mind the theory of the radii of an ellipsoid, we have the following proposition:—

The force of translation on an æolotropic sphere is greatest when its axis of (numerically) greatest magnetic susceptibility is parallel to the lines of force, and least when the axis of (numerically) least susceptibility is in the same position.

Or, using permeability instead of susceptibility,—

The force of translation is greatest for a paramagnetic sphere when its axis of greatest permeability is parallel to the lines of force, for a diamagnetic sphere when the axis of least permeability is parallel to the lines of force, and vice versa.

Or, yet again, in the words of Faraday:—

The force of translation exerted upon a paramagnetic sphere is greatest when it is so placed that the greatest number of lines of force pass through it, whereas in the case of a diamagnetic sphere the force is greatest when it is so placed that the least number of lines of force pass through it, and vice versa.

Approximate theory for bodies of finite size.

Approximate Theory of the Action on Bodies of Finite Size in a Non-Uniform Field.—We have seen that, if the square of the susceptibility be negligible, the effect of the form of the body and the disturbance of the field arising from the induced magnetism may be neglected. In that case we may replace the spheres of the foregoing discussion by cubes, and determine the action on a body of finite size by integrating the action on the elementary cubes of which it is composed. Thus the potential energy will be $-\frac{1}{2}\iiint(s_1\alpha_0^2+s_2\beta_0^2+s_3\gamma_0^2)dv$, and the body need not necessarily be homogeneous. From this expression we can deduce the force under given circumstances.

It is quite easy to see, without any mathematical calculation, what will happen in a field of force which diminishes in intensity outwards from an axial line. If we suspend an elongated paramagnetic body with its centre in the axis of the field, it will evidently be in stable equilibrium with its longest dimension placed axially; for if it were slightly displaced every little cube of it would move into a place of weaker force, and would therefore tend to return. If, on the other hand, the body were diamagnetic, it would be in stable equilibrium in an equatorial position; for any displacement from that position would bring every little cube nearer the axis of the field, *i.e.*, into a place of stronger force, and therefore each such cube would tend to return.

General Problem of Magnetic Induction.—It will be instructive to consider for a little the theory of induced magnetism in its most general form.

We shall suppose the induction to arise from given magnetic force $(\alpha_0,\beta_0,\gamma_0)$, arising from pre-existing magnetism (A_0,B_0,C_0) or otherwise. Letters with suffix 1 denote components of induced magnetism, of force arising therefrom, and so on. Letters without suffix denote components of total force, total magnetization, &c. Thus V_0, V_1, V denote the potentials due to pre-existent, induced, and total magnetism respectively; and we have $V=V_0+V_1$, and the like relation in other cases.

We suppose all the media within the field to have definite permeability; but there may be æolotropy and heterogeneity to any extent, and discontinuity along given surfaces.

[1] That is, the number of lines of force passing through the sphere (see above, p. 244).

[2] See Wiedemann, *Galvanismus* (ed. 1874), ii. 665; Todhunter, *Natural Philosophy for Beginners*, pt. i. § 387.

General problem of magnetic induction.

Resolving along the principal magnetic axes at (x, y, z), we get, by the law of induced magnetism, (l_1, m_1, n_1), (l_2, m_2, n_2), (l_3, m_3, n_3) being the direction cosines of the axes $\varpi_1, \varpi_2, \varpi_3$,

$$al_1 + bm_1 + cn_1 = \varpi_1(\alpha l_1 + \beta m_1 + \gamma n_1) + 4\pi(A_0 l_1 + B_0 m_1 + C_0 n_1),$$

and two similar equations.

Multiplying these by l_1, l_2, l_3, adding and so on, we get

$$\left.\begin{aligned} a &= s_1\alpha + t_3\beta + t_2\gamma + 4\pi A_0 \\ b &= t_3\alpha + s_2\beta + t_1\gamma + 4\pi B_0 \\ c &= t_2\alpha + t_1\beta + s_3\gamma + 4\pi C_0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (90),$$

where

$$s_1 = \varpi_1 l_1^2 + \varpi_2 l_2^2 + \varpi_3 l_3^2, \quad t_1 = \varpi_1 m_1 n_1 + \varpi_2 m_2 n_2 + \varpi_3 m_3 n_3,$$

&c. ;—that is to say, given functions of x,y,z.

Besides these, we have the conditions of normal continuity for $\mathfrak{B}$, viz.,

$$\frac{da}{dx} + \frac{db}{dy} + \frac{dc}{dz} = 0,$$

and at a surface of discontinuity, λ, μ, ν being the direction cosines of the normal at any point from the first medium to the second,

$$(a - a')\lambda + (b - b')\mu + (c - c')\nu = 0,$$

dashed letters referring to values on the first side of the surface, undashed letters to values on the second.

From these we get finally, for the determination of V,

$$\frac{d}{dx}\left(s_1\frac{dV}{dx} + t_3\frac{dV}{dy} + t_2\frac{dV}{dz}\right) + \&c. + \&c. + 4\pi\rho_0 = 0 \quad . \quad (91).$$

and

$$\left\{ s_1'\frac{dV'}{dx} - s_1\frac{dV}{dx} + t_3'\frac{dV'}{dy} - t_3\frac{dV}{dy} + t_2'\frac{dV'}{dz} - t_2\frac{dV}{dz} \right\}\lambda$$
$$+ \left\{ \&c. \right\}\mu + \left\{ \&c. \right\}\nu + 4\pi\sigma_0 = 0 \quad . \quad . \quad (92).$$

Here

$$\rho_0 = -\left(\frac{dA_0}{dx} + \frac{dB_0}{dy} + \frac{dC_0}{dz}\right),$$

$$\sigma_0 = (A_0 - A_0')\lambda + (B_0 - B_0')\mu + (C_0 - C_0')\nu;$$

i.e., they are Poisson's volume and surface densities for the pre-existing magnetization.

It may be shown by a method[1] essentially the same as that used in the article ELECTRICITY, vol. viii. p. 27, that equations (91) and (92), with the condition that V be continuous everywhere and vanish at infinity, lead to a unique determination of V. When V is known, A_1, B_1, C_1 can be found at once from (90).

Case of homogeneous isotropic medium with no pre-existing magnetization.

In what follows we shall confine ourselves to homogeneous isotropic media, and we shall suppose that in parts of the medium inductively magnetizable there is no pre-existing magnetism. The equations (91) and (92) then reduce to

$$\frac{d^2V}{dx^2} + \frac{d^2V}{dy^2} + \frac{d^2V}{dz^2} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (93),$$

and

$$\varpi\frac{dV}{d\nu} + \varpi'\frac{dV'}{d\nu'} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (94),$$

$d\nu, d\nu'$ being elements of normals drawn inwards in the two media. Equations (90) reduce to

$$a = \varpi\alpha, \quad b = \varpi\beta, \quad c = \varpi\gamma;$$

whence

$$A_1 = -\frac{\varpi - 1}{4\pi}\frac{dV}{dx}, \quad B_1 = -\frac{\varpi - 1}{4\pi}\frac{dV}{dy}, \quad C_1 = -\frac{\varpi - 1}{4\pi}\frac{dV}{dy} \quad (95).$$

Induced magnetization in this case both solenoidal and lamellar.

From these last, combined with (93), we have the important consequence that the induced magnetization is both solenoidal and lamellar. This is true only for homogeneous isotropic media in which the pre-existing magnetism, if any there be, is solenoidal.

In all cases such as we are now considering, the part of the magnetic potential due to induced magnetism may be calculated wholly from surface distributions at the surfaces of discontinuity. If σ_1 be this surface density, we have

$$\frac{dV}{d\nu} + \frac{dV'}{d\nu'} + 4\pi\sigma_1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (96).$$

From equations (94) and (96)

$$\sigma_1 = \kappa_1\frac{dV}{d\nu} = \kappa_1'\frac{dV'}{d\nu'},$$

where $\kappa_1 = (\varpi - \varpi')/4\pi\varpi', \quad \kappa_1' = (\varpi' - \varpi)/4\pi\varpi.$

Let us suppose that a body A of permeability ϖ is suspended in a medium of permeability ϖ'. If the susceptibilities be small, the forces arising from the induced magnetism will be so small that the direction of the normal force at the surface of A will be the same as if the field were undisturbed by its presence.

Differential action.

First, let the medium be vacuum, for which we suppose $\varpi' = 1$, then, if A be paramagnetic (*i.e.*, $\varpi > 1$), κ_1 will be positive, and the surface magnetism will be positive where the lines of force leave the body, and negative where they enter it. If A be diamagnetic (*i.e.*, $\varpi < 1$), κ_1 will be negative, and the magnetic polarity of the body as a whole will be opposite to what it was in the former case.

Secondly, let the surrounding medium have permeability ϖ', then κ_1 is positive or negative according as $\varpi >$ or $< \varpi'$; in the former case A will behave like a paramagnetic body in vacuo, in the latter like a diamagnetic body in vacuo.

It appears then that, *by virtue of differential action, a body may behave paramagnetically or diamagnetically according as it is placed in a less or in a more permeable medium than itself.*

Poisson's equation.

In practice it is most convenient in general to determine V_1 instead of V. The above equations can be easily modified to admit of this. In fact we get at once, remembering that $dV_0'/d\nu' = -dV_0/d\nu$, since V_0 has no discontinuity at the surface of the media,

$$\frac{d^2V_1}{dx^2} + \frac{d^2V_1}{dy^2} + \frac{d^2V_1}{dz^2} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (97);$$

$$\varpi\frac{dV_1}{d\nu} + \varpi'\frac{dV_1'}{d\nu'} + (\varpi - \varpi')\frac{dV_0}{d\nu} = 0 \quad . \quad . \quad . \quad . \quad (98).$$

These equations, together with the condition that V_1 be finite and continuous and vanish at infinity, determine V_1 completely. Since the induced magnetization is lamellar, we may write $A_1 = d\phi_1/dx$ &c., we then get by (95)

$$\phi_1 = -\frac{\varpi - 1}{4\pi}(V_0 + V_1) = -\kappa(V_0 + V_1) \quad . \quad . \quad . \quad (99),$$

which give the components of moment in terms of the known function V.

J. Neumann's transformation theorem.

The number of cases in which the solution of the induction problem can be worked out is very small. Besides those already treated synthetically, one or two more, affording examples of the general method, will be mentioned in the historical summary below. Meantime, we must not omit to mention an extremely elegant transformation theorem, due to J. Neumann,[2] which enables us to deduce the magnetic moment of any body as a whole under the action of any forces whatever, when its magnetization in a uniform field is known.

Let A_1', B_1', C_1' be the components of induced magnetization produced in the body A by the uniform field whose components are $\alpha_0', \beta_0', \gamma_0'$; A_1, B_1, C_1 the magnetization produced in A by any field whatever $(\alpha_0, \beta_0, \gamma_0)$. Let $\int dv$ denote volume integration throughout A; and consider the function

$$U = \int dv(\alpha_0 A_1' + \beta_0 B_1' + \gamma_0 C_1').$$

U is known, since we suppose $\alpha_0, \beta_0, \gamma_0$, A_1', B_1', C_1' to be known. But, since $A_1 = \kappa(\alpha_0 + \alpha_1)$, &c., $A_1' = \kappa(\alpha_0' + \alpha_1')$, &c., we have

$$U = \int dv\left\{\left(\frac{A_1}{\kappa} - \alpha_1\right)\kappa(\alpha_0' + \alpha_1') + \&c. \quad . \quad . \quad .\right\}$$

$$= \int dv(\alpha_0' A_1 + \&c.) + \int dv(\alpha_1' A_1 + \&c.) - \int dv(\alpha_1 A_1' + \&c.).$$

Now the last two terms destroy each other; for they are simply different expressions for the mutual potential energies of the induced magnetism due to $(\alpha_0, \beta_0, \gamma_0)$ and to $(\alpha_0', \beta_0', \gamma_0')$, regarded as separate rigid systems, although coincident in position. Hence we get

$$U = \alpha_0'\int dv A_1 + \beta_0'\int dv B_1 + \gamma_0'\int dv C_1,$$

whence

$$\int dv A_1 = \frac{dU}{d\alpha_0'}, \quad \int dv B_1 = \frac{dU}{d\beta_0'}, \quad \int dv C_1 = \frac{dU}{d\gamma_0'}.$$

[1] See Thomson, *Reprint of Papers on Electrostatics and Magnetism*, pp. 548 *sq.*

[2] *Crelle's Jour.*, xxxvii. 44 (1848). The proof given is a modification of Kirchhoff's, *Crelle*, xlviii. 366 (1854).

For an ellipsoid this gives at once for the components of moment

$$P=\frac{\kappa}{1+\kappa L}\int dv\alpha_0\,,\quad Q=\frac{\kappa}{1+\kappa M}\int dv\beta_0\,,\quad R=\frac{\kappa}{1+\kappa N}\int dv\gamma_0\,.$$

An interesting particular case is that of an infinite cylinder. If P be the component of the moment parallel to its axis, $P=-\kappa\iint dydz\,(V_\infty - V_{-\infty})$. If the inducing system be magnetic bodies at a finite distance, then $V_\infty = V_{-\infty}=0$, and $P=0$. If the cylinder be magnetized by a spiral current i, of n windings, of whatever form, then, r being the radius of the cylinder, $P=4\pi^2\kappa r^2 ni$.[1]

Generalization of the Theory for Isotropic Media in which κ is not constant.—In the above theory we have supposed the magnetic susceptibility to be constant. This is by no means the case in nature, however. It is of importance therefore to consider how the theory must be modified when we assume κ to be a function of the magnetization already induced. Subject to the restriction (obviously necessary for isotropic media) that the resultant magnetization shall coincide in direction with the total resultant magnetic force ($\mathfrak{H}$), the most general assumption that can be made is

Kirchhoff's extension of Poisson's theory.

$$A=f(I)\alpha\,,\quad B=f(I)\beta\,,\quad C=f(I)\gamma \quad . \quad . \quad . \quad . \quad (100),$$

where f is a function depending on the nature of the substance. From these equations, by squaring, adding, and extracting the square root, we get $f(I)/I=1/\mathfrak{H}$, in other words, I, and therefore $f(I)$, are functions of $\mathfrak{H}$. Hence we may write the equations (95).

$$A_1=F(\mathfrak{H})\alpha\,,\quad B_1=F(\mathfrak{H})\beta\,,\quad C_1=F(\mathfrak{H})\gamma \quad . \quad . \quad . \quad (101).$$

It is easy by means of these to introduce the requisite modifications into the general equations of magnetic equilibrium. For the details we refer our readers to Kirchhoff's memoir in *Crelle's Journal*,[2] where the matter was first fully worked out. It will be seen at once that the induced magnetization is in general neither solenoidal nor lamellar.

Cases in which the magnetization is uniform.

There is one important class of cases in which the conclusions arrived at on the assumption that κ is constant still hold, viz., those in which the induced magnetization is uniform. In such cases I has the same value throughout the body, and κ is therefore constant throughout the body *in any one case*, although it differs from one case to another. For example, in the case of an ellipsoid the equations (85) above given for the components of magnetization still hold good, provided we understand κ to be defined by the equation

$$\kappa=F\left[\left\{\left(\frac{\alpha_0}{1+\kappa L}\right)^2+\left(\frac{\beta_0}{1+\kappa M}\right)^2+\left(\frac{\gamma_0}{1+\kappa N}\right)^2\right\}^{\frac{1}{2}}\right] \quad . \quad (102).$$

It is clear, therefore, that by experiments on an ellipsoid placed in a uniform field we could determine the function $F(\mathfrak{H})$, and also test the truth of the mathematical theory. For, A_1, B_1, C_1 being obtained by observation, one of the equations (85) will enable us to determine κ, and the argument $\mathfrak{H}$ can be calculated from α_0, β_0, γ_0 and A_1, B_1, C_1; the test of the truth of the theory would be the agreement of the three values of κ obtained from the three equations (85).

Historical Remarks on the History of the Mathematical Theory.—Although the *Tentamen* of Æpinus, published in 1759, and the discoveries of Mayer and Lambert did much to make clear the exact nature of the problems involved in the modern mathematical theory of magnetism, yet the origin of that theory is usually, and with justice, dated from Coulomb.[3] Not only did the results of his careful and judicious experiments afford the means of bringing a mathematical theory to the test, but the marvellous sagacity he displayed in analysing the phenomena enabled him actually to lay the foundations upon which such a theory could be constructed. After him, Biot[4] and Hansteen,[5] of whose services we have already spoken, are to be reckoned as pioneers. The theory as it now stands was virtually created by Poisson in four of the most admirable memoirs[6] to be found in the whole literature of mathematical physics. In the first two he investigates expressions for the force due to bodies magnetized in any manner; he then applies his formulæ to the case of bodies inductively magnetized but having no coercive force. Although he confines his investigations to the case of isotropic bodies, he is quite aware of the general nature of the consequences of æolotropy, and in fact distinctly predicts as possible the magnecrystallic phenomena afterwards discovered by Plücker and Faraday. The formulæ he gives are practically identical with those given above (p. 248). He works out in detail the solution for the case of a hollow or solid sphere exposed to any system of inducing forces having a potential,[7] and in particular compares the results, when the inducing field is uniform, with the experiments of Barlow. In the second memoir he works out the solution of his equations for an ellipsoid in a uniform field, examining specially the case of an ellipsoid of revolution and its extreme cases (see above, p. 245). At the end of this memoir he discusses the disturbing forces on a compass, arising from the earth's induction on any distribution of soft iron, and shows that the given components of the disturbing force are expressed by linear functions of the components of the earth's force, involving nine constants which depend on the quantity and distribution of the iron. The third memoir, on magnetism in motion, is an attempt to explain the phenomena of the deviation of the magnetic needle caused by rotating metal spheres or disks. Although the physical interest of this memoir was in a great measure destroyed by the discoveries of Faraday as to the true nature of this action, yet, as a piece of profound mathematical investigation, this work of Poisson's is still worthy of study; nor is it perfectly certain that his theory will not after all be required to explain certain residual phenomena. The fourth memoir develops the mathematical theory of the deviation of the compass caused by the iron of ships. After Poisson the most important investigators are Green and Gauss. Green's services have already been alluded to in the article ELECTRICITY; we need only mention here his approximate solution of the problem of the magnetic distribution on cylindrical bars, which gives a formula agreeing with that of Biot. The all-important work of Gauss has already been detailed.

Coulomb. Biot. Hansteen. Poisson. Green. Gauss.

In *Crelle's Journal* for 1848 J. Neumann worked out the solution of the induction problem for an ellipsoid of revolution under the action of any conservative system; and six years later, in the same journal, Kirchhoff worked out the case of a circular cylinder of infinite length. We are not aware that the solution of Poisson's equations in particular cases has been carried any farther, unless we include as new the case of a hollow ellipsoid treated by A. G. Greenhill in the *Journal de Physique* for 1881.

Neumann. Kirchhoff. Greenhill.

The most important contributions to the general theory of magnetism since Poisson are to be found in a series of memoirs[8] by Sir William Thomson, the first of which appeared in the *Philosophical Transactions* for 1851. He divests the theory of Poisson of all particular assumptions connected with the two-fluid theory, and bases it on a

Thomson.

[1] Kirchhoff, *l. c.*
[2] xlviii. 370, 1854.
[3] *Mém. de l'Acad. de Paris*, 1780, 1785, &c.
[4] *Traité de Physique*, 1816.
[5] *Magnetismus der Erde*, 1819.
[6] *Mém. de l'Inst.*, v., 1821 (two memoirs); vi., 1823; and xvi., 1838.
[7] He did not use the word "potential," although he uses the corresponding function.
[8] Reprinted in 1872 under the title of *Papers on Electrostatics and Magnetism*.

small number of principles drawn from observation. He enters more fully than Poisson had done into the specification of magnetic distribution. He gives simple synthetic solutions of the induction problem for spheres and ellipsoids in a uniform field. He gives for the first time with full generality the theory of induction in æolotropic media, and shows that Poisson's theory thus fully developed leads to all the laws of paramagnetic and diamagnetic action discovered by Faraday, and also to the laws of magnecrystallic action discovered by Plücker and Faraday. The value of his theory was fully recognized by Plücker,[1] and apparently also by Faraday; indeed one of its ablest expositors was Beer[2] the friend and coadjutor of Plücker. The experimenters who followed these masters were less intelligent, and the theory of Thomson was for a number of years misunderstood or neglected, the result being much fruitless discussion in which the true issues were often confused. Of late the theory has obtained wide currency and the adhesion of every physicist worthy of the name. Quite recently Thomson's theory has been further developed in an interesting paper by Helmholtz,[3] chiefly with a view to its application to the phenomena of dielectric polarization.

Plücker. Beer. Helmholtz.

For the benefit of the mathematical reader we append a list of the more important papers on the mathematical theory of magnetism that have appeared recently, and are not quoted above:—

Plana, "Mémoire sur la théorie du magnétisme," *Ast. Nach.*, xxxix., 1854; F. Neumann, *Vorlesungen über die Theorie des Magnetismus*, delivered 1857, edited by C. Neumann, 1881; Riemann, *Schwere, Electricität, und Magnetismus*, lectures delivered in 1861, edited by Hattendorf, 1876; Lamont, "Beitrag zu einer mathematischen Theorie des Magnetismus," *Sitzber. d. Bayer. Akad.*, 1862; L Weber, *Zur Theorie der Magnetischen Induction*, Kiel, 1877, see *Wied. Beibl.*, 1878; Rowland, *Silliman's Jour.*, 1879 (calculation of couple on a body suspended in a heterogeneous magnetic field); Boltzmann, "Magnetisirung eines Eisenringes," *Wied. Beibl.*, 1879; Id., "Ueber die auf Diamagnete wirkende Kraft," *Wien. Ber.*, 1879; Riecke, *Wied. Ann.*, 1881 (approximative solutions of the problem of magnetic induction).

Induction in Strongly Magnetic Bodies.

Experiments of Barlow and Christie.

The earliest experiments bearing on the mathematical theory of magnetic induction are those of Barlow[4] and Christie, who determined the deflexion of a compass needle placed in various positions relatively to spheres of cast iron inductively magnetized by the earth's force. They found that the deflexion α of the compass could be represented by $\tan\alpha = A\sin\theta\cos\theta\sin\phi/r^3$, where θ is the angle between the line of dip and the line joining the centres of the sphere and compass, and ϕ the angle between the plane of these two lines and the plane of the magnetic meridian. It was also found that the deflexion produced by a hollow sphere was as great as that produced by a solid sphere so long as the thickness of the former was not less than the $\frac{1}{127}$th of its radius.

Magnetic screens.

All these results of Barlow and Christie are in agreement with the theory of Poisson.[5] Another consequence of great practical importance follows from the mathematical theory, viz., that inside a hollow iron sphere of any considerable thickness the magnetic force is very small in comparison with the external inducing force. Sir William Thomson takes advantage of this principle to render his marine galvanometers independent of external magnetic force by surrounding them with a tube of soft iron.

Along with the experiments of Barlow we may rank those of Plücker[6] and Dronke[7] as affording us the means of testing the general applicability of the mathematical theory to the magnetization of soft iron. In Plücker's experiments an ellipsoid of soft iron was fixed in a graduated brass ring with its longest and shortest axes (a and c) in the plane of the ring. When the ring was suspended with the longest axis a vertical in the nearly uniform field between the two flat vertical faces of the poles of an electromagnet, the mean axis b set itself parallel to the horizontal line of force; as the point of suspension was moved along the circumference of the ring a point was reached at which the plane of b and a ceased to set parallel to the lines of force, and the plane of a and c began to do so; ω, the number of degrees between this point and the end of the axis a, was observed. The times of vibration, T_a and T_c, of the ellipsoid, when suspended so that a and c were vertical, were then observed. By the theory we ought to have

Plücker and Dronke.

$$\tan^2\omega = T_c^2(b^2+c^2)/T_a^2(a^2+b^2).$$

The value of ω calculated by means of T_c and T_a from this formula was 30° 13′; the value observed was about 29°. The relation connecting T_a, T_b, T_c according to the theory is

$$(a^2+b^2)/T_c^2 + (b^2+c^2)/T_b^2 - (c^2+a^2)/T_c^2 = 0\ ;$$

and the observed values of T_a, T_b, T_c did, in fact, satisfy this equation very nearly. Dronke's experiments on ellipsoids of iron and nickel were of a similar character.

First observations of the deviation.

Deviation of the Compass.—One of the earliest and certainly the most important of the applications of the mathematical theory of magnetic induction was the discussion of the deviation of the compass caused by the magnetism of the iron in ships. This disturbance seems to have been first noticed by Wales the astronomer, who accompanied Cook on his voyages of discovery (1772 to 1779). The same thing was noticed during the voyage of D'Entrecasteaux in search of La Pérouse; and Beautemps-Beaupré, who accompanied him, calls attention to the errors thence arising in the surveying of coasts by means of the compass. Flinders,[8] using the numerous observations made by Wales and by himself, endeavoured without success to construct empirical formulæ for correcting the errors of the compass. He also attempted to correct the errors partially by means of a vertical bar of soft iron placed near the binnacle. Barlow[9] and Scoresby[10] also occupied themselves with the problem.

The unusually great deviations observed during the Arctic voyage of the "Isabella" and "Alexander" in 1818 attracted the attention of Poisson, and gave rise to his memoir on the subject already alluded to. Important as the matter then appeared, it became still more so after the introduction of iron ships. Investigations both theoretical and experimental were made in England by Johnson,[11] Airy,[12] Evans,[13] Smith,[13] &c. It is to Smith that the mathematical theory as it now stands is mainly due.

Causes of deviation.

The cause of the deviation of the compass is twofold; it arises partly from the permanent magnetism of the ship, partly from the temporary or induced magnetism. The permanent magnetism of the ship is acquired for the most part during the process of building. The earth's force acts on the iron, and the constant jarring in the process of construction enables it to induce a considerable permanent magnetization, which the ship carries with her to sea. The quantity and distribution of this magnetism will depend greatly on the build of the ship (whether of wood or of

[1] See *Phil. Trans.*, 1858, p. 587.

[2] See his *Einleitung in die Electrostatik, die Lehre vom Magnetismus, und die Electrodynamik*, published after the death of its accomplished author, under the editorship of Plücker. This is one of the best works on the subject.

[3] *Monatsber. d. Ber. Akad.*, 1881.

[4] Barlow, *An Essay on Magnetic Attractions*, London, 1820.

[5] See Poisson's first memoir, or Maxwell, *El. and Mag.*, vol. ii. §433.

[6] *Phil. Trans.*, 1858, p. 555.

[7] *Pogg. Ann.*, 1862.

[8] *Phil. Trans.*, 1805.

[9] *Ib.*, 1831.

[10] *Ib.*, 1819 and 1832, &c.

[11] *Ib.*, 1836.

[12] *Ib.*, 1839, &c.

[13] See *Admiralty Manual for the Deviation of the Compass*, 4th ed., 1874; also a very interesting obituary notice of Smith by Sir W. Thomson, *Proc. Roy. Soc. Lond.*, 1874.

Permanent and subpermanent magnetism.

iron), and on her position with respect to the magnetic meridian during building. A considerable portion of it is what Airy calls subpermanent; *i.e.*, it diminishes gradually as the ship is worked. This magnetic settling down will take place more rapidly in a steamer which is constantly agitated by the jarring of machinery than in a sailing ship, unless the latter be subjected to shocks from the impact of waves in rough weather. After a time the ship reaches a more or less stationary condition as to permanent magnetism. Along with the phenomenon of subpermanent magnetism has to be classed what is sometimes called the sluggishness of ships' magnetism; this arises from the fact that all the temporary magnetism of a ship which has sailed for some time on any one magnetic course in any one latitude does not at once disappear when the course or the latitude is changed, so that to the permanent magnetism of the ship has to be added a subpermanent magnetism depending on her course and position several days before. It is evident that the cause of disturbance at present under discussion is somewhat capricious, and can only be controlled by constant attention on the part of the mariner.

Sluggishness.

Temporary magnetism.

The temporary induced magnetism depends on the ship's position on the earth, and on her angular position relative to the magnetic meridian; but, so long as the iron in the ship or the position of the compass is not altered, the constants which determine it remain the same; the disturbance can be foreseen, and either allowed for or mechanically corrected with much greater certainty than in the case of the permanent magnetism.

Mathematical Formulæ for the Deviation.—Let the origin be at the centre of suspension of the compass card; and let the axes of x, y, and z be drawn in the direction from stern to head, in the perpendicular direction from port to starboard, and vertically downwards respectively, the ship for the present being supposed to be on even keel. Let P, Q, R be the components of the magnetic force parallel to these axes arising from the permanent magnetism of the ship; x, y, z the components of the earth's force; and x', y', z' the components of the whole force at the centre of the compass card. Then

Poisson's equations.

$$\left.\begin{aligned} x' &= x + ax + by + cz + \mathrm{P} \\ y' &= y + dx + ey + fz + \mathrm{Q} \\ z' &= z + gx + hy + kz + \mathrm{R} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (103)$$

are, according to Poisson's general theory, the fundamental equations of the subject. P, Q, R are constants depending on the permanent, and $a, b, c, d, e, f, g, h, k$ constants depending on the temporary induced magnetism.

Nine rods to represent the induction constants.

By a synthetic process of great interest and importance we may show that the nine constants $a, b, c, d, e, f, g, h, k$ are all independent. For example, if we place a rod of practically infinite length with its end before the binnacle, and stretching forward, or with its end abaft the binnacle and stretching aft, it will give rise to the term ax in x'. If a be negative the rod must be finite and it must run under the binnacle, ending a little fore and aft; again, to represent dx, we must have a pair of infinite rods with their ends to starboard and port of the binnacle, and running fore and aft or aft and fore respectively, according as d is positive or negative; finally, to represent gx, a pair of infinite rods with ends above and below the binnacle, running fore and aft or aft and fore respectively. The reader will have no difficulty in completing the scheme, the rule being that the ends lie in the direction of x', y', or z', and the lengths in the direction of x, y, or z.

From equations (103) the deviation of the compass is expressed in terms of the magnetic or of the compass course as follows. Let H be the horizontal force of the earth; H′ the horizontal force of the earth and ship; θ the dip; ζ the "magnetic course," *i.e.*, the azimuth of the ship's head eastward from magnetic north; ζ' the "compass course," *i.e.*, the azimuth of the ship's head eastward from the direction of the disturbed needle; $\delta=\zeta-\zeta'$ the easterly deviation of the compass. Then

Deviation in term of magnetic and compass courses.

$$\left.\begin{aligned} \frac{\mathrm{H}'}{\lambda\mathrm{H}}\sin\delta &= \mathfrak{A} + \mathfrak{B}\sin\zeta + \mathfrak{C}\cos\zeta + \mathfrak{D}\sin 2\zeta + \mathfrak{E}\cos 2\zeta \\ \frac{\mathrm{H}'}{\lambda\mathrm{H}}\cos\delta &= 1 + \mathfrak{B}\cos\zeta - \mathfrak{C}\sin\zeta + \mathfrak{D}\cos 2\zeta - \mathfrak{E}\sin 2\zeta \end{aligned}\right\} \quad (104),$$

where

$$\lambda = 1 + \frac{a+e}{2}\,, \quad \mathfrak{A} = \frac{d-b}{2\lambda}\,, \quad \mathfrak{D} = \frac{a-e}{2\lambda}\,, \quad \mathfrak{E} = \frac{d+b}{2\lambda}\,,$$

$$\mathfrak{B} = \frac{1}{\lambda}\left(c\tan\theta + \frac{\mathrm{P}}{\mathrm{H}}\right), \quad \mathfrak{C} = \frac{1}{\lambda}\left(f\tan\theta + \frac{\mathrm{Q}}{\mathrm{H}}\right).$$

From (104) we get

$$\tan\delta = \frac{\mathfrak{A} + \mathfrak{B}\sin\zeta + \mathfrak{C}\cos\zeta + \mathfrak{D}\sin 2\zeta + \mathfrak{E}\cos 2\zeta}{1 + \mathfrak{B}\cos\zeta - \mathfrak{C}\sin\zeta + \mathfrak{D}\cos 2\zeta - \mathfrak{E}\sin 2\zeta} \quad . \quad (105),$$

which gives the deviation on any given magnetic course.

From (105) we get by substitution

$$\sin\delta = \mathfrak{A}\cos\delta + \mathfrak{B}\sin\zeta' + \mathfrak{C}\cos\zeta' + \mathfrak{D}\sin(2\zeta'+\delta) + \mathfrak{E}\cos(2\zeta'+\delta) \, (106),$$

an equation connecting the deviation with the compass course.

When the deviation is not greater than 20° or so, then (106) may be replaced with sufficient accuracy by

$$\delta = \mathrm{A} + \mathrm{B}\sin\zeta' + \mathrm{C}\cos\zeta' + \mathrm{D}\sin 2\zeta' + \mathrm{E}\cos 2\zeta' \quad . \quad . \quad (107),$$

where $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$, are nearly the natural sines of A, B, C, D, E.

Effect of heeling.

In the above it is supposed that the ship is on even keel. Strictly we ought to take into account both the pitch and the heel of the ship; in practice the pitch is always so small as to be of no consequence, but the heel, especially in a ship under sail, may be very considerable. When the ship heels through an angle i, the deviation is obtained from the above formulæ by writing a_i, b_i, &c., in place of a, b, &c., where

$$\begin{aligned} &a_i = a, \quad b_i = b\cos i - c\sin i, \quad c_i = c\cos i + b\sin i, \\ &d_i = d\cos i - g\sin i, \quad e_i = e - (f+h)\cos i\sin i - (e-k)\sin^2 i, \\ &f_i = f + (e-k)\cos i\sin i - (f+h)\sin^2 i, \quad g_i = g\cos i + d\sin i, \\ &h_i = h + (e-k)\cos i\sin i - (f+h)\sin^2 i, \\ &k_i = k + (f+h)\cos i\sin i + (e-k)\sin^2 i, \\ &\mathrm{P}_i = \mathrm{P}, \quad \mathrm{Q}_i = \mathrm{Q}\cos i - \mathrm{R}\sin i, \quad \mathrm{R}_i = \mathrm{R}\cos i + \mathrm{Q}\sin i. \end{aligned}$$

If the soft iron be symmetrical with respect to the fore and aft central line, and if i be so small that its square may be neglected, then

$$\lambda_i = \lambda, \; \mathfrak{D}_i = \mathfrak{D}, \; \mathfrak{A}_i = \frac{c-g}{2\lambda}i, \; \mathfrak{E}_i = -\frac{c+g}{2\lambda}i, \; \mathfrak{B}_i = \mathfrak{B},$$

$$\mathfrak{C}_i = \mathfrak{C} + \frac{1}{\lambda}\left(e - k - \frac{\mathrm{R}}{\mathrm{Z}}\right)\tan\theta\, i = \mathfrak{C} + \mathrm{J}i;$$

and if δ_i represent the deviation for the given compass course ζ' when the ship heels i to starboard, δ the deviation on the same course on even keel, then

$$\delta_i = \delta + \frac{c-g}{2\lambda}i + \mathrm{J}i\cos\zeta' - \frac{c+g}{2\lambda}i\cos 2\zeta' \quad . \quad . \quad . \quad (108).$$

Constant deviation.

The part of the deviation which depends mainly on $\mathfrak{A}$ is called the "constant deviation"; it can only arise from horizontal induction on soft iron unsymmetrically placed.

Semicircular deviation.

The part depending mainly on $\mathfrak{B}$ and $\mathfrak{C}$, viz., $\mathrm{B}\cos\zeta' + \mathrm{C}\sin\zeta'$, is called the "semicircular deviation" because it vanishes and changes sign on two diametrically opposite compass courses, or neutral points. The principal coefficient of the semicircular deviation is $\mathfrak{B} = (c\tan\theta + \mathrm{P}/\mathrm{H})/\lambda$; $c\tan\theta/\lambda$ arises from vertical induction in soft iron before or abaft the compass; $\mathrm{P}/\lambda\mathrm{H}$ arises from the permanent magnetism of the ship. The second coefficient $\mathfrak{C} = (f\tan\theta + \mathrm{Q}/\mathrm{H})/\lambda$ consists of $f\tan\theta/\lambda$, arising from soft iron unsymmetrically placed, and therefore in general very small, and $\mathrm{Q}/\lambda\mathrm{H}$ arising from permanent magnetism. $\mathfrak{B}$ can be reduced to zero by a magnet placed fore and aft with its centre in a transverse vertical plane passing through the compass, $\mathfrak{C}$ by means of a transverse magnet in a fore and aft plane through the compass.

In wooden ships the courses for which the semicircular deviation vanishes are nearly north and south; but in iron ships they approximate to those points of the compass towards which the stem and stern lay in building.

Quadrantal deviation.

The terms $\mathrm{D}\sin 2\zeta' + \mathrm{E}\cos 2\zeta'$, depending mainly on the constants $\mathfrak{D}$ and $\mathfrak{E}$, are called the "quadrantal deviation." This part is alternately easterly and westerly in the four quadrants, vanishing on four compass courses. $\mathfrak{D} = (a-e)/2\lambda$ is the principal coefficient of the quadrantal deviation; it depends on horizontal induction in symmetrically placed fore and aft or transverse soft iron. It is in general positive, and in that case can be reduced to zero by two transverse rods with their ends symmetrically placed to starboard and port of the compass. In practice two hollow spheres an inch or so thick are used instead of the rods. The other coefficient $\mathfrak{E} = (d+b)/2\lambda$ is in general small, as it depends on horizontal induction in soft iron unsymmetrically placed. It is only when the ship heels that this coefficient is in general of any importance.

Whereas the semicircular deviation depends both on the geographical position of the ship and on the state of its subpermanent magnetism, the quadrantal deviation is independent of both, and can be corrected mechanically once for all, or allowed for by means of tables constructed from observations made in any one place. The amount of the semicircular deviation in England does not exceed 10° for wooden ships of war, but in iron-built ships it frequently exceeds 30° even at the standard compass. The quadrantal deviation in wooden ships does not often exceed 1° or 2°; in ordinary iron ships it ranges from 3° to 7°, but in some armour-plated iron ships of war it has reached as much as $8\frac{1}{2}$° at the standard compass, and 15° for compasses less favourably placed.

The chief part of the heeling deviation is the term $Ji\cos\zeta'$, depending on the coefficient $J=(e-k-R/Z)\tan\theta/\lambda$. This coefficient may be reduced to zero by increasing or diminishing the earth's vertical force by means of a vertical magnet under the compass.

Determination of deviations by "swinging."

The usual way of ascertaining the deviations of a ship's compass is to "swing" the ship gently round so that her head comes into various positions, and to observe with the compass the magnetic bearing of some well-defined distant point (compass mark) on shore. The true magnetic bearing of this point is then ascertained, which may be done by taking the compass ashore, carefully placing it in a line joining the compass mark with the point on board at which the compass was formerly placed, and then taking the magnetic bearing of the mark once more. Care must of course be taken that there is no local magnetic disturbance at the shore station. The differences between the bearings on board and the bearing on shore give of course the deviations for the various positions of the ship's head.

When the deviations have thus been ascertained they may be either corrected by means of tables, by graphical methods, such as the steering diagram of Napier or the dygograms of Smith, or mechanically as we have partially explained. For full details on the subject the reader should consult the *Admiralty Manual on the Deviation of the Compass.*

Thomson's compass.

Of late years Sir W. Thomson has devoted his great scientific knowledge and well-known practical sagacity and inventive skill to the improvement of the compass. By reducing the size of the magnets and increasing their number he has succeeded in reducing Airy's apparatus for the mechanical correction of the quadrantal deviation within convenient bulk, and by lightening the card and suspension of the magnets in a very ingenious manner (at the same time throwing all the remaining weight as much as possible to the circumference) he has reduced the friction on the pivot to a minimum while retaining a sufficiently long period of vibration to secure perfect steadiness. He has also contrived apparatus for facilitating the determinations of the deviation on different courses and of the heeling error.[1]

Experimental difficulties.

The *experimental investigation of induced magnetism* reduces itself mainly to the investigation of the dependence of the magnetic susceptibility κ[2] (or the magnetic permeability ϖ) upon the magnetizing force $\mathfrak{H}$. Confining ourselves to the strongly magnetic metals, iron, nickel, and cobalt, it will be seen presently that κ depends, not only upon $\mathfrak{H}$, but also upon the magnetic condition of the body at the actual moment when $\mathfrak{H}$ is in action, and upon its previous magnetic history. κ also depends greatly on the temperature, on the state of the body as to purity (notably in the case of iron and steel on the percentage of carbon present), and on the temper. Thus, if we make one experiment on a body by magnetizing it in any way, we permanently alter its magnetic properties, and can restore it to the magnetically virgin condition only by heating it to a high temperature; but in this process we are very apt to permanently alter its molecular condition, so that, although magnetically indifferent, it is physically changed. Owing to the fact, already insisted upon, that we cannot infer the magnetic distribution inside a heterogeneously magnetized body from its external magnetic action, and to the fact, presently to be established, that κ varies with $\mathfrak{H}$, it is of the last importance to choose the experimental circumstances so that both the magnetic field and the induced magnetization shall be uniform, or very approximately so. A further necessity for the fulfilment of these conditions arises from the fact that we must in all cases be able to render an account of the effect of the *form* of the magnetized body, because the true argument of κ is not the strength of the original field but the whole force $\mathfrak{H}$ due to the original field and the induced magnetism together.

Importance of uniform magnetization.

Uniform field.

The simplest method for securing a uniform field whose strength can be controlled is to place the body inside a hollow cylindrical coil (usually called the magnetizing spiral), whose length so far exceeds that of the body that the disturbance arising from the ends of the coil may be neglected in the neighbourhood of the body. The results in all cases where the length of the body or core is nearly equal to or exceeds that of the coil are impure, and can only be used with the greatest caution in drawing general conclusions as to the value of κ. The core should always be either exactly or approximately one of the calculable forms, but preferably such that the dimension parallel to the axis of the spiral very much exceeds the others, because in this case the effect of the form is of secondary importance compared with the effect of the susceptibility (see above, p. 245). Thus a very thin cylindrical core is convenient, because the force inside it differs very little from that of the undisturbed field, and any small difference can be easily calculated by supposing the cylinder replaced by a very elongated ellipsoid. On the other hand, a thick cylindrical bar is a bad form of core for the determination of κ, both because the magnetizing force inside it is less than the intensity of the undisturbed field by a large quantity, which it is impossible to calculate, and because the magnetization at the end is not uniform, and the disturbance thereby arising is so great that it may mask the general character of the function κ altogether.

Best form of core.

Disturbances at make and break.

A further question arises as to how far the time during which a magnetizing force acts affects the resulting magnetization, whether temporary or permanent. It is also important to consider the disturbances arising during the make and break of the current in the magnetizing spiral. As the resistance in the circuit is usually small, and the self-induction and capacity sensible, oscillatory currents may arise; to these will correspond oscillatory magnetizing forces, which may even vary in sign. When we consider that the permanent magnetization produced by any force may be very much weakened or even altogether destroyed by a smaller force in the opposite direction, it is evident that we have no right to conclude that these disturbances, especially at break, will be without effect upon the permanent magnetization. In order to elude these difficulties, some experimenters have followed the practice of first establishing the current, then gently[3] introducing the core into its place, and finally removing it before breaking the circuit. In this way the disturbances just alluded to are avoided; but another difficulty is raised, for it is clear that in this operation the core passes through a heterogeneous field before it reaches the final position where the magnetizing force is uniform; different parts of it have therefore been subjected successively to different influences, and we are not at liberty *a priori* to conclude that this fact will not influence the results. Perhaps the best plan would be to place the core in its position, and allow the current to rise very slowly to the maximum value required, and then to fall slowly to zero. This, however, is not the place to dogmatize concerning the best method of experimenting; all that is necessary is to furnish the reader with points of

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[1] For a description of his compass see art. COMPASS, vol. vi. p. 228. Detailed descriptions of the compass with instructions for its adjustment are issued in the form of a small pamphlet (Maclehose, Glasgow, 1879).

[2] κ is sometimes called by Continental writers the magnetization function. They have also a habit of speaking of the ratio of whole magnetic moment of a body of any form divided by its volume to the strength of the field in which it is placed as the magnetization function for that particular form. This is a most inconvenient practice, and has led to considerable confusion.

[3] Carefully avoiding all shocks or tremors which exercise a very important influence on the induced magnetism, see below, p. 268.

view from which to criticize the experimental results now to be cited.

Lenz and Jacobi. κ constant. In the researches of Lenz and Jacobi[1] the magnetic moment of the core was measured by the induction current in a secondary coil placed upon the magnetizing spiral. A considerable portion of their work was directed to proving principles which we here take for granted, *e.g.*, that the magnetizing force is independent of the thickness of the wire of the magnetizing spiral, of the radius of its windings, and so on. They concluded from these experiments that the magnetization is proportional to the magnetizing force; *i.e.*, κ is constant for a given quality, &c., of metal.

Joule. The experiments of Joule,[2] which were made independently about the same time, led in general to a similar result. His method consisted in measuring by means of a balance the attraction P between two electromagnets actuated by the same current C. If the magnetization of the core were strictly proportional to the magnetizing force, *i.e.*, to the current, then P would be proportional to C^2, and P/C^2 would be constant. In most cases this was so; but in two cases, where the cores of the electromagnets were very thin and the windings more than usually numerous, the ratio P/C^2 was found to decrease as the current increased. **κ decreases for large forces.** This shows that the magnetization tends to a maximum value as the current increases, in other words, that, for very large values of $\mathfrak{H}$, κ decreases.

Müller. Müller,[3] using the method of deflexions, arrived at a similar conclusion. His cores were 56 cm. long and from 9 mm. to 44 mm. thick, his magnetizing spirals from 48·2 cm. to 53·2 cm. long; his results are therefore impure, and the empirical formula by means of which he represents them of comparatively little importance; but the approach to a maximum of magnetization (saturation) is quite clearly demonstrated. **Maximum of magnetization.** He found, in accordance with theory, that if we increase the *external* magnetizing force ($\mathfrak{H}_0$) saturation is more quickly reached in thin than in thick bars. Somewhat similar experiments were made by Von Waltenhofen,[4] who deduces[5] from some of his own experiments with very thin cores, and from the experiments of Müller, Weber, and Dub, 1678 to 2125 mm. mg. sec. units of magnetic moment per mg. of iron as the maximum of magnetization. This would give from 1317 to 1668 C.G.S. units for the maximum magnetic intensity in iron. These numbers, derived from more or less impure results, are merely rough approximations, but they agree very well with those derived at a later date by methods less open to theoretical objections.

Koosen's experiment. The approach to saturation may be very neatly demonstrated as follows.[6] The same current is sent through a galvanometer and through the coil of an electromagnet with a thin core. The electromagnet is so placed that its action on the needle of the galvanometer just compensates the action of the galvanometer coil for a particular strength of current; the needle then points to zero. If now the current be increased, since the increase of magnetization does not keep up with the increase of the current, the action of the coil prevails, and the needle deviates accordingly.

Wiedemann's researches. The most extensive and important of the earlier researches into the general nature of magnetic induction are those of Wiedemann.[7] An epitome[8] of his results, with references to contemporary or preceding researches in the same direction, will put the reader in possession of almost all the more important general facts known until the quantitative experiments of Stoletow, Rowland, and their followers gave a complete account of the general characteristics of the function κ.

Experimental method. In these experiments the method of deflexion was used. The magnetizing spiral was placed magnetic east and west, and in the continuation of its axis was hung a magnetic steel mirror in a thick copper box to damp its oscillations. The deflexions of this mirror, read as usual with a scale and telescope when the core was not in, gave a measure of the current; and the increase of the deflexion on introducing the core gave a measure of the magnetic moment of the core. The cores were cylinders 22 cm. long., 1·35 cm. thick, and the length of the spiral was only 24 cm.,—so that perfectly pure results could not be obtained. To compensate to some extent for the shortness of the spiral, the bars were gently drawn to and fro several times before being placed in the final position for which the reading was taken. In order to measure the permanent magnetism the core was removed, the current broken, the core returned to its former position, and a reading again taken. The conclusions arrived at were as follows.

Maximum of magnetization and turning point. I. When a steel or iron bar is magnetized for the first time by a current C, the temporary moment K produced during the action of the current at first increases faster than the current, then more slowly, and finally tends to a maximum, as shown by Joule and Müller. The period of quicker increase is more marked in long than in short bars; it shows itself even on remagnetizing bars that have been several times magnetized and demagnetized. As C increases, the maximum of K is reached sooner in thin and long bars than in short and thick bars. Between the period of increase of K/C and its period of decrease there is no period of any considerable length for which it is constant. This last fact may be shown by means of the experiment of Koosen described above; viz., if the compensation be made for very small currents, when the current is increased, at first the electromagnet prevails, and the needle goes to one side of zero, then the current in the coil prevails, and the needle returns towards zero, and finally deviates on the other side.

The point at which the ratio K/C has its maximum for any particular electromagnet is called by Wiedemann the "turning point" (Wendepunkt). The turning point relates to the body as a whole, and the value of the external magnetizing force $\mathfrak{H}_0$ for which it occurs depends both on the form of the body and on the nature of the metal. It has therefore no very definite physical meaning. It must be carefully distinguished from the "saturation point." Any element of a body is said to be magnetized to saturation when no increase of the magnetic force can increase its magnetization any farther. It may happen, however, that some parts of a body are magnetized to saturation while others are not. With regard to the turning point, Dub[9] has shown that with similar and similarly wound cores the turning point occurs for the same value of the current. This is of course in agreement with an obvious corollary of the general theory of magnetic induction.[10]

II. In a freshly[11] magnetized bar the permanent moment which remains after the action of the current has ceased at first increases quicker than the producing current; but for stronger currents a turning point is reached; and then the moment increases more slowly than the current, and approaches a maximum.

III. In attempting to destroy the permanent magnetism of a bar by means of a demagnetizing current, it may happen that a current, which, during its action, already

[1] *Pogg. Ann.*, xlvii., 1839.
[2] Sturgeon's *Annals of Electricity*, vol. iv., 1839; *Phil. Mag.*, ser. 4, vol. ii.
[3] *Pogg. Ann.*, lxxix., 1850.
[4] *Sitzber. d. Wien. Akad.*, 1865.
[5] *Pogg. Ann.*, cxxxvii., 1869.
[6] Koosen, *Pogg. Ann.*, 1852; also Dub, *Ib.*, 1853.
[7] *Pogg. Ann.*, c., 1857; *Ib.*, cvi., 1859; *Ib.*, cxvii., 1862.
[8] Abridged from the author's own work, *Galvanismus*, Bd. ii. §§ 309 *sq.*
[9] *Pogg. Ann.*, 1868.
[10] See Thomson, quoted by Joule, *Phil. Trans.*, vol. cxlvi., 1856.
[11] That is, after being heated white hot to destroy all pre-existing magnetism.

Demagnetization easier than magnetization.

produces a temporary magnetic moment of opposite sign, still leaves on ceasing to act a permanent magnetic moment of the same sign as before, although less in amount.[1] On increasing the demagnetizing current still farther the permanent moment is at last destroyed. In this process the permanent magnetism decreases faster than the demagnetizing current increases,—so that *the current required to destroy a given permanent magnetism is less than the current that originally produced it.*[2]

Unilateral property of demagnetized bar.

IV. When a fresh bar has been magnetized with any permanent moment, and then demagnetized by a current $-C'$, opposite to the magnetizing current C, a second application of $-C'$, or of any *weaker* current in the same direction, will not produce a reverse *permanent* moment, although a current C' in the same direction as C *will* magnetize the bar permanently in the original direction more or less strongly. It follows therefore that demagnetizing by an opposite magnetic force, although it may destroy the permanent magnetism of a body, does not render it magnetically indifferent, as heating to a white heat would do. The body remains in fact more easily magnetizable in one direction than in another.[3]

V. In certain cases a fresh bar was magnetized by a current C, and then partly demagnetized; it was then found that a current C was required to bring it back to its original permanent moment.

VI. In another case a fresh bar was magnetized by a current C to permanent moment K, then reduced by a demagnetizing current C' to permanent moment K', then by a direct current C'' less than C brought to permanent moment K''. It was then found that a current C' was necessary to bring it back to permanent moment K'; and this held whether K' was positive, zero, or negative.

Repeated magnetization and demagnetization.

VII. When a bar is repeatedly magnetized and demagnetized by currents of the same intensity, the permanent magnetic moments corresponding to a given force become, to begin with, a little greater than at first; to begin with, they increase faster than the magnetizing force, though not so fast as at the first. The turning point, however, occurs for a weaker current than before. The magnetization obtained with the strongest current gradually decreases a little. The moments left by the demagnetizing current decrease less rapidly than before, so that a current at first capable of demagnetizing the bar altogether leaves after repeated magnetization and demagnetization a slowly increasing residual moment. After a large number of repetitions of the operation of magnetization by a current C and demagnetization by a current $-C'$, the bar finally reaches a constant state, so that each magnetization and demagnetization leaves a corresponding invariable permanent moment. When we pass beyond the limits C and $-C'$, these phenomena are repeated in the same order as before.[4]

Temporary and permanent magnetism in hard and soft steel and in soft iron.

VIII. All the above phenomena are most clearly seen in hard steel, less clearly in soft steel and iron. For small magnetizing forces the temporary moment in hard steel is less than in soft steel, and greatest of all in soft iron. The general rule is, the harder the material the less the temporary and the greater the permanent moment for a given magnetizing force.

IX. If, however, we consider the ratios of the temporary moments in soft steel and iron to the temporary moment in hard steel, all for the same force, then these ratios decrease gradually as the force increases; so that the temporary moment in soft iron reaches its maximum sooner than in soft steel, and still sooner than in hard steel.[5]

Earlier values of κ.

The earliest experiments from which definite values of κ have been calculated are those of Weber.[6] A cylindrical bar, 10·02 cm. long and ·36 cm. thick, was placed inside a spiral so long that the magnetizing force throughout the length of the bar could be assumed to be uniform. The moment of the bar was measured by the method of deflexion, the action of the spiral on the deflected magnet being compensated by means of a part of its own circuit suitably arranged. The intensity of the current in the spiral was found in absolute measure by means of a tangent galvanometer. Assuming that the bar could be replaced by a very elongated ellipsoid, Kirchhoff calculated by means of the theory explained above (p. 249) the values of κ for values of $\mathfrak{H}$ ranging from 29·6 to 248·4 (C.G.S. units), and found that it decreased steadily from 25·0 to 5·6. In the experiments of Von Quintus Icilius[7] bars were used which had been reduced by filing as nearly as possible to the form of ellipsoids of revolution. The magnetic moments were measured partly by the deflexion method, partly by the method of electromagnetic induction. In this last method a secondary spiral is placed upon the magnetizing spiral, and the induced current in it, caused by reversing the magnetizing current, is observed first when the ellipsoid is in the magnetizing spiral, secondly when it is not. When these currents are known in absolute measure, the moment of the ellipsoid can be calculated. The experimenter did not himself reduce his results so as to obtain κ, but contented himself with remarking that the ratio of the whole moment of the ellipsoid K to the strength of the undisturbed field $\mathfrak{H}_0$ reached a maximum as $\mathfrak{H}_0$ was increased, this maximum occurring for smaller values of $\mathfrak{H}_0$ the more elongated the ellipsoid. The true meaning of his results was brought out by Stoletow,[8] who reduced them, and established the interesting fact that, as the magnetizing force[9] $\mathfrak{H}$ increases from very small values, κ at first increases rapidly, then reaches a maximum, and afterwards decreases more slowly. For one ellipsoid κ increased from 30·5, for $\mathfrak{H} = ·24$, to a maximum 120·4, for $\mathfrak{H} = 4·56$, and then decreased to the value 39·4, for $\mathfrak{H} = 30·07$. In another, the initial value was 20·1 for $\mathfrak{H} = ·518$, the maximum value 107·5 for $\mathfrak{H} = 4·92$, and the final value 2·86 for $\mathfrak{H} = 454·1$.

Quintus Icilius.

Stoletow's deductions.

Thalén.

Thalén, adopting a method indicated by Weber,[10] determined the value of κ for small magnetizing forces. Long bars were placed in the axis of a cylindrical coil considerably exceeding them in length. This coil was caused to rotate 180° about a horizontal axis, so that the magnetization induced by the earth's vertical force was reversed relatively to the coil. The current thus caused was meaured by means of the swing of a galvanometer in circuit with the coil; from this (see above, p. 240) the moment of the induced magnetism was calculated; and thence, assuming the bar to be replaceable by an ellipsoid, κ was calculated. From three bars of the same metal each 400·4 mm. long, having diameters of 36·4, 29·94, and 23·87 mm. respectively, the values of κ deduced were 32·32, 31·80, and 32·64. For other specimens of iron he found values of κ ranging from 27·24 to 44·23.

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[1] See Poggendorff, *Pogg. Ann.*, 1852.

[2] This result had also been arrived at by Abria, *Ann. d. Chim. et d. Phys.*, 1844; and by Joule, *Phil. Mag.*, 1847, *Phil. Trans.*, 1855.

[3] Similar conclusions were arrived at by Ritchie, *Phil. Mag.*, 1833; Jacobi, *Pogg. Ann.*, 1834; Marianini, *Ann. Chim. et d. Phys.*, 1846.

[4] On the same subject see Joule, *Phil. Trans.*, 1856; also Von Waltenhofen, *Pogg. Ann.*, 1864.

[5] Similar results by Plücker, *Pogg. Ann.*, 1852 and 1855.

[6] *Electrodynamische Maasbestimmungen*, Bd. iii. § 26.

[7] *Pogg. Ann.*, cxxi., 1864. Similar results were obtained by Oberbeck, *Pogg. Ann.*, cxxxv., 1868.

[8] *Pogg. Ann.*, cxlvi. p. 443, 1872.

[9] $\mathfrak{H}$ here means the whole magnetizing force, arising partly from the inducing field and partly from the induced magnetism. Experimenters have needlessly complicated the already complex problem of ferro-magnetic induction by neglecting the all-important distinction between $\mathfrak{H}$ and $\mathfrak{H}_0$.

[10] *Abh. d. Gött. Gesellschaft*, Bd. 6.

Riecke.

A set of observations on ellipsoids of revolution were made by Riecke,[1] by the method just described. The ellipsoids, seven in number, were all cut from the same piece of soft iron, but varied in volume and in eccentricity. The resulting values of κ were found to be independent of the volume of the ellipsoids and of the part of the iron from which they were cut; but, on the other hand, with one slight exception, they increased with the eccentricity of the ellipsoids. Kohlrausch, in communicating these results to *Poggendorff's Annalen*, remarked that they stand in contradiction with the theory of Poisson and Neumann; in so saying he probably considered the constant vertical force of the earth ($\mathfrak{H}_0$) to be the argument of the function κ; but this is not so, as Stoletow points out in the paper already quoted. The actual magnetizing forces are greater in the more elongated ellipsoids; and Riecke's results simply prove that for values of $\mathfrak{H}$ varying from ·031 to ·072 κ increases from 13·5 to 25·4.

Stoletow's experiments.

In order to establish the initial increase of the magnetization function κ beyond all doubt, Stoletow (*l. c.*) made a new set of experiments on a carefully annealed iron ring[2] of rectangular section (exterior diameter 20 cm., interior diameter 18 cm., height 1·47 cm.). The ring was carefully wound throughout with a primary coil of n (=800) windings; over this, in one or more shorter or longer stretches, was wound a secondary coil of n'(=50 to 750) windings. The induction current in the secondary, due to the reversal of a known current i in the primary, was sent through a galvanometer, and thus measured. If E be the electromotive force of this current, then (see above, p. 246) $E = 4nn'i(4\pi\kappa M + P)$, where M and P can be calculated from the dimensions of the ring and its primary coil. All then that is necessary is to know E/i in absolute measure. We refer the reader to the original paper for the details of the measurements. The results are very interesting, and fully confirm the conclusions drawn from the results of Von Quintus Icilius and Riecke. The smallest value of $\mathfrak{H}$ was ·43, and the corresponding value of κ 21·5; the maximum value of κ was 174, for $\mathfrak{H}=3·2$; the last value observed was $\kappa = 42·1$, for $\mathfrak{H} = 30·7$. The temperature varied from 15° C. to 20° C., but it appeared from the experiments that κ did not alter much for moderate changes of temperature. In figure (34) is given a transcription of the curve that represents the results of

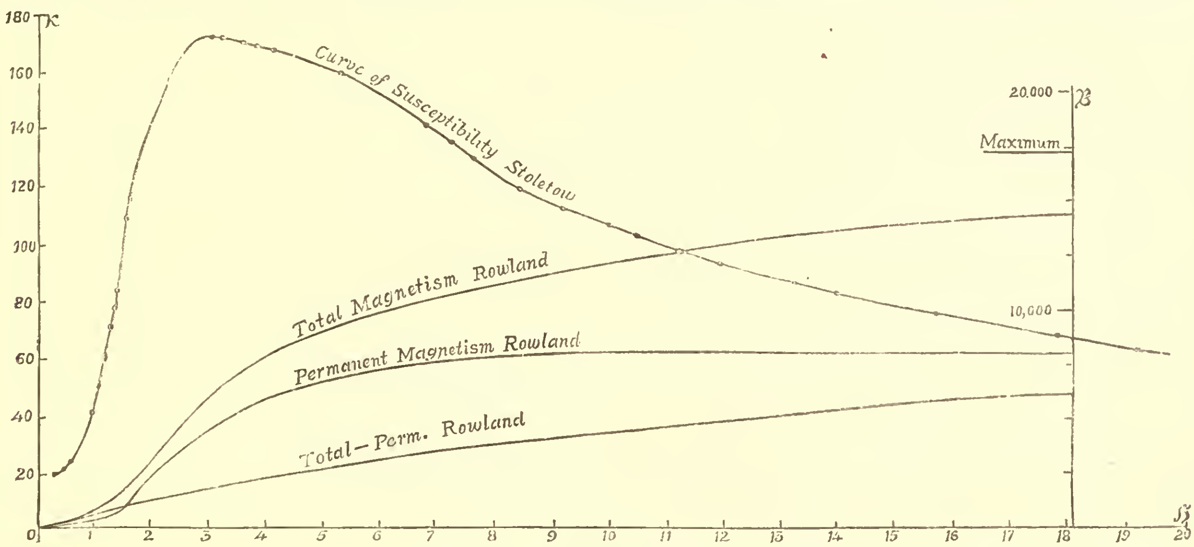

Fig. 34.

Stoletow's experiments; the abscissæ represent the values of $\mathfrak{H}$ in C.G.S. units, and the ordinates the corresponding values of κ.

Rowland's experiments.

About the same time as Stoletow, and independently, Rowland[3] made a much more extensive series of experiments, the results of which form one of the most important contributions yet made to our knowledge of magnetic induction. The experiments were made partly on very long bars; but the published results were mostly obtained from rings, it having been found that the effect of the ends of the bar was sensible even when the length was as much as 144 times the diameter. About a dozen rings of iron, nickel, and cobalt were used; the section was circular in all cases; and a primary and a secondary coil were used as in Stoletow's experiments. The primary current was measured by means of a tangent galvanometer in which 1, 3, 9, 27, or 48 coils could be brought into operation according to the sensibility required. The induction current in the secondary was measured by the swing of a Thomson's galvanometer fitted with a heavier needle than usual. The indications of this last were reduced to absolute measure by taking the swing caused by turning over a horizontal coil of known area, inserted in its circuit, so as to produce the full induction current due to the earth's vertical force. In order to obtain the total induced magnetization the primary current was reversed. To obtain the permanent magnetism it was simply broken; this gives the part of the induced magnetism that disappears with the inducing force (temporary magnetism Rowland calls it); subtracting this from the total magnetization, we get the permanent magnetization. Care was taken in these experiments always to work with magnetizing forces of ascending magnitude, as it was found that the effect of any force is considerably modified if a greater force has previously acted on the body,—in other words, that the magnetic permeability of iron or steel is much affected by pre-existing permanent magnetism. This fact raises an objection to the ring method; for permanent magnetization in a ring is not easily discoverable, and would give it a one-sidedness, so that a magnetizing force would produce much more alteration when exerted in one direction than it would when exerted in the other.[4] Rowland publishes about thirteen different tables, relating to rings of iron and steel in different states, and also to nickel and cobalt, under different conditions as to temper,

[1] *Pogg. Ann.*, cxli., 1870.
[2] A method suggested by Kirchhoff, *Pogg. Ann.*, Ergbd. v., 1870.
[3] *Phil. Mag.*, 1873, 1874.
[4] See Rowland, *Phil. Mag.* (4), 48, p. 336; also above, p. 254.

magnetization, and so on; the results for cobalt are, however, held to be less satisfactory than those for iron and nickel, for a variety of reasons which he assigns.

In treating his results graphically, two methods are followed. In the first the magnetic induction $\mathfrak{B}$ is plotted against the magnetizing force $\mathfrak{H}$ as abscissa. Figure 34 shows the curve obtained in this way from one of his tables. In the second method (1) the permeability ϖ is plotted against the magnetic induction $\mathfrak{B}$, or (2) the susceptibility κ is plotted against the intensity of magnetization $\mathfrak{I}$. Either variety of the second method leads to a curve having the general form shown in figures 35 and 36.

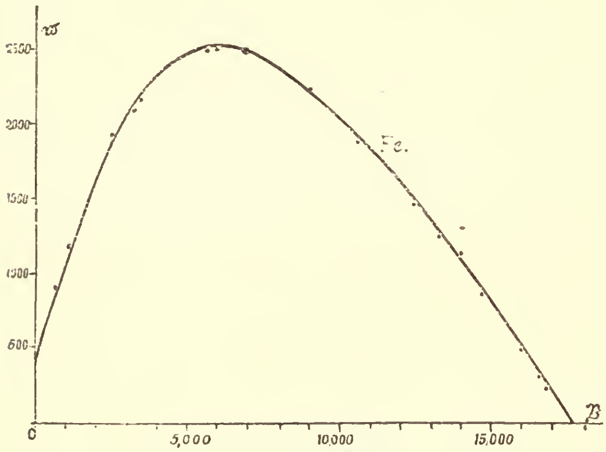

Fig. 35.—Curve $\varpi\mathfrak{B}$ for Iron.

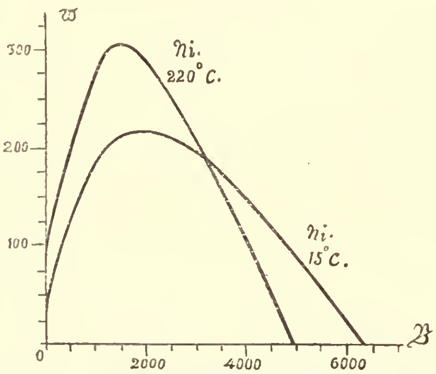

Fig. 36.—Curves $\varpi\mathfrak{B}$ for Nickel at different temperatures.

The curves obtained, whether for ϖ and $\mathfrak{B}$, or for κ and $\mathfrak{I}$, fall very rapidly, and ultimately to all appearance almost straight, towards the axis of $\mathfrak{B}$ or $\mathfrak{I}$. This suggests that $\mathfrak{B}$ or $\mathfrak{I}$ or both reach a maximum when $\mathfrak{H}$ is increased indefinitely. Supposing such an increase of $\mathfrak{H}$ possible, the question arises as to which it is that actually reaches a maximum. Most experimenters seem to assume that $\mathfrak{I}$ does so, but it must be remarked that this is simply an assumption.[1] Several delicate points of great physical interest might be discussed here, but it will be sufficient to refer the reader to the introduction to Rowland's second paper.

General conclusions.

The general conclusions to be drawn from these experiments are as follows:—

1. The magnetic properties of iron, nickel, and cobalt at ordinary temperatures differ in degree but not in quality.

2. As the magnetizing force $\mathfrak{H}$ increases from 0 upwards, the permeability of iron, nickel, and cobalt increases until it reaches a maximum, and after that diminishes down to a very small value. The maximum value[2] is reached when the metal has attained a magnetization of from ·24 to ·38 of the maximum. The following table will give some idea of the order of the magnitudes involved; ϖ_0 denotes the permeability for $\mathfrak{H}=0$, ϖ' the maximum permeability, and $\mathfrak{H}'$ the force for which it occurs. In some cases the actual maximum is given, in other cases simply the greatest recorded in the tables of experimental results, and the values of $\mathfrak{H}$ are stated roughly; strict accuracy is of no consequence, owing to the great variability of all the magnitudes.

Shape.	Material.	Temper.	State.	ϖ_0	ϖ'	$\mathfrak{H}'$
Ring.	Very fibrous iron wire.	Annealed.	Burnt.	120	1106	...
Bar.	Soft wire.	"	"	180	2467	...
Ring.	Burden's best iron.	"	Normal.	352	2475	2·5
"	" "	"	Magnetic.	216	2459	2·4
"	" "	Carefully annealed.	Burnt.	544	3621	1·6
"	Norway iron.	" "	Normal.	720	5515	...
"	"	" "	Magnetic.	440	4656	1·2
"	Bessemer steel.	Natural.	Normal.	200	1281	5·6
Bar.	Stubbs' steel.	"	"	76	331	25·0
Ring.	Cast nickel.	Annealed.	"	38	169	11·6
"	" at 15° C.	Natural.	"	...	222	9·1
"	" at 12° C.	"	Magnetic.	...	224	8·8
"	" at 220° C.	"	"	...	314	5·3
"	Cast cobalt at 5° C.	"	Normal.	...	142	18·9
"	" at −5° C.	"	Magnetic.	...	144	16·8
"	" at 230° C.	"	"	...	236	10·1

The smallest permeabilities (for large forces) observed were—for iron 258, for $\mathfrak{H}=64$; for steel 246, for $\mathfrak{H}=48$; for nickel 41, for $\mathfrak{H}=131$; for cobalt 55, for $\mathfrak{H}=147$.

3. The curve showing the relation between κ and $\mathfrak{I}$, or between ϖ and $\mathfrak{B}$, is of such a form that a diameter can be drawn bisecting chords parallel to the axis of $\mathfrak{I}$ or $\mathfrak{B}$, and its equation is approximately

$$y = \mathrm{B}\sin\left(\frac{x+by+d}{\mathrm{D}}\right),$$

where $y=\kappa$ or ϖ, $x=\mathfrak{I}$ or $\mathfrak{B}$, and b, d, B, D are constants.

4. If a metal is permanently magnetized, its permeability is less for low magnetizing forces, but is unaltered for high magnetizing forces. This applies to the permanent state finally attained after several reversals of the magnetizing force; but if we strongly magnetize a bar in one direction, and apply a weak magnetizing force in the opposite direction, the change of magnetization will be very great.

Maximum intensity of field and of magnetization.

5. Iron, nickel, and cobalt all probably have a maximum of magnetization, although its existence can never be entirely established by experiment, and must always be a matter of inference. If such a maximum exists, then at ordinary temperatures it will be roughly as follows:—

For iron when $\mathfrak{B}=17{,}500$, or when $\mathfrak{I}=1390$;
For nickel when $\mathfrak{B}=6{,}340$, or when $\mathfrak{I}=494$;
For cobalt when $\mathfrak{B}=10{,}000$, or when $\mathfrak{I}=800$.[3]

[1] All the more so that it has been found by some experimenters that the curve ($\kappa\mathfrak{I}$) actually has a point of inflexion and becomes convex to the axis of $\mathfrak{I}$ for very large values of $\mathfrak{H}$.

[2] Baur, *Wied. Ann.*, ii. p. 395, 1880, has remarked that the intensity of magnetization corresponding to the maximum permeability seems to be about the same for different sorts of soft iron; *e.g.*, for two of the ellipsoids of Von Quintus Icilius it is 550 and 540; for Stoletow's ring, 550; for Baur's ring, 540. It would seem that it is much higher for *steel*, judging by Rowland's tables.

[3] The maximum of magnetization for soft iron was calculated from the observations of various experimenters by Von Waltenhofen (*Wien. Ber.*, 1869; or *Pogg. Ann.*, cxxxvi.). He finds 1670, or thereby, for the maximum intensity of magnetization. Stefan, using Rowland's graphical method (*Wien. Ber.*, 1874), had found 1400. Fromme (*Wied. Ann.*, xiii., 1881), who had himself actually observed an intensity of as much as 1531, examined the curve for κ and $\mathfrak{I}$, and found, in agreement with Haubner (*Wied. Beibl.*, v., 1881), that there is a point of inflexion about $\mathfrak{I}=1200$; taking this into account, he finds for the maximum value of $\mathfrak{I}$ 1730, as a mean of results varying between 1720 and 1750. From a result of Weber's (*Elec. Maasbest.*, p. 573) he calculates the value 1737.

For the maximum permanent magnetization of steel, Weber (*Res. d. Mag. Ver.*, 1840) gives 314 (common steel magnet); Von Waltenhofen (*Pogg. Ann.*, 1871) 369 (glass hard wolfram steel); Schneebeli (*Wied. Galv.*, Bd. ii. § 308) 557 to 671 (sewing needles 25 to 66 mm. long and ·6 mm. thick), and 765 to 832 (knitting needles 198 to 210 mm. long and ·83 to 1·75 mm. thick). It must

6. The permeability of any metal depends on the quality of the metal, on the amount of permanent magnetization, on the total magnetization, and on the temperature.

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7. The permeability of nickel and cobalt varies very much with temperature. In nickel for a moderate amount of magnetization the permeability increases with rise of temperature, but for high magnetization it decreases. This is very well shown in fig. 36, where the permeability curves for 15° C. and 220° C. intersect each other. In cobalt, on the other hand, the permeability appears to be always increased. The permeability of iron is not much affected by moderate changes of temperature.

8. The maximum of magnetization of iron and nickel decreases with rise of temperature, at least between 10° C. and 220° C., the first very slowly, the second very rapidly. At 220° C. the maximum for iron is $\mathfrak{B} = 17200$ or $\mathfrak{I} = 1360$, and for nickel $\mathfrak{B} = 4900$ or $\mathfrak{I} = 380$.

The researches of Stoletow and Rowland have undoubtedly made clear the main phenomena of magnetic induction; but in so doing they have raised a host of other questions which have not as yet been settled. There is no lack of recent work bearing on them, but it would be a difficult matter to give succinctly a complete account of the conclusions arrived at. The results of the different experimenters are not seldom contradictory, and the circumstances of experiment are often so complicated that criticism with the view of reconciling them seems hopeless in the meantime. While, therefore, we shall give a fairly complete list of the literature, the reader must not expect in this article an exhaustive analysis of the different memoirs that have recently appeared. Any remarks we shall make have chiefly for their object to call attention to the prominent questions that have been raised by the different workers.

Iperi- nts vh ep- ıls al s eres. ke, mme, Gz.

Riecke[1] made a series of experiments on ellipsoids of soft iron; he expresses his results in terms of p the magnetization function for a sphere, and finds, as he ought to do, that, for a considerable range of values of the magnetizing force, p is approximately constant.[2] In point of fact this method of representation is bad, for the quality of the metal only begins to affect p about the fourth or fifth decimal place. Similar experiments on spheres and ellipsoids of soft iron were made by Fromme;[3] and a very extensive series by A. L. Holz[4] on ellipsoids of iron and steel, in which he gives tables and curves showing the values both of p (to a large number of decimals) and of κ; and the values of the temporary, permanent, and vanishing magnetisms for a considerable range of magnetizing forces. The results, although wanting in regularity and smoothness for the harder kinds of steel, agree in the main with those of Stoletow and Rowland. Holz enters largely in this and in a former paper[5] into speculations concerning the effect of the molecular structure of the metal upon its magnetic properties.

ıty.

Relating more particularly to the phenomena of the permanent and temporary magnetization of steel we have important memoirs of recent date by Bouty, Fromme, and Auerbach. Bouty's papers,[6] besides copious references to the general literature of the subject and interesting critical discussions of magnetic theory, contain the results of careful investigations as to the permanent magnetization attained by repeated applications of magnetic force under various circumstances, and verifications of the formulæ of Green for the magnetic distribution in thin needles and cylindrical bars of steel. Two points as to his methods are worthy of notice. He employs a very simple method of measuring the magnetic moment of small pieces of steel: a small needle of moment m attached to a stiff stem, which carries a mirror, is freely suspended and allowed to come to rest in the magnetic meridian; the needle whose moment x is to be measured is then inserted into a tube fixed to the stem with its axis at right angles to the former needle. The deviation α of the compound system being measured by means of the mirror, we have $x = m \tan\alpha$. He studies the magnetic distribution in very thin hard needles by the method of rupture, finding that, if the needle be carefully broken, so that the distortion or shock caused by the bending does not extend far from the point of rupture, the magnetic moment of the different parts is little, if at all, affected. For thicker magnets he uses the ordinary method of deflexion.

Measurement of small moments.

Rupture of needles.

Bouty found, in agreement with Hermann Scholz and Frankenheim,[7] that, although the *continued* application of a magnetizing force does not increase the resulting permanent magnetization, the *repetition*[8] of its application will. He finds for the magnetic moment y of a thin needle passed x times through a magnetizing spiral the formula $y = A - B/x$, where A and B are constants: *e.g.*, in one case, $A = 57{\cdot}78$, and $B = 6{\cdot}32$. The ratio $A/(A - B)$, that is, the ratio of the moment attained by an infinite number of applications of the magnetizing force to that attained by one, decreases as the force increases; on the other hand, if R′ be the force required to produce by a single application the same effect as R produces by an infinite number, he finds the ratio R′/R fairly constant[9] (viz., from 1·060 to 1·065 in his best experiments) for values of R ranging from 10 to 42. In certain cases where the magnetization was effected by induced currents, he finds the formula $y = A + B\,(1 - e^{-\alpha x})$ to represent the results better.[10]

Effect of repeated application of magnetizing force.

He found that Green's formula,

$$y = A\alpha^2\left(x - \frac{2}{\beta}\,\frac{e^{\frac{1}{2}\beta x} - e^{-\frac{1}{2}\beta x}}{e^{\frac{1}{2}\beta x} + e^{-\frac{1}{2}\beta x}}\right),$$

where $$\beta = \frac{B}{\alpha},$$

giving the moment of a cylinder of length x and diameter α, was sufficiently accurate both for temporary and for permanent magnetism, and for hard or soft tempered steel, whether saturated or not, provided the bars were in a virgin condition before magnetization. For example, in a saturated bar of soft steel ($\alpha = 7$ mm.), for the temporary magnetism $A = 4{\cdot}081$, $B = 1/7{\cdot}142$; for the permanent magnetism $A = 2{\cdot}34$, $B = 1/17{\cdot}857$. In a non-saturated bar of soft steel ($\alpha = 10$ mm.), for temporary magnetism $A = {\cdot}9966$, $B = 1/7{\cdot}142$; for permanent magnetism $A = {\cdot}723$, $B = 1/17{\cdot}857$; so that B is independent of the magnetic force. With hard tempered bars, A was less, both for temporary and permanent magnetism, than with soft bars; B was independent of the magnetizing force for temporary magnetism, but increased for permanent magnetism with large magnetizing forces. He calls the magnetic distribution long or short according as B is small or great, and

be remembered that the maximum of *permanent* magnetization which a body can attain is essentially conditioned by its form; since the more elongated the form the less the demagnetizing force arising from the existing magnetization.

[1] *Pogg. Ann.*, cxlix., 1873. [2] $= 3/4\pi = {\cdot}2387$.

[3] *Pogg. Ann.*, clii., 1873. This paper contains also some results as to the permanent magnetism of soft iron.

[4] *Pogg. Ann.*, Ergbd. viii., 1877. [5] *Pogg. Ann.*, cli., 1873.

[6] *Comptes Rend.*, 1875; *Jour. d. l'Éc. Norm. Sup.*, 1875, 1876.

[7] *Pogg. Ann.*, cxxiii., 1864.

[8] In a very interesting paper (*Phil. Mag.*, 1869 and 1870) dealing with certain phenomena of induced currents, Lord Rayleigh incidentally arrives at the conclusion that the magnetizing force of a current depends on its maximum intensity more than on its duration, or on the whole quantity of electricity that passes. This observation has an important bearing on certain experiments of Bouty as to the effect of the "extra current," which it does not seem necessary to mention here.

[9] This conclusion is not in agreement with the results of Fromme.

[10] The formula $y = B(1 - e^{-\alpha x})$ was used by Quetelet for the moment induced in a steel bar by rubbing it x times with a magnet.

explains the phenomena of demagnetized or remagnetized bars by the superposition of long and short distributions. His final conclusion is that there is a greater independence between permanent and temporary magnetism than is usually admitted; and he starts a theory that magnetic bodies are composed of a mixture of two kinds of magnetic molecules, one kind retaining all the induced magnetism, the other wholly devoid of coercive force.

Magnetic after-effect.

It is obvious, from the results of Wiedemann, Frankenheim, and Bouty just alluded to, that the assumption made in the mathematical theory, that the effect of a magnetizing force is independent of the previous magnetic history of the body, is not even a first approximation to the actual truth. It becomes a matter of importance therefore to study the modification in the induced magnetism corresponding to any force produced by the forces that have preceded it. This effect has been called by German experimenters the *magnetic after-effect* (Magnetische Nachwirkung). Fromme and Auerbach have recently occupied themselves with this subject, and it may be of some interest to the reader to indicate a few of their conclusions.

Fromme.

In his first paper[1] Fromme experiments with rotational ellipsoids of soft steel, using partly the method of Weber, Thalén, and Riecke, partly the ordinary method of deflexion. He found, in the first place, that the generalized theory of magnetic induction was applicable for values of $\mathfrak{H}$ varying from ·0061 to ·132, κ decreasing between these limits from 23·5 to 8·68. He attempted to find the maximum force for which permanent magnetism first appears, and fixes it with some reserve at from ·2 to ·3.[2] The curve which he indicates for the temporary magnetization of soft steel has two points of inflexion, being first concave to the axis of $\mathfrak{H}$, then convex, and finally concave again.

He confirms the observation of Frankenheim that repeated applications of the magnetizing force increase the permanent magnetization up to a certain limit, and finds that when that limit is reached the body behaves towards all smaller forces having the same direction as if it were devoid of coercive force. Experimenting on ellipsoids permanently magnetized in this way, he found the mathematical theory of Kirchhoff to be inapplicable, it being impossible to fit the results obtained with the different ellipsoids together; and the discrepancy was greater with the softer than with the harder steel. For forces that are not sufficient to alter the permanent magnetization, κ decreases with decreasing force, as is the case with soft iron, so long at all events as the forces are not very great; and, again, for such forces the variation of κ is more regular the greater the permanent magnetization.

The number of impulses required to saturate with permanent magnetism was greater the greater the ratio of the moment of saturation to the initial moment, *e.g.*, greater for hard than for soft steel. It was found, in extension of a result of Frankenheim's, that, if U be the original moment, R_1 that produced by one and R that produced by an infinite number of impulses of the magnetizing force, then $(U+R_1)\ (U+R)$ is tolerably constant; but R_1/R decreases with increasing magnetizing force.

With reference to the non-permanent magnetism of a bar repeatedly magnetized by the same constant current, he concludes from his researches that it diminishes, but in such a way that the total induced magnetism remains constant,—so that what is lost in non-permanent is gained in permanent magnetism.

In his second paper[3] Fromme experimented both with iron and with steel cylinders, pointed at the end, of lengths varying from 140 to 220 mm., and of thicknesses from 1·5 to 8 mm. The method of deflexion was used, the effect of the magnetizing spiral itself being compensated by an auxiliary spiral suitably placed. The cores were carefully introduced into the spiral after the current was established, removed before it was broken, and then replaced when the permanent magnetism was determined.

In the following extract from his conclusions T_n denotes the total induced magnetization, R_n the whole residual or permanent magnetization, V_n the non-permanent or vanishing magnetization, after n impulses of a given magnetizing force, the suffix being dropped when the number of impulses is not in question, and replaced by ∞ when the number is so great that by further increasing it no alteration in the effect is produced.

Varying effect of successive impulses on temporary magnetism.

A constant force greater than all preceding induces a T which varies with successive impulses, sometimes increasing, sometimes decreasing. If a bar previously heated white hot be subjected to a large force, successive impulses usually give a decrease of T. If, however, the force is preceded by one somewhat smaller, successive impulses usually give an increase. It depends merely on the magnitude and the number of impulses of the preceding force P whether the repeated impulses of a force p will give an increasing or a decreasing T.

Effect on permanent magnetism.

R always increases with successive impulses until the limit is reached, and always faster than T; hence increase of R and decrease of V go hand in hand; the magnitude of this increase depends on P and p, and approaches zero with $P-p$.

In order that the action of a force p may not be influenced by the after-effect of smaller forces preceding it, it must be applied so often that its further application ceases to increase R. When saturation for R is thus reached, then T, R, and V have the values corresponding to frequent impulses of p for a fresh bar.

R_1/R_∞, R_2/R_∞, &c., all starting from unity, decrease as the force p increases from zero, diverging more and more until they all reach minima for the same value of p; they then converge again towards unity, which they all reach at the maximum of permanent magnetization. The values of p corresponding to the maxima of R_∞/p, ... R_2/p, R_1/p are in ascending order of magnitude, and the first of them is the value corresponding to the minima of R_1/R_∞, R_2/R_∞, &c.

What was stated for R_1/R_∞, R_2/R_∞, &c., holds word for word for T_∞/T_1, T_∞/T_2, &c. Hence the decrease of T is conditioned solely by the increase of R; so that it would appear that the after-effect of a preceding force P depends on the R which it produces. It would therefore be more correct to say that the after-effect depends on $r-R$ than to say that it depends on $p-P$.

Laws of after-effect.

When a bar has been magnetized by any force P, all *smaller* succeeding forces leave R unaltered, yet by repeated impulses of p ($<P$) T decreases until it reaches a certain limit. We may repeat the process as often as we please by always beginning with a new application of a larger force P; if we vary P, keeping p constant, T_1, T_2, &c., vary, but the limit T_∞ is always the same. In these experiments it was indifferent whether a few seconds or several hours elapsed between the applications of P and p; time had no influence on the vanishing of this species of magnetic after-effect. On the other hand, several impulses of the greater force gave no more after-effect than a single impulse, of whatever duration. If N denote the after-effect of a greater force P upon the action of a smaller p, the law of the phenomenon is

$$N = cp^a(P-p)^b,$$

where c is a constant and a and b are constant positive

[1] *Pogg. Ann.*, Ergbd. vii., 1875.

[2] So far confirming Maxwell's conclusions from his modification of Weber's theory of molecular magnets, *El. and Mag.*, vol. ii. § 445.

[3] *Wied Ann.*, iv., 1878.

numbers, b being a proper fraction, and a possibly very near unity. This of course gives $N=0$ for $p=0$ and for $p=P$, and gives a maximum value of N for some value of p between 0 and P.

The interposition of a force P′ between P and p increases the after-effect if $P'>P$, diminishes it if $P'<P$; and this holds irrespective of the sign of $P'-p$.

If we denote by k the susceptibility of a body for vanishing magnetism (V) induced by any force p, the question arises how far this is influenced by the permanent magnetism R induced by preceding greater forces. Jamin holds that k is approximately, and Chwolson that it is absolutely, independent of such permanent magnetism. Fromme finds that, when a force p, capable of itself producing a permanent magnetism r, acts on a bar already possessing a permanent magnetism $R>r$, then k is increased (by the presence of R) if $R-r$ is small, but diminished when $R-r$ is great.[1] The after-effect for small forces p may therefore be either increase or decrease of k; but for large forces p it is always increase.

At the conclusion of his paper Fromme points out the contrast between magnetic and elastic after-effect, and dwells upon the analogy between his results and those of Thalén [2] concerning the limits of elasticity in solid bodies.

The experimental method followed by Auerbach [3] was much the same as that of Fromme, except that the core was left in the magnetizing spiral during the make and break of the current. The core was generally a hollow cylinder of soft iron 148·1 mm. long, 17·8 mm. in diameter, 1·6 mm. thick, with end plates 1·5 mm. thick. He distinguishes two kinds of magnetic after-effect. The first kind consists in alteration of the magnetization of the body during the action of a constant force, or after it has ceased to act. The second kind is that already mentioned, in which the action of any force is influenced by preceding forces. It is this second kind of after-effect that is dealt with in the paper from which we are quoting.

The leading peculiarity of his view of the phenomenon is the introduction of the force *zero*, both as a preceding and as a final force. The fundamental principle laid down is the following:—

When the force p, which, following immediately after the force 0, would produce a magnetization T_0, is preceded by a series of forces $P_1, P_2 \ldots P_n$, the magnetization which results is T, differing from T_0 by an amount N called the after-effect. N is wholly determined by the first of the preceding forces P_z, which is such that all the forces that act between P_z and p lie in magnitude between P_z and p.

This general law is, however, subject to exceptions. For example, let the whole series of forces acting be P_{10}, p, P_9, p (evidently an extreme case), then experience shows that neither T_{10} nor T_9 is the resulting magnetization, but something intermediate, much nearer to T_{10}, however, than to T_9. In order to obtain T_9 a force $P_0<p$ must be interposed before P_9; even then the magnetization varies a little with P_0, but, if the stationary condition for P_9, p be established by alternating P_9, p many times after applying P_0, thus $P_{10}, p, P_0, P_9, p, P_9, p, P_9, p, \ldots$ the limit is found to be independent of P_0, and is held to be the true value of T_9.

In this way, for a given p, T can be determined as a function of P. It is necessary, however, to attend to the following principle,—that, of two preceding forces lying in magnitude on different sides of p, the second determines the after-effect exclusively only when it differs more from p than the first; in other cases both contribute to the after-effect; in no case does the first exclusively determine the after-effect. In the case where both preceding forces lie on the same side of p, the exceptions to the general law are far less marked; only where the second force is very nearly equal to p does it exercise a disturbing influence on the after-effect of the first.

The process used for obtaining T as a function of P, for a given p, say 10, is therefore to cause the influencing forces to alternate with the influenced, the succession of the former being such that the one preceding p always differs less from p than the one following. The stationary condition is supposed to be established for each pair as above explained; *e.g.*, starting with $P=11$, the series might be 11, 10, 8, 10, 13, 10, 6, 10, 15, 10, 4, 10, &c. In this way T_{11}, T_8, T_{13}, &c., can be determined.

When the values of T are plotted against the values of P, the curves corresponding to different values of p have all a similar character (see figure 37). They consist of two congruent parts lying on the two sides of a point of inflexion, which is the only point that has any marked character. To the right of the inflexion the concavity is towards the axis of P, to the left in the opposite direction. The infinite branches appear to approach (Curves of temporary magnetism with after-effect.)

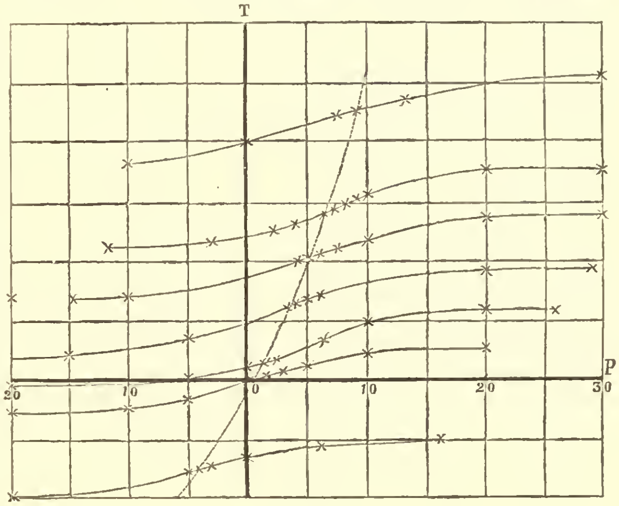

Fig. 37.

asymptotes parallel to the axis of P. The abscissa of the point of inflexion for any particular curve p is $P=p$; the ordinate is T_p, which may be called the normal magnetization corresponding to p when p alone has acted before. This of course is an ideal case; but a process is indicated for determining T_p directly.[4] The dotted curve in the figure is the curve of normal magnetization, whose abscissa and ordinate are p and T_p.

From the symmetry of the curves representing the after-effect Auerbach concludes that the after-effect of forces on opposite sides of p as to magnitude, and equidifferent from it, is equal and opposite, and ascribes the failure to observe the after-effect of forces smaller than p to the interposition of the force zero. He further concludes that the after-effect depends in the same way on $P-p$ as T_p depends on p.

There is one of the curves of after-effect, that, viz., for $p=0$, which has a special meaning. It is clearly the curve

[1] These conclusions are in agreement with the results of Herwig obtained from experiments on the longitudinal and circular magnetization of iron tubes, *Pogg. Ann.*, clvi., 1875.

[2] *Pogg. Ann.*, cxxiv., 1865.

[3] *Wied. Ann.*, xiv., 1881.

[4] A particular case of this process is interesting and practically important; viz., in order to demagnetize a core (*i.e.*, to find T_0) possessing a moment T. Apply in succession the forces $-P$, $+(P-\epsilon)$, $-(P-2\epsilon)$, $+(P-3\epsilon)$, &c., down to 0, P being chosen of sufficient magnitude, rather too great than too small (the smaller ϵ the better).

of permanent or residual magnetism, which is thus in Auerbach's view a particular case of after-effect. To it we can apply the general rule given above, subject of course to like exceptions.

It would be premature to pronounce any opinion as to the ultimate value of Auerbach's results; but the elegance of his representation of the phenomena will scarcely be disputed. In the latter part of his paper he applies his views to explain the peculiarities in the curve of magnetization with forces of ascending magnitude obtained when the after-effect is neglected, and to the cyclical process discussed by Warburg.[1] He also discusses the influence of the duration of the impulse of the magnetizing force and of the sudden closing and opening of the current. His conclusions agree in the main with those of Fromme: in particular he inclines to Fromme's view[2] that there is a specific magnetic effect produced in certain cases by the breaking of the current while the core is in the spiral. This effect in certain cases (with short thick cores) is so great that a permanent magnetization of opposite sign to the total induced magnetism remains.[3] This "anomalous magnetization" was first observed by Von Waltenhofen,[4] who also establishes the more general result, of which this is an extreme case, viz., that the residual magnetism of the core depends upon the rapidity with which the magnetizing force is reduced to zero. Auerbach lays down as a general principle that when the variation of the magnetizing force is slow and continuous the velocity of the transition does not influence the final magnetization; but sudden transition causes the final magnetization to be less or greater than that obtained by gradual transition, according as the passage is from a greater to a less or from a less to a greater force.

Effect of duration and repetition of impulse.

Additional literature.

The reader who wishes to pursue the present subject farther should consult the works of the following experimenters:—

Jamin,[5] who holds what he apparently regards as a new theory of magnetization. It is in point of fact merely a modification of the theory of solenoids, somewhat restricted in its application to the phenomena of magnetic induction. His special point is that the lines of magnetization in a bar magnetized (say) by a magnetizing spiral only penetrate to a limited depth, which is greater the greater the current. The following experiments[6] are adduced in confirmation of his views. The steel tube of a Chassepot rifle was plugged at both ends by screwing into it bolts of the same metal. Inside was placed a cylindrical rod. It was found that, so long as the current in the spiral was not very great, the rod was not sensibly magnetized; but, as the current increased, it became more and more affected, and by and by was as much permanently magnetized as if the enveloping tube had been absent. Again, the rod having been magnetized to saturation and inserted in the tube, a demagnetizing force was applied to the whole, and it was found possible to render the tube and core together seemingly neutral, or even oppositely magnetic, while the rod when taken out proved to be still powerfully magnetized in the original direction. Again, a bar was magnetized by a powerful current, and then magnetized in the opposite direction by another current. The surface of the bar was then eaten away to a certain depth; and it was found that the original magnetization reappeared. These experiments, although most interesting in themselves, do not appear to warrant the interpretation which their author puts upon them. Jamin has made extensive researches on the magnetic distribution in bars and ribbons of steel, partly with a view to obtain empirical rules for the construction of powerful permanent magnets, in which he has been very successful.

Gaugain, *Comptes Rendus*, passim; *Ann. d. Chim. et d. Phys.*, (5) xi.

Christiansen, "Researches on the Magnetic Distribution in an Iron Bar, on one part of which is placed a Short Magnetizing Spiral," *Wied. Beibl.*, i., 1877.

Ruths, "Ueber den Magnetismus weicher Eisencylinder und verschieden harter Stahlsorten" (Dortmund, 1876), *Wied. Beibl.*, i., 1877.

Whipple, "Induction Constants of Permanent Magnets of various shapes, from the determination at Kew," *Proc. Roy. Soc. Lond.*, 1877.

Oberbeck, "Ueber die Fortpflanzung der magnetischen Induction im weichen Eisen" (Halle, 1878), *Wied. Beibl.*, ii., 1878.

Külp, "Experimentaluntersuchungen über magnetische Coërcitivkraft," *Carl. Rep.*, 1880.

Baur, "Experiments with an Iron Ring on the Magnetization Function for very small Forces," *Wied. Ann.*, xi., 1880.

Riecke, "On the Experimental Test of Poisson's Theory," *Wied. Ann.*, xiii. p. 485, 1881.

Siemens, a very interesting paper, "On the Effect of the Magnetization of Iron in any Direction upon its Permeability in the Perpendicular Direction," *Wied. Ann.*, xiv., 1881.

Righi, "Contributions to the Theory of the Magnetization of Steel," *Mem. d. Acc. d. Bologna*, 1880; *Wied. Beibl.*, v., 1882.

For a succinct account of several of the foregoing memoirs, see the "Nachträge" to Wiedemann's *Galvanismus*, and a paper by the same author in *Poggendorff's Annalen*, clvii. p. 257, 1876.

Influence of hardness and structure.

Influence of the Hardness and Structure of Iron and Steel on Permanent Magnetism.—Some information has already been given incidentally on this subject, and a lengthy discussion would be out of place here. The statements of the various authorities are very contradictory. This is not to be wondered at; for those best qualified to prepare the materials for experiment are generally deficient in the scientific knowledge requisite to enable them to form a sound judgment as to the result, while thoroughly trained scientific men have not as a rule acquired a command over the delicate manipulation of the forging and tempering of steel, an art which those who possess it usually find difficult to describe in words or reduce to rules. There is the further circumstance that many who have been successful in making good steel for magnetic or other purposes have found it for their interest not to publish the process by which success was attained.

Fineness of grain and uniformity of temper.

Fineness of grain and uniformity of temper are the greatest requisites in steel for permanent magnets. The latter in bars of any size is never attained in perfection, for the surface is always harder than the interior. The mischief which thereby arises may be understood by taking the extreme case of a thin steel tube magnetized to saturation, and then fitted with a perfectly soft iron core. It is clear that the core will act very much like the armature of a horse-shoe magnet; the lines of force will run back through it, and the external action will be in a great measure destroyed.

The different tempers of steel may be roughly classified as glass hard, straw colour, blue, and soft. The current statement is that the harder the steel the more difficult it is to magnetize, but the better it retains its magnetism. If this were so, provided sufficient magnetizing force to produce saturation were at command, the best temper for magnets would be glass hard. Lamont, however, whose experience was great, states that he found the loss after magnetization to be as great, and to continue as long, with glass hard as with blue tempered magnets. The same experimenter gives it as his opinion that great differences in the quality of magnets arise more from defects as to homogeneity, continuity, and uniformity of temper than from the quality of the steel in other respects; he inclines, however, to a preference for English cast steel.

Purity and homogeneity of structure are equally necessary in iron of high magnetic inductive susceptibility and small coercive force. Hammering, rolling, and drawing diminish the susceptibility and increase the coercive force. Rolling does so more in the direction of rolling than transversely, so that the iron becomes æolotropic. It is advisable in all cases where high susceptibility is wished to anneal the

[1] *Wied. Ann.*, xiii., 1881; *cf.* Fromme, *Ib.*, xiii., 1881; also Himstedt, *Ib.*, xiv., 1881. A similar phenomenon was observed by Meyer and Auerbach during their experiments on the gramme machine, *Wied. Ann.*, v., 1878.

[2] See an elaborate paper which we can only mention here, *Wied. Ann.*, v., 1878.

[3] Experiments on the same subject have been made by Righi. *Comptes Rendus*, 1880, or *Wied. Beibl.*, iv., 1880; and by Bartoli and Alessandro, *N. Cim.*, 1880, or *Wied. Beibl.*, iv., 1880. *Cf.* Fromme, *Wied Ann.*, xiii., 1881.

[4] *Wien. Ber.*, 1863.

[5] *Comptes Rendus*, passim.

[6] *Comptes Rendus*, lxxx., 1875.

body carefully after manufacture, by heating it in a wood fire and allowing it to cool very gradually; this process is still more effective when the iron is covered all over beforehand with half an inch or so of clay.

The reader who wishes for further details on this subject should consult Lamont's *Handbuch des Magnetismus*, chap. v. The following references to the literature may be useful.

Michell, *Treatise of Artificial Magnets*, 1750; Coulomb, *Mém. de l'Acad.*, 1784; Barlow, *Phil. Trans.*, 1822; Kater, *Phil. Trans.*, 1821; Sabine, *Phil. Trans.*, 1843; Hansteen, *Pogg. Ann.*, 1825; Häcker, *Pogg. Ann.*, 1848; Poggendorff, *Ib.*, 1850; Müller, *Ib.*, 1852; Matthiessen, *Phil. Mag.*, 1858; Airy, *Ib.*, 1863; Von Waltenhofen, *Pogg. Ann.*, 1864; Trève, *Comptes Rendus*, 1869; A. L. Holz, *Wied. Ann.*, v., 1878; Ruths, *Wied. Beibl.* i. 1877; Cheesman, *Wied. Ann.* 1882.

Special Magnetic Character of Nickel and Cobalt.—Besides the results of Rowland above quoted, we have on record experiments by the following physicists:—Biot, *Traité de Phys.*, 1806; Gay Lussac, *Ann. d. Chim. et d. Phys.*, 1824; Lampadius, *Schwegger's Jour.*, 1814; E. Becquerel, *Comptes Rendus*, 1845; Plücker, *Pogg. Ann.*, 1854; Arndtsen, *Ib.*, 1858; Hankel, *Wied. Ann.*, 1877; Becquerel, *Ann. d. Chim. et d. Phys.*, 1879; Gaiffe, *Comptes Rendus*, 1881; Wild, *Wied. Beibl.*, 1877.

Experiments with Finely Divided Magnetic Metals and with Electrolytic Iron.—These have been made by various physicists, mostly to test the theory of molecular magnets. The earliest of the experiments with finely divided iron was made by Coulomb, who mixed iron filings with wax, and found that the magnetic moment was proportional to the mass of magnetic metal. Similar experiments were made by the elder Becquerel,[1] his result being that the magnetic moment was proportional to the weight of magnetic substance, so long as the filings were not too densely distributed; with increasing density the mixture acquires magnetic properties more like those of a continuous metallic mass. Several modern experimenters have gone into the matter with considerable care; but their results are not sufficiently concordant, or of sufficient general interest, to justify us in dwelling at length upon them here. A few references to recent memoirs will suffice.

Boernstein, *Pogg. Ann.*, 1875; Toepler and Von Ettingshausen, *Ib.*, 1877; Von Waltenhofen, *Wied. Ann.*, 1879; Auerbach, *Ib.*, 1880; Baur, *Ib.*, 1880.

Experiments on electrolytically deposited iron have been made by Beez, *Pogg. Ann.*, 1860; Jacobi, *Ib.*, 1873; Beez, *Ib.*, 1874; Holz, *Ib.*, 1875; Baur, *Wied. Ann.*, 1880.

Using a fine scratch on a varnished silver wire as electrode, Beez deposited a thread of iron between the poles of an electromagnet, and thus obtained a permanent magnet of extreme tenuity. It was found that the inductive susceptibility of this linear magnet was very small, and that considerable magnetizing force produced no increase of its permanent magnetism. Thus in one case the original magnetism was 360, the total magnetism under the inducing force 370, the magnetism remaining after the force ceased to act 360. Broader, but equally thin, magnets deposited in a strong field in the same way gave more temporary magnetism than the linear magnets, but never more permanent magnetism than they possessed originally. Thicker plates exhibited greater temporary magnetism, and also an increase of the permanent magnetism acquired during deposition. With continued reversals of the magnetizing force electrolytic iron gave a continual decrease of the temporary magnetism down to a certain limit (as does steel); but the negative permanent magnetism never approaches so near the positive after many reversals as in the case of steel. On the other hand, Jacobi found that iron reduced electrolytically from ferrous sulphate and sulphate of magnesia, even after tempering, took a considerable temporary moment, but retained very little permanent magnetism. Holz found that the iron reduced from the solution of Jacobi and Klein was not sensibly hardened by heating and suddenly cooling, although its density was increased, and that its coercive force was diminished. On the other hand, it was found that hard tempering decreased the density of steel. He draws the conclusion that the coercive force is greater the farther apart the molecules. Baur's main result is that the maximum of magnetization with electrolytic iron occurs for much larger forces than with ordinary iron. These results are not wholly concordant; but the discrepancies may be reasonably assigned to differences in the preparation of the metal.

Magnetic Properties of Matter in General.

Among the earliest statements of the properties of the loadstone we find accounts of its action on other bodies; but it is clear from their surroundings that these statements are purely fabulous. Many experimenters at a later date found indications of magnetic action in other metals besides iron; but with praiseworthy caution they ascribed them for the most part to the admixture of small quantities of iron.[2] There can be no doubt that the results of Cavallo[3] obtained with brass (especially hammered brass) were due to impurity, for Bennet[4] failed to obtain any indications of magnetism with pieces of brass made from pure zinc and copper, whereas he was immediately successful on adding small traces of iron to the metal.

Early observations.

It very soon appeared, however, that an independent magnetic property must be ascribed to nickel and cobalt, and to these were by and by added with more or less certainty manganese and chromium.[5]

Brugmans[6] seems to have been the first to observe the repulsion by a magnet of a body not permanently magnetized. He found that a piece of bismuth floating upon mercury in a small paper boat was repelled by both poles of a magnet. Lebaillif[7] confirmed the observation of Brugmans, and found that antimony possessed a like property. Saigey,[8] who experimented on the same subject, concluded that all bodies when suspended in air behave like bismuth, unless they contain traces of iron.

Notwithstanding these results and others which we pass over,[9] the whole matter remained in obscurity till the repulsion of neutral bodies was rediscovered by Faraday in 1845. He speedily unravelled the laws of the phenomenon, showing how much depends on the nature of the body, and how much upon the nature of the magnetic field. His observations enabled him in fact to comprehend under a few general principles the action of all magnetic bodies whether of the nature of iron or of the nature of bismuth. The earlier observers had fallen into difficulties by neglecting the effects due to heterogeneity of field; these were pointed out for the first time by Faraday, and since then order reigns where there was formerly confusion.

Faraday's rediscovery and full investigation.

The best arrangement for testing the behaviour of weakly magnetic bodies is to suspend either a small sphere of the substance or else a small cylinder in a heterogeneous magnetic field. This field is usually produced by placing two pointed soft iron poles (fig. 38) on the arms of a powerful electromagnet. The line joining these poles is called the *axial* direction of the field; directions perpendicular to this line are called *equatorial*. The magnetic force varies

Experimental arrangements for testing weakly magnetic bodies.

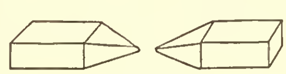

Fig. 38.

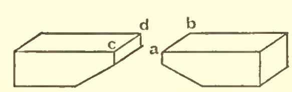

Fig. 39.

along the axial line, being less in the middle than at the poles; and it decreases everywhere from the axial line outwards. For some purposes poles of the shape shown in figure 39 are used; here the line along the upper edges of the poles are lines of greatest force, whereas the line in the plane of the upper faces equidistant from the upper edges is a line of weakest force; the force also decreases to the right of *ab* and to the left of *cd*.

In suspending small spheres the best plan is to hang them from one end of an arm of wood *db* (fig. 40). At the other end of this arm is placed a counterpoise *b*, and the whole is suspended by a fibre of unspun silk *u* from a torsion head *t*, by means of which the arm *db* can be brought into

[1] *Traité Complet du Magnétisme*, chap. ii. p. 73.

[2] *Cf.* Lehmann, *Nov. Comm. Petrop.*, 1766; Brugmans, *Magnetismus seu de Affinitatibus Magneticis Observationes Academicæ*, Leyden, 1778; Coulomb, *Mém. de l'Inst.*, 1812; Biot, *Traité de Physique*, 1816, &c.

[3] *Phil. Trans.*, 1786; or *Treatise on Magnetism*, 1787.

[4] *Phil. Trans.*, 1792.

[5] Ritter, *Gilb. Ann.*, 1800.

[6] *Loc. cit.*

[7] *Pogg. Ann.*, 1827.

[8] *Bull. Univ. d. Sc.*, 1828.

[9] See Von Feilitsch, *Karsten's Ency.*, Bd. xvi.; Wiedemann's *Galvanismus*, Bd. ii. p. 546.

any required position, and if necessary kept there by the exertion of a known torsional couple. The arm and suspension must be carefully guarded from draughts by enclosing it in a glass case, which fits over the poles of the electromagnet, and is provided with a door and with means for bringing the torsion head *t* over any given part of the magnetic field. When a cylindrical piece is to be tested it is suspended from the fibre *u* so as to hang horizontally. For this purpose Faraday was in the habit of using a stirrup of carefully selected writing paper attached to the lower end of the fibre. It is of the utmost importance to guard against magnetic action on the suspension; the least trace of iron in the arm *db* for instance, or in the paper stirrup, would in many cases be more than sufficient to mask the action proper to a weakly magnetic body.

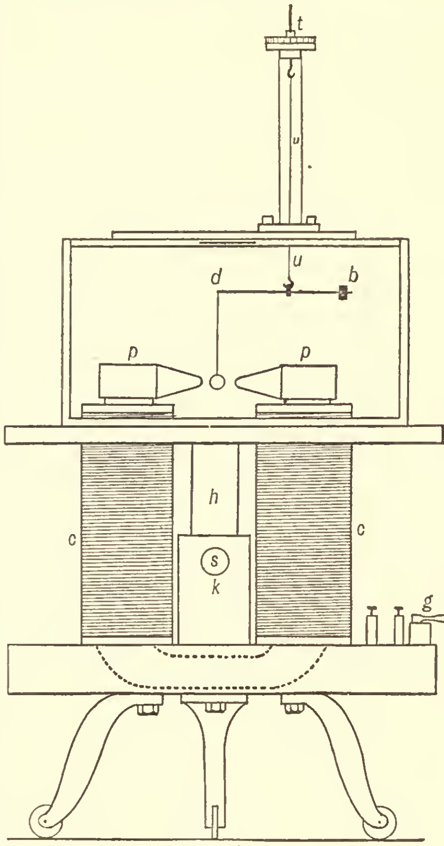

Fig. 40.

In every experiment the magnetic behaviour of the support should be tested by itself beforehand, so that if any residual effect be present it may be allowed for. The greatest caution is also requisite in choosing the material to be experimented upon. There must be no chemical impurity, especially no trace of iron; the spheres and cylinders must not be worked with iron tools or even with dirty hands. A source of error[1] to be specially guarded against in experiments with metals, or other good conductors, is the action arising from induced currents in the mass of the tested body caused by the increase and decrease of the strength of the magnetic field when the circuit of the electromagnet is made and broken. This error is wholly avoided by waiting till the suspended body has come to rest, and attending only to deflexions which are permanent after the intensity of the field has become steady.

Behaviour of heavy glass.

The first substance with which Faraday experimented was a bar of the heavy glass with which he had discovered the rotation of the plane of polarization of light. It took up the equatorial position between the poles of the electromagnet as soon as the current was established. There was no distinction between its ends, or according to the direction of the lines of force; the bar always took the shortest course to the equatorial position, and remained there in stable equilibrium. When placed in the axial position it was in unstable equilibrium, and on the slightest displacement either way it moved off in that direction to the equatorial position. A further action was observed when the bar was placed with its centre of mass out of the centre of the field; it was then repelled as a whole away from the nearest pole (no matter which). On testing a small cube or sphere of the substance, no pointing tendency was observed, but the mass as a whole when it was placed unsymmetrically with respect to the poles tended to pass away from the poles towards the centre of the field, and from the axial line outwards.

Setting of elongated bodies and translation of spheres and cubes.

Experimental law of paramagnetics and diamagnetics.

Faraday sums up the matter by saying that every element of the heavy glass tends to move from places of stronger to places of weaker resultant magnetic force. This is exactly the opposite of the law for bodies like iron (see mathematical theory above, p. 247). All bodies that follow the same law as heavy glass he calls *diamagnetics*, all that follow the opposite law, like iron, *paramagnetics*. For the purposes of experimental demonstration it is better to take some weaker paramagnetic than iron, *e.g.*, a tube filled with a solution of ferric chloride; for the order of magnitude of the effect obtained is then the same as with diamagnetics, and there is no danger of complications arising from the mutual action of the particles of the substance (see above, p. 245).

List of diamagnetics.

Faraday found the following substances to be diamagnetic; *i.e.*, pieces of them tended to set their longest dimension equatorial between pointed poles, and spheres and cubes of them tended to pass from places of stronger to places of weaker force:—rock crystal, sulphate of lime, sulphate of baryta, sulphate of soda, sulphate of potash, sulphate of magnesia, alum, muriate of ammonia, chloride of lead, chloride of sodium, nitrate of potash, nitrate of lead, carbonate of soda, Iceland spar, acetate of lead, tartrate of potash and antimony, tartrate of potash and soda, tartaric acid, citric acid, water, alcohol, ether, nitric acid, sulphuric acid, muriatic acid, solutions of various alkaline and earthy salts, glass, litharge, white arsenic, iodine, phosphorus, sulphur, resin, spermaceti, caffeine, cinchonia, margaric acid, wax from shellac, sealing wax, olive oil, oil of turpentine, jet, caoutchouc, sugar, starch, gum arabic, wood, ivory, mutton (dried), beef (dried), blood (dried or fresh), leather, apple, bread.

Liquids.

In testing liquids Faraday used a very thin glass tube of the form shown in figure 41; the opening being very fine, there was no need for a cork or other stopper which might have caused disturbance; the slight diamagnetic effect arising from the glass was allowed for. Another way of testing a liquid[2] is to place it in the bottom of a watch glass which rests on the edges of the pole of the electromagnet. When the fluid is paramagnetic, it collects in the places of greater force, forming a depression in the centre of the field as in figure 42; when it is diamagnetic, it collects in the places of weaker force in the centre of the field, as in fig. 43. Yet another method[3] is to put a small quantity of the fluid in a narrow tube, and place the tube horizontally in the equatorial line so that the end of the liquid column is just on the axial line. When the electromagnet is excited the liquid will be driven away from the axial line or drawn in according as it is diamagnetic or paramagnetic.

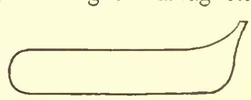
Fig. 41.

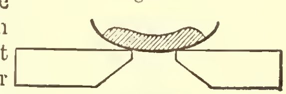
Fig. 42.


Fig. 43.

Powders.

Faraday found that breaking a weakly magnetic body into pieces, or even reducing it to powder, produced no effect upon its magnetic behaviour provided its general form was unaltered. In order to avoid disturbance from

[1] See Faraday, *Exp. Res.*, 2309 *sq.*

[2] Plücker, *Pogg. Ann.*, 1848.

[3] Quet, *Comptes Rendus*, 1854.

the magnecrystallic effect to be described presently, it is often advisable to reduce certain substances to powder before testing them; the powder is filled into a thin glass tube and then tested like a liquid. By means of powdered bismuth the tendency of a diamagnetic to pass from places of stronger to places of weaker force can be very prettily shown. If the powder be strewn upon the circular end of the core of an electromagnet, it will leave the edges and collect in the centre, whereas iron filings will leave the centre and arrange themselves round the edges, the fact being that at the edges the force is much more intense than in the centre.[1]

[...]aday's [...] of [...]gnetic [...]l dia[...]gnetic [...]tals.

Faraday arranges the metals in the following order of descending magnetic susceptibility:—

Paramagnetic.

Iron.	Chromium.	Palladium.
Nickel.	Cerium.	Platinum.
Cobalt.	Titanium.	Osmium.
Manganese.		

Diamagnetic.

Bismuth.	Mercury.	Arsenic.
Antimony.	Lead.	Uranium.
Zinc.	Silver.	Rhodium.
Tin.	Copper.	Iridium.
Cadmium.	Gold.	Tungsten.
Sodium.		

[...]ldi[...]nal [...]t of [...]tals.

Silicium is given as strongly paramagnetic, and beryllium,[2] aluminium, potassium, and sodium[3] as weakly magnetic; the last three were given as diamagnetic by Faraday; the magnetic character appears to depend on the method by which the material is prepared, being doubtless determined by the presence or absence of slight impurities. The copper of commerce is magnetic, owing to traces of iron; but when it is reduced by means of zinc from the chloride or sulphate it is diamagnetic. It would appear that the paramagnetism of titanium, palladium, platinum, and osmium is due to iron impurity.[4] Platinum[5] reduced from very pure chloroplatinate of ammonium by heating in a current of air is diamagnetic. According to Graham the magnetism of palladium when charged with hydrogen is due to the presence of hydrogenium; Blondlot,[6] however, has recently found that palladium is less magnetic when charged with hydrogen than when uncharged, from which he concludes that condensed hydrogen is pretty powerfully diamagnetic. Tellurium, sulphur, selenium, and thallium are strongly, and niobium and tantalum weakly diamagnetic.

[...]arly [...]sults.

Magnetic Properties of Gases.—The earliest results of Faraday were of a negative description, but the discovery by Bancalari[7] of the powerful diamagnetic action of flame again drew the attention of Faraday,[8] Plücker,[9] and Becquerel[10] to the subject. Faraday caused the gas under examination to stream vertically upwards or downwards (according as it was lighter or heavier than the surrounding gas) between the poles of an electromagnet, and observed how the stream was deflected. In the case of colourless gases the deflexion was observed by allowing small traces of hydrochloric acid to mix with the gas, and then placing in different parts of the field small tubes containing pieces of filter paper moistened with ammonia; by noticing in which of these the white fumes of ammonium chloride were formed the course of the gaseous current could be determined. Another method employed was to fix two thin glass tubes containing gases to be tested to the ends of a cross piece on one end of the arm of a torsion balance; the tube containing the most magnetic then moved towards the axial line. Another method, employed both by Plücker and by Faraday, is to blow soap bubbles with the gas to be tested, and observe their behaviour in the magnetic field, allowing of course for the feeble diamagnetism of the water film. Faraday's results are as follows:—

[...]radav's [...]peri[...]nts.

List of gases.

	In Air.	In Carbonic Acid.	In Hydrogen.	In Coal Gas.
Air	0	+	+ weak	+
Nitrogen	−	−	− strong	−
Oxygen	+	+	+ strong	+ strong
Hydrogen	− strong	−	0	
Carbonic acid	−	0	−	− weak
Carbonic oxide	−	−	−	− weak
Nitrous oxide	−	− weak	−	
Nitric oxide	− ? weak	+	+	
Nitrous acid	+ ? weak			
Olefiant gas	−	−	−	− weak
Coal gas	− strong	−		0
Sulphuric acid	−			
Hydrochloric acid	−	−	− ? weak	
Hydriodic acid	−			
Fluosilicic acid	−			
Ammonia	−	−	−	
Chlorine	−		− weak	
Iodine	−			
Bromine	−			
Cyanogen	− strong			

+ means magnetic relatively to the surrounding gas, − diamagnetic; the epithets strong and weak relate of course to the apparent behaviour under the circumstances of the experiment.

Oxygen.

It appears therefore that oxygen is the most paramagnetic of all the gases; on this account Faraday conceived that it probably played an important part as a cause of terrestrial magnetism.[11] Becquerel[12] has concluded from recent experiments of his own that the specific magnetism of ozone is still greater than that of oxygen. Faraday was able by filling thin glass bulbs with oxygen at different densities to show that the magnetic susceptibility decreased with the density, apparently in simple proportion. Some numbers giving an idea of the magnetic susceptibility of the various weakly magnetic bodies are given below.

Faraday's experiments on differential magnetic action.

In all experiments with gases or fluid media, and indeed in every possible magnetic experiment more or less, it is important to notice that the resulting magnetic action is the difference between the action of the movable body and the action on the surrounding medium. This was first pointed out by Faraday.[13] He prepared three solutions of ferrous sulphate. No. 1 contained 74 grains of the hydrated salt for every ounce of water; No. 2 was formed by diluting one volume of No. 1 with two volumes of water, No. 3 by diluting one volume of No. 1 with fifteen volumes of water. Three glasses g_1, g_2, g_3 and three tubes t_1, t_2, t_3 were filled with the respective solutions. The glasses were placed in succession between the pointed poles of the electromagnet, and the tubes tested in them with the following result:—

	In g_1.	In g_2.	In g_3.
t_1	0	+	+ +
t_2	−	0	+
t_3	− −	−	0

+ means pointed axially; + + the same with greater decision; − pointed equatorially; 0 was indifferent.

We have here the experimental confirmation of the important theoretical conclusion (see above, p. 248) that any body will behave paramagnetically or diamagnetically according as it is surrounded by a medium less or more magnetic than itself. In cases where the square of the

[1] This fact explains the astonishing behaviour of a flat disk of thin iron when placed on the centre of the pole.
[2] See Wiedemann, *Galvanismus*, Bd. ii. § 552.
[3] Laing, *Ann. d. Chim. et d. Phys.*, 1857.
[4] Wiedemann, *l.c.*
[5] Wiedemann.
[6] *Comptes Rendus*, 1877.
[7] Zantedeschi, *Pogg. Ann.*, 1848.
[8] *Phil. Mag.*, 1847; or *Exp. Res.*, vol. iii. p. 467.
[9] *Pogg. Ann.*, 1848, &c.
[10] *Ann. d. Chim. et d. Phys.*, 1850.
[11] See *Exp. Res.*, 2847 *sq.*; also art. METEOROLOGY.
[12] *Comptes Rendus*, 1881.
[13] *Exp. Res.*, 2362, 1845.

susceptibility may be neglected, it is clear that the resultant action on any body is the difference between the action upon it and the portion of the medium which it displaces. This principle, which is the analogue of the Archimedean law for floating bodies, is of great use in quantitative magnetic experiments. It was exemplified by Plücker,[1] and extensively applied in magnetic observations by Becquerel.[2] Becquerel found, for instance, that the differences between the couples tending to set a small rod of sulphur in water and in air, in magnesium chloride and in air, and in nickel sulphate and in air were very nearly the same as the corresponding differences for a rod of wax.

Plücker and Becquerel.

Very curious qualitative illustrations of differential magnetic action are obtained by scattering drops of alcoholic solution of chloride of iron in olive oil;[3] the drops of chloride collect and displace the olive oil in the places of stronger force. Another form[4] of the same experiment consists in placing a layer of oil of violets over a layer of solution of chloride of iron. When a narrow cell filled in this way is placed equatorially with the interface of the two liquids in the axial line, on exciting the electromagnet the iron solution rises in the equatorial plane forming a disk-shaped mass around the axial line. Notwithstanding these results the general opinion of experimenters seems to be that no separation of the parts of a solution can be effected magnetically once the constituents have been thoroughly mixed. Thus Faraday[5] could obtain no evidence of the concentration of an iron solution near the pole of a magnet, although it was exposed for days together in the magnetic field, and found no separation of the oxygen and nitrogen of atmospheric air, although they differ greatly in their magnetic character.

Different liquids.

Constituents of a thorough mixture not separated.

Plücker[6] endeavoured to show that the air enclosed in a vessel placed between the poles of an electromagnet was rarefied by the magnetic action. Faraday, however, with almost identical experimental arrangements arrived at a negative result.

Rarefaction of air doubtful.

Elaborate investigations of the magnetism of chemical compounds have been made by G. Wiedemann with a view to connect their magnetic properties with their composition. A full account of these researches will be found in Wiedemann's *Galvanismus*, Bd. ii. § 590 *sq.*[7] The following are some of the more important of his conclusions as to the effect of composition.

Magnetic behaviour of chemical compounds. Wiedemann.

1. The magnetic susceptibility of the dissolved salt by itself is nearly independent of the solvent, being proportional to the concentration.

2. If the magnetic moment m induced by a field of unit intensity in a unit of weight of the salt dissolved in water be called the "specific susceptibility," and the product $\mu = Am$, where A is the molecular weight of the salt, the "molecular susceptibility," then the molecular susceptibility of the dissolved salt of the same metal with different acids is approximately the same. The mean molecular susceptibilities for nickelous, cobaltous, ferrous, and manganous salts are as 142 : 313 : 387 : 468.

3. The molecular susceptibility of cobaltous salts stands about midway between the molecular susceptibilites of nickelous and manganous salts; and the ferrous salts stand midway between cobaltous and manganous.

4. The molecular susceptibility of dry salts (combined with water of crystallization) is for the most part nearly the same as their molecular susceptibility in solution.

A similar law holds to a certain extent for insoluble salts freshly precipitated; and generally, with like chemical properties of the metallic molecule, the molecular susceptibility remains the same.[8]

5. Two diamagnetic elements may give a magnetic compound; *e.g.*, copper and bromine, both diamagnetic, give bromide of copper, which is paramagnetic.

6. When two solutions are mixed and the salts exchange their constituents by double decomposition, the specific magnetism of the solutions taken together is unchanged. Whence the conclusion is drawn that the susceptibility of a binary compound is made up by addition of the susceptibilities of its constituents, and that these constituents preserve their susceptibilities unaltered when their constitution or atomic arrangement in composition is unaltered.

Magnecrystallic Action.—In what precedes we supposed the inductively magnetized body, whether paramagnetic or diamagnetic, to be isotropic, and all experiments on its magnetic properties to be conducted in a heterogeneous magnetic field. In a uniform field such a body would be acted upon neither by force of translation nor by rotational couple. The case is otherwise if the body be magnetically æolotropic. In this case, according to the mathematical theory, (1) the body ought to set in a uniform field so as to place its axis of greatest magnetic permeability (*i.e.*, of greatest paramagnetic and of least diamagnetic susceptibility) parallel to the lines of force, and (2) in a heterogeneous field Faraday's translational force from places of less to places of greater resultant force in the case of paramagnetic, and from places of greater to places of less in the case of diamagnetic bodies, ought to be greatest when the axis of greatest susceptibility is parallel to the lines of force, least when the axis of least susceptibility is in the same position, and intermediate for other positions of the body.

Magne-crystall action.

Two kinds o it.

In observing the first class of phenomena above mentioned, poles with flat faces are placed on the electromagnet. Faraday recommends that the faces should be placed at a distance of about one-third of their breadth. He warns the experimenter, however, that the uniformity with this arrangement is by no means perfect, although in general sufficient. The best arrangement would be to use the magnetic field in the interior of a cylindrical coil of sufficient length were it not for the difficulty of attaining the requisite intensity in this way. In cases where there is any doubt it is well to give the body under examination a spherical or cubical shape, and so eliminate the tendency to set arising from heterogeneity of field.

Approx mately uniforn field betweer flat pol used fo first kin of magne-crystall action.

The first observations of the magnecrystallic couple were made by Plücker,[9] and elaborate investigations of the phenomenon were made by him in conjunction with Beer,[10] in the course of which the magnetic properties of a large number of crystalline bodies were examined. Plücker also detected the magnecrystallic property in a rapidly cooled cylinder of glass. Shortly after Plücker's first results were published, Faraday discovered the magnecrystallic action of crystallized bismuth. At first, misled no doubt by the language in which Plücker stated the newly discovered facts, he did not recognize the identity of the two phenomena; but on further investigation he was able to class all the observations under a few simple laws,[11] which in the mathematical form given to them by Thomson constitute the theory already given. To the observations of Plücker and Faraday Knoblauch and Tyndall added the important discovery that bodies in which the linear density in one direction is greater than in another, whether as a consequence of compression or of stratification artificial or natural, exhibit magnetic æolotropy.

Magne-crystall couple dis-covered by Plücker

Faraday

Knob-lauch and Tyndall

[1] *Pogg. Ann.*, 1849.
[2] *Ann. d. Chim. et d. Phys.*, 1850.
[3] Matteucci, *Comptes Rendus*, 1853.
[4] Marangoni, *Wied. Beibl.*, 1881.
[5] *Exp. Res.*, 2757; see also Righi, *Wied. Beibl.*, 1878.
[6] *Pogg. Ann.*, 1848; see also Beer's treatise referred to above, p. 250.
[7] See also *Phil. Mag.*, 1877.
[8] For qualifications see Wied., *Galv.*, *l.c.*
[9] Plücker, *Pogg. Ann.*, 1847, 1848, 1849, 1852.
[10] Plücker and Beer, *Pogg. Ann.*, 1850, 1851.
[11] *Exp. Res.*, 2797 *sq.*, 1850.

Magnetic classification of crystals.

It is convenient, following the analogy of physical optics, to divide magnetically æolotropic bodies into (*a*) "uniaxal" bodies, *i.e.*, those that are symmetrical about one principal axis of magnetic susceptibility, or, in other words, have two of the principal coefficients of magnetic susceptibility equal ($\kappa_2 = \kappa_3$); and (*b*) "biaxal" bodies, *i.e.*, those that have the three principal susceptibilities unequal.

Uniaxals positive and negative, paramagnetic and diamagnetic.

Class (*a*) naturally divides itself into those in which the susceptibility parallel to the axis of symmetry is greater and those in which it is less than that in the plane perpendicular to it. The former (where $\kappa_1 > \kappa_2$) are said to be positive, the latter ($\kappa_1 < \kappa_2$) negative uniaxals. We have also to attend to the distinction which arises according as the mass of the crystal is paramagnetic or diamagnetic (κ_1 and κ_2 both +, or both −). We have then the following experimental behaviour in uniaxal bodies :—

		Sets the Axis of Symmetry
Positive	Paramagnetic	Parallel to lines of force.
	Diamagnetic	Perpendicular to lines of force.
Negative	Paramagnetic	Perpendicular to lines of force.
	Diamagnetic	Parallel to lines of force.

Faraday found for example that a crystal of bismuth suspended with its plane of smoothest cleavage vertical set with this plane perpendicular to the lines of force, but was indifferent when suspended with this plane horizontal. The axis of magnetic symmetry is therefore perpendicular to the plane of smoothest cleavage, and, since the substance is diamagnetic, it is a negative uniaxal. When suspended in any other way the crystal set so that the magnetic axis rested in a vertical plane through the direction of the lines of force. The difference between the behaviour of magnetic and diamagnetic uniaxals is beautifully illustrated by the behaviour of pure Iceland spar, which is a positive diamagnetic uniaxal, and sets the optic axis, which is the magnetic axis, equatorially; when, however, as sometimes happens, the calcium is partly replaced by iron, its physical properties (optical included) being thereby unchanged, except that the mass of the crystal becomes magnetic, it sets the optic axis axial.[1]

Magnecrystallic couple independent of surrounding medium.

All these cases are of course included in the single rule that the body sets the axis of greatest permeability parallel to the lines of force. Since the setting of weakly magnetic æolotropic bodies depends merely on the differences between the principal magnetic susceptibilities, it follows that it is independent of the medium in which the body is placed. This was established experimentally by Faraday,[2] who found the magnecrystallic couple exerted on a crystal of bismuth to be the same whether it was surrounded by air, by water, or by a saturated solution of protosulphate of iron.

Plücker gives the following list of uniaxal æolotropic bodies :—

MAGNETIC.

Positive.	*Negative.*
Spathic iron ore.	Tourmaline.
Scapolite.	Beryl.
Green uranite.	Dioptase.
Ferruginous sulphate of magnesia.	Vesuvian.
	Sulphate of nickel.
	Ammoniochloride of copper.

DIAMAGNETIC.

Positive.	*Negative.*
Calc-spar.	Bismuth.
Antimony.	Arsenic.
Molybdate of lead.	Ice.
Arsenide of lead.	Zircon.
Sulphate of potash.	Mellite.
Nitrate of potash.	Cyanide of mercury.
	Arseniate of ammonium.

The phenomena in the case of biaxal æolotropies are naturally more complicated; but they are all comprehended in the simple rule given above (page 244) that the axis of greatest paramagnetic or of least diamagnetic resultant susceptibility in the horizontal plane tends to set itself parallel to the lines of force, or, in the words of Faraday, the body tends to set so as to allow the greatest number of lines of magnetic induction to pass through it. In the azimuth just mentioned the body is in stable equilibrium, in the perpendicular azimuth in unstable equilibrium.

Faraday's experimental law.

Plücker's two magnetic axes.

There are two axes of suspension in the plane of the axes of least and greatest susceptibility, viz., the normals to the circular sections of the ellipsoid $\kappa_1 x^2 + \kappa_2 y^2 + \kappa_3 z^2 =$ constant, such that the body behaves indifferently; these axes were called by Plücker the "magnetic axes" of the body. If we observe the times of vibration T_1, T_2, T_3 of a sphere of the substance, when the axes κ_1, κ_2, κ_3 respectively are vertical, then we have at once by the theory already given

$$T_1 : T_2 : T_3 :: 1/\sqrt{\kappa_2 - \kappa_3} : 1/\sqrt{\kappa_1 - \kappa_3} : 1/\sqrt{\kappa_1 - \kappa_2} ;$$

whence $1/T_1^2 + 1/T_3^2 = 1/T_2^2$, and $\tan\omega = T_3/T_1$, ω being the angle between either magnetic axis and the axis of greatest magnetic susceptibility. These results were verified experimentally by Plücker.[3]

Phenomena of second kind.

Magnecrystallic phenomena of the second kind were looked for by Faraday very early in the history of the subject, but at first he was unsuccessful in detecting them.[4] He seems, however, to have understood and clearly represented to himself in his own way their close connexion with the phenomena of the first kind, for he alluded to the subject more than once, and finally in the twenty-sixth series of his experimental researches, where he explained at length his magnetic theory, he showed that such an effect ought to exist, and actually succeeded in observing it in the case of a crystal of bismuth, which he found to be less repelled from places of stronger to places of weaker force when its axis was parallel to the lines of force than when it was perpendicular to them. He concluded that with Iceland spar the translational force ought to be greatest when the axis is parallel to the lines of force, and least when it is perpendicular to them; but his apparatus was not sufficiently delicate to show the effect.

First discovered by Faraday in bismuth.

Phenomena of the second kind depend on the surrounding medium.

Unlike the magnecrystallic phenomena of the first kind, those of the second kind depend on the difference between the susceptibilities of the body and of the surrounding medium. Faraday[5] demonstrated this conclusion experimentally by covering crystals of the red prussiate of potash with a thin layer of wax to prevent dissolution, and immersing them in solution of sulphate of iron of various strengths between the pointed poles of an electromagnet. In water the crystal was attracted to places of stronger force in all positions, in concentrated solution of sulphate of iron repelled in all positions, while in a solution of 14 or 15 volumes of the concentrated solution to 6 volumes of water it was attracted when the axis of symmetry was parallel to the lines of force and repelled about as strongly when the axis was perpendicular to them. Here then the crystal actually behaved paramagnetically in one direction and diamagnetically in the other. Similar results can be obtained with Iceland spar in a mixture of alcohol and water.

Faraday and Thomson.

The prediction of the second class of magnecrystallic phenomena is one of the most extraordinary instances of the theoretic insight which formed so large a part of the genius of Faraday. The laws of the phenomena of the first class might be regarded as merely a skilful classification of observed facts, but the passage therefrom to the second class was a step of the first magnitude; it constitutes in fact the root of the whole matter. To Sir William

[1] Tyndall and Knoblauch, *Phil. Mag.*, 1850.
[2] *Exp. Res.*, 2498 *sq.*, 1848. A later but much more extensive series of experiments led to the same result (*Exp. Res.*, ser. xxx., 1855).
[3] *Phil. Trans.*, 1858.
[4] *Exp. Res.*, 2552, October 1848.
[5] *Exp. Res.*, ser. xxx., 1855.

Thomson belongs the credit of throwing the laws of magnecrystallic action into the appropriate mathematical form, and of showing that they range themselves quite naturally under the theory of Poisson.[1]

Tyndall verifies the prediction of Faraday and Thomson for Iceland spar.

Tyndall succeeded, where Faraday had failed, in showing the magnecrystallic phenomenon of the second kind in Iceland spar. It is particularly instructive to compare his results for carbonate of iron and carbonate of lime, both positive uniaxals, but the one magnetic and the other diamagnetic. His results are as follows :—

Substance.	Axis Axial.	Axis Equatorial.	Magnetic Character.
Carbonate of iron	100	71	+
Carbonate of lime	100	90	−
Sulphate of iron..............	100	85	+
Bismuth	71	100	−

Hankel.

Hankel[2] measured the repulsion on a cylinder of bismuth placed with its magnetic axis inclined at angles of 15°, 45°, and 75° with the lines of force, and compared his results with the theoretical formula $90{\cdot}7 + 45{\cdot}3 \sin^2\phi$; the result was as follows :—

	±15°.	±45°.	±75°.
Observed repulsion	94·1	113·3	132·4
Calculated repulsion	93·7	113·3	133·0

Relation of magnetic æolotropy to crystalline form.

Influence of Crystalline Form, Compression, &c., in producing Magnetic Æolotropy.—In general the magnetic æolotropy stands in close relation to the crystalline form, and consequently to a considerable extent also to the optical properties. Thus crystals of the regular system exhibit as a rule no magnecrystallic properties, but there appear to be exceptions in the case of certain pyroelectric crystals such as boracite. Again, crystals that have one crystallographic axis of symmetry are usually magnetically uniaxal, but the optical distinction of positive and negative does not involve the corresponding magnetic distinction, as is shown by the results of Tyndall and Knoblauch with pure Iceland spar and Iceland spar in which part of the calcium is replaced by iron. Crystals that are optically biaxal are as a rule magnetically biaxal, but the magnetic properties cannot be deduced immediately from the optical.

Effect of compression. Tyndall and Knoblauch.

If a small cylinder be made of a paste formed with finely ground bismuth and gum water it will point equatorially in a heterogeneous field, but if the roll be squeezed flat the plate thus formed will point axially, although its length be ten times its breadth. A roll of paste of powdered carbonate of iron, again, will point axially, the plate formed by squeezing it flat equatorially.[3] From these results Tyndall and Knoblauch concluded that, if the arrangement of the particles of any body be such as to present different degrees of proximity in different directions, then the line of closest proximity, other circumstances being equal, will stand axial if the mass be magnetic, equatorial if the mass be diamagnetic.

Effect of laminar structure.

They constructed parallelepipeds (1 in. × ¼ in. × ¼ in.), first, by gumming together rectangular slips of sandpaper (1 in. × ¼ in.), secondly, by gumming together squares of the same (¼ in. × ¼ in.). The paper was comparatively indifferent, while the sand by itself was magnetic ; and it was found that the first model set its longest dimension axially, while the second set its longest dimension equatorially ; *i.e.*, the layers of sand set in both cases axially.

Stratified and fibrous bodies.

Tyndall[4] has observed similar magnecrystallic actions with naturally stratified bodies such as shale, and in fibrous bodies such as wood. He was even able by squeezing plates of bismuth to apparently reverse the magnetic character of the substance ; for the compression rendered the plates æolotropic with an axis perpendicular to their longest dimension, and in consequence they set axially like plates of a paramagnetic substance. A crystal of bismuth compressed in a direction perpendicular to the ordinary magnetic axis, *i.e.*, parallel to the planes of principal cleavage, had its behaviour reversed as to the second class of magnecrystallic effects, the ratio of the repulsions when the crystal was set with its original axis axial and with its original axis equatorial having been changed from 71 : 100 to 112 : 100.

Imitation by compression of a biaxal crystal.

It was also found possible by squeezing a ball of bismuth dough unequally in two perpendicular directions to imitate a biaxal magnetic crystal such as heavy spar. Tyndall and Knoblauch attempt to explain the magnetic phenomena exhibited by crystals proper by means of these results. They assume that the planes of cleavage are directions of closer aggregation, and therefore tend to point axially in magnetic and equatorially in diamagnetic crystals.

Theory of Tyndall and Knoblauch.

For example, the first of the above-mentioned sandpaper models would represent magnetic crystals that cleave parallel to their axis, the second magnetic crystals which cleave perpendicular to their axis. If we regard this theory merely as a way of representing the facts of observation, even if we allow it to be sufficient, it is far inferior in simplicity to the theory of Faraday and Thomson, the sufficiency of which is not disputed. Regarded as an attempt to penetrate a little farther into the relation between molecular structure and magnetic properties, it is of great interest and importance, even if we admit that like most other speculations of the kind it leads us but a little way; for the question arises immediately, How does proximity of the molecules increase specific inductive capacity? This last question is all the more difficult to answer that no experiment has ever yet been adduced wherein the effect of the mutual induction of the parts of a diamagnetic or weak paramagnetic body plays an undoubted part.[5]

Controversy concerning diamagnetic polarity. Faraday.

Discussion as to the Existence of Diamagnetic Polarity.—Soon after Faraday's first discovery of diamagnetism, an animated discussion arose as to the proper way of stating the facts involved in the new phenomenon. Faraday himself inclined in the first instance to put the matter by saying that under the action of an inducing force a diamagnetic body is magnetized in a direction opposite to that of soft iron ; at a later period he abandoned this form of statement in favour of what he called the theory of magnetic conduction, which fitted better with his ideas as to the part played by the surrounding medium by means of which magnetic action is transmitted from one body to another.

Weber and others. Tyndall.

Faraday's first theory under the name of the theory of diamagnetic polarity was immediately adopted by the Continental physicists, such as Weber, Reich, and Poggendorff, who naturally found it consonant with their favourite views as to action at a distance. It was also supported in England by Tyndall and others. Many experiments were advanced on both sides of the question, and the result was much instructive illustration of the laws of magnetic action. But the controversy settled nothing, because in point of fact there was nothing to settle.

The discussion differences as to words merely. Thomson.

Either theory was perfectly sufficient, when properly applied, to represent the phenomena, and each left the question of the ultimate nature of paramagnetic and diamagnetic action where it found it. This ought to have been evident after Thomson had shown that the phenomena were included in a perfectly natural generalizatian of Poisson's theory, indicated in fact by

[1] *Phil. Mag.*, March 1851 ; or *Reprint*, chap. x.
[2] In 1851 ; see Wied., *Galv.*, ii. § 639.
[3] Tyndall and Knoblauch, *Phil. Mag.*, 1850.
[4] *Phil. Mag.*, 1851.
[5] Faraday, *Exp. Res.*, 2825, &c. There is a further difficulty in the case of diamagnetic bodies. See Thomson's letter to Tyndall, *Reprint of Papers on Elec. and Mag.*, p. 536.

Poisson himself, and demonstrated that Faraday's conception of the phenomena was only another method of viewing the facts leading to identical conclusions. Faraday himself[1] seems in the end to have considered that the difference was a matter of phrases. Since Clerk Maxwell's elaborate mathematical reconstruction of the theories of Faraday this seems to be universally recognized, and the discussion has subsided. For a full account of the various interesting experiments that were made during the controversy the reader may be referred to Wiedemann's *Galvanismus*, § 558 *sq.*, and to the reprint of Tyndall's *Papers on Diamagnetism and Magnecrystallic Action*, pp. 76 *sq.*

Numerical Data respecting the Susceptibility of Weakly Magnetic Bodies.—The earlier experimenters arrived for the most part at the conclusion that the susceptibility κ of weakly magnetic bodies is constant. Among these may be mentioned Weber, who experimented with bismuth, E. Becquerel,[2] Tyndall,[3] Joule,[4] Reich,[5] and Matteucci,[6] who experimented on various substances by means of the torsion balance; Christie,[7] who worked with bismuth, and Arndtsen,[8] who worked with ferric sulphate and ferric chloride, both using Weber's diamagnetometer; and Wiedemann,[9] who experimented with solutions of a variety of salts. E. Becquerel, however, in some of his experiments, *e.g.*, with sulphate of nickel, found that κ showed a tendency to decrease for very large values of the magnetizing force; Plücker,[10] who tested a great variety of substances (powdered or in solution) by measuring with a delicate balance the attraction or repulsion exerted upon them by an electromagnet, arrived at a similar conclusion; but the methods of both these experimenters are open to suspicion.

A large number of relative results were obtained by the earlier experimenters,[11] but in some cases the methods employed were not satisfactory, and in others the results so evidently depend on the state of aggregation of the material that they are of little importance. The following tables will give the reader some idea of the relative magnitudes of the susceptibilities of different substances:—

Plücker's Table for Magnetics.

Iron	100,000	Ferric chloride, conc. soln.	98
Magnetic iron ore	40,227	Ferric sulphate ,,	58
Ferric oxide	286	Ferrous chloride ,,	84
Hematite	134	Ferrous sulphate ,,	126
Specular iron ore	533	Nickelous oxide	35
Hydrated ferric oxide	156	Hydrate of do.	106
Ferric sulphate	111	Hydrated manganic oxide	70
Green vitriol	78	Mangano-manganic oxide	167
Nitrate of iron, conc. soln.	34		

The numbers here denote specific magnetic susceptibility; *i.e.*, equal weights of the substances are compared.

Results of Faraday and Becquerel.

Ferrous chloride, conc. solution	+ 655	Hydrogen	− 0·1
Ammoniacal solution of cuprous oxide	+ 134	Ammonia gas	− 0·5
Do. of cupric oxide	+ 120	Cyanogen	− 0·9
Oxygen	+ 17·5	Glass	− 18·2
Air	+ 3·4	Pure zinc	− 75
Olefiant gas	+ 0·6	Ether	− 75
Nitrogen	+ 0·3	Alcohol absolute	− 79
Vacuum	0·0	Oil of lemons	− 80
Carbonic acid	0·0	Camphor	− 82
		Camphire	− 83
		Linseed oil	− 85
Olive oil	− 86	Chloride of arsenic	− 122
Wax	− 87	Fused borate of lead	− 137
Nitric acid	− 88	Phosphorus*	− 167
Water	− 96·6	Selenium*	− 168
Ammonia solution	− 98	Pure copper*	− 171
Bisulphide of carbon	− 100	Pure silver*	− 235
Sat. solution of nitre	− 100	Pure gold*	− 350
Sulphuric acid	− 104	Bismuth	− 1967
Sulphur	− 118		

The results marked with an asterisk are taken from Becquerel; the rest are from Faraday. The numbers relate to equal volumes of the substances, and the medium is supposed to be vacuum; so that water in air would be represented by 100.

The numbers of Faraday, Becquerel, and Matteucci agree very fairly; *e.g.*, according to Faraday the susceptibilities of water, oxygen, and air are as − 100 : + 1·8 : + ·352, according to Becquerel as − 100 : + 1·82 : + ·382. Plücker's results do not agree so well with those of Faraday and Becquerel; but his method was faulty.

Within the last five years a large number of absolute determinations of κ have been made, chiefly for bismuth and ferric chloride. Toepler and Von Ettingshausen[12] in their experiments on bismuth used with some alteration the method of induced currents employed by Weber[13] in the earliest attempts that were made to determine the susceptibility of bismuth. Like Weber they compare bismuth with iron, an unsatisfactory procedure on account of the great variability of the susceptibility of iron for different magnetizing forces, and for different samples with the same magnetizing force.

Silow worked with ferric chloride. In his first set of experiments[14] he observed the time of vibration of an astatic needle suspended over a cylindrical vessel filled with the solution; in his second investigation[15] the solution was placed in a glass globe, on the outside of which insulated wire was wound so that a given current in it produced a uniform magnetic field whose strength could be calculated;[16] the deflexion of a properly astatized needle suspended inside the globe, was observed when the globe was empty and when it was full, and thence κ was calculated; in his third determination[17] he used the method of Toepler and Von Ettingshausen so improved as to allow an absolute determination of κ to be obtained directly.

Borgmann[18] enclosed one coil within another, and filled the hollow cylindrical space between them with the solution of ferric chloride to be tested; he also used the ring method of Stoletow and Rowland.

Jacques,[19] following a method elaborated by Rowland, measured the repulsion of crystals of bismuth and Iceland spar placed with their magnetic axes axially and equatorially between the poles of a Ruhmkorff's electromagnet, the field of which was carefully explored after the manner of Verdet by means of a small coil moved through a known distance in different parts of it; from these observations the two principal magnetic susceptibilities were calculated.

Schuhmeister[20] experimented with ferric chloride, using the same method as Rowland and Jacques.

In the experiments of Eaton[21] the method formerly employed by Wiedemann was adopted; the data in his paper are, however, insufficient for an absolute determination either of the magnetizing force or of κ; in fact he determines merely the force with which the magnetic body is attracted and the magnetic moment of the electromagnet, assuming that the strength of the magnetic field at a given point is proportional to the latter,—which is not necessarily true, for the magnetic distribution in the core of the electromagnet may alter with increasing current.

[1] See a letter to Matteucci dated November 2, 1855, published in Bence Jones's *Life and Letters of Faraday*, reprinted in Tyndall's *Diamagnetism and Magnecrystallic Action*, p. 180.
[2] *Ann. d. Chim. et d. Phys.*
[3] *Phil. Mag.*, 1851.
[4] *Phil. Mag.*, 1852.
[5] *Pogg. Ann.*, 1856.
[6] *Ann. d. Chim. et d. Phys.*, 1859.
[7] *Pogg. Ann.*, 1858.
[8] *Pogg. Ann.*, 1858.
[9] *Pogg. Ann.*, 1865.
[10] *Pogg. Ann.*, 1854.
[11] *E.g.*, Plücker, *Pogg. Ann.*, 1848, 1851, &c.; E. Becquerel, *Ann. d. Chim. et d. Phys.*, 1850, 1851, 1855, &c.; Matteucci, *Comptes Rendus*, 1853, and *Cours d'Induction*, 1854; Wiedemann, *Pogg. Ann.*, 1865, 1868, &c.
[12] *Pogg. Ann.*, 1877.
[13] *El. Maasbest.*, Thl. iii.
[14] *Wied. Ann.*, 1877.
[15] *Wied. Beibl.*, 1879.
[16] See Maxwell, *El. and Mag.*, vol. ii. § 672.
[17] *Wied. Ann.*, 1880.
[18] *Wied. Beibl.*, 1879.
[19] Silliman's *Jour.*, 1879. The published results are vitiated by some error of calculation; but the experiments are to be repeated.
[20] *Wien. Ber.*, 1882.
[21] *Wied. Ann.*, 1882.

Von Ettingshausen. Von Ettingshausen[1] in the most recent research on the subject with which we are acquainted has made determination of the susceptibility of bismuth by four different methods. The first of these was that formerly used by Toepler and himself, with the addition that the action of the bismuth bar was compared with that of a solenoid of as nearly the same dimensions as possible through which flowed a current of given strength (an artifice previously used by Christie). The second method consisted in measuring the force with which a portion of the diamagnetic substance hung in the axis of a coil and near one of its ends was repelled out of the coil when a known current passed through it. The third method was that of Rowland and Jacques. The fourth consisted in measuring the deflexion of a magnetometer needle produced by placing a piece of the diamagnetic substance between the poles of a powerful magnet under whose action the magnetometer needle had come to rest in the first instance.[2] The agreement between the results obtained by all the different methods was very fair considering the smallness of the effects to be measured in some of them. The second method is pronounced to be the best, and by means of it he gives also a determination of κ for ferric chloride.

Results for bismuth. Some of the results of the different experimenters for bismuth are given in the following table :—

Magnetizing Force.	$-10^6\kappa$.	Authority, &c.
63 301	14·6 14·9	Calculated by Stoletow from certain results of Weber's, see Silow, *Wied. Ann.*, 1882.
...	16·4	Calculated by Von Ettingshausen, *l.c.*, from Weber.
...	14·6	Calculated by Von Ettingshausen, *l.c.*, from Christie.
25·8 to 128 71·4 to 110·2 39·2 to 82·2	13·99 14·54 13·48	Three different samples by Von Ettingshausen's second method.

Most of the specimens contained slight traces of iron. Although the range of the magnetizing force in Von Ettingshausen's experiments was considerable, κ was very nearly constant; if there was any tendency to variation, it was decrease with the large magnetizing forces.

Results for ferric chloride. The results for ferric chloride are not so concordant. Silow, after comparing his own earliest result ($10^6\kappa = 81$ for a solution of density 1·475, magnetized by the earth's horizontal force) with those of Borgmann ($10^6\kappa = 48·8$, density 1·87, magnetic force 40 to 59), concluded that the susceptibility of ferric chloride probably follows the same law as that of iron; *i.e.*, it first increases, then reaches a maximum, and afterwards decreases more or less slowly. His later experiments confirm this conjecture, and he finds that κ has a maximum value for a magnetizing force of about ·4 C.G.S. The smallest force used was about ·08 C.G.S. and the corresponding value of $10^6\kappa$ was 34; the largest value of $10^6\kappa$ occurring in his tables is 179. The values obtained in his last investigation are smaller than those given in his first table, but there is the same increase and decrease. The following are his latest results :—

Silow.

$\mathfrak{H}$	$10^6\kappa$.	$\mathfrak{H}$	$10^6\kappa$.
1·15	96	2·45	104
1·35	104	3·73	70
1·60	131	5·33	69
1·70	131	5·35	68
1·81	142	6·54	65
1·90	141	7·00	62
1·96	131	10·00	60
2·13	111	12·60	55
2·40	99		

[1] *Wien. Ber.*, 1882.

[2] This was one of the experiments adduced by Weber in the controversy regarding diamagnetic polarity; see *Pogg. Ann.*, 1848.

The unit of $\mathfrak{H}$ is the earth's horizontal force, presumably at Moscow.

From the observations of Arndtsen on a solution of density 1·495 Silow[3] calculates $10^6\kappa = 57·5$ (magnetic force 20·3). For a solution of density 1·395, with magnetizing forces from 38 to 252, Schuhmeister gets $10^6\kappa = 30$ to 39. Von Ettingshausen, for a solution of density 1·48, with magnetizing force 14 to 20, gets $10^6\kappa = 59$ to 56.

The following are the values of $10^6\kappa$ obtained by Schuhmeister for various substances.

Schuhmeister.

$\mathfrak{H}$	61·5	130·8	252·7
Water	– ·55	– ·45	– ·44
Alcohol	– ·45	– ·42	– ·38
Bisulphide of carbon	– ·46	– ·39	– ·37
Ether	– ·40	– ·29	

$\mathfrak{H}$	66·8	141·8	272·2
Oxygen from chlorate of potash	·046 ·056	·059 ·067	·122 ·128
Oxygen from electrolysis ozonized	·117 ·103	·181 ·177	... ...
Nitrogen	·0278 ·0232	·0377 ·0380	·0496 ·0437

Relation of Magnetism to other Physical Properties.

Shocks, Jarring, or Vibration.—The effect of these in aiding the action of an inductive magnetic force was known to Gilbert; and it was also known to the earlier experimenters that the permanent magnetism of a body not subject to external magnetizing force was destroyed by like causes. The action is precisely similar to that found in the case of bodies temporarily or permanently deformed by mechanical stress, and, again, to the first effects of temperature on bodies temporarily or permanently strained, or temporarily or permanently magnetized.[4] The effect may be conceived as consisting of a loosening of the molecules for the moment, so that they follow more easily any force acting on them whether mechanical or magnetic. The following parallel statements, taken from the results of Wiedemann, who has devoted much careful study to these phenomena, will sufficiently illustrate the matter :—

Wiedemann's parallel statements.

1. Jarring a body under twisting stress causes increase of twist.
2. Permanent twist in a wire is diminished by jarring.
3. A wire permanently twisted and then partly untwisted loses or gains twist when jarred according as the untwisting is small or great.[5]

I. Jarring a bar under magnetizing force causes increase of magnetization.
II. Permanent magnetization in a bar is diminished by jarring.
III. A bar permanently magnetized and then partly demagnetized loses or gains magnetization according as the demagnetization is small or great.[5]

Minuter details regarding the effects of jarring will be found in memoirs by Wiedemann, Fromme, Auerbach, and others already quoted. The reader may also consult Warburg, *Pogg. Ann.*, 1870, and Villari, *Pogg. Ann.*, 1869.

Joule's discovery of the magnet strains. *Mechanical Strain produced by Magnetization.*—The starting point of accurate research on this subject was the discovery made by Joule[6] in 1842 that a bar of soft iron lengthened when it was temporarily magnetized in the longitudinal direction. When the magnetizing force was removed the bar shortened, but in general not quite to its

[3] *Wied. Ann.*, 1882.

[4] Compare also the effect of the same causes on the temporary and residual charge of Leyden jars, art. Electricity, vol. viii. p. 40.

[5] It is possible in this way even to cause a wire to reverse its twist and a bar to reverse its magnetization by jarring.

[6] His attention had been drawn to the subject in 1841 by a Mr Arstall, who had suspected the existence of some such effect. Joule's papers on the subject are in Sturgeon, *Ann. of El.*, 1842, and *Phil. Mag.*, 1847.

original length. This residual extension was due in part to permanent magnetism, but he found that the permanent magnetization due to a current 1088 was reversed from – 1·3 to + ·25 by a current 175, while two-thirds of the permanent extension was still left. The actual elongation of an iron bar magnetized to saturation was found to be from $\frac{1}{720000}$th to $\frac{1}{200000}$th of its whole length. The extension varied approximately as the square of the intensity of magnetization (temporary or permanent). The general character of the phenomena is the same in soft or hard iron, and in soft or hard steel;[1] but the effects are smaller with hard than with soft bars.

ffect of ‹nsion.

It was found that longitudinal compression of the bar influenced the magnetic extension little if at all; on the other hand, longitudinal traction was found to diminish it, and in the case of thin wires under considerable tension the magnetization caused a contraction. Thus in the case of a bar 1 foot long, $\frac{1}{4}$ inch in diameter, with a weight of 600 lb, there was neither extension nor contraction, even with a current of 1600; with weights of 1040 lb and 1680 lb, and a current of 1804, there was a contraction of ·00002 inch and ·000032 inch respectively. The contraction under tension was found to vary approximately as the product of the magnetizing current and the intensity of magnetization. After the magnetizing force was withdrawn the wire regained its original length, permanent magnetization notwithstanding.

ʼo alteration of olume.

Joule made careful experiments to determine whether the magnetization of an iron bar produced any alteration of its volume, but could find none. He therefore concluded that the longitudinal extension of a magnetized bar is accompanied by an equal lateral contraction; and, in accordance with this conclusion, he found that when an iron tube is circularly magnetized, perpendicular to its length, by passing a current along its axis, it contracts longitudinally.

The results of Joule have been verified and to some extent added to by Wertheim,[2] Buff,[3] Beez,[4] Tyndall,[5] Mayer,[6] Righi,[7] and Ader.[8] The three first experimented with magnetizing coils shorter than the bar, and found that the extension was much greater when the coil was near the free end than when it was near the fixed end of the bar. This of course raises the question how far the extension is due to electromagnetic action between the coil and the bar, and how far to internal molecular disturbance.[9] Mayer's results are in agreement with Joule's except in the case of bars of soft steel, which (not under traction) when the magnetizing current was first established, elongated in some cases and retracted in others,—at the first break elongated, and subsequently retracted at make and elongated at break. Righi's results for longitudinal magnetization are in agreement with those of Joule; he also gives a variety of interesting results regarding the effects of circular and longitudinal magnetization on the length of iron wires. Barrett[10] has recently arrived at the interesting result that nickel behaves oppositely to iron,—retracting about $\frac{1}{130000}$th when magnetized to saturation; he gives for the elongation of iron and cobalt under like circumstances $\frac{1}{200000}$th and $\frac{1}{425000}$th respectively.

Effect of traction on magnetization. Matteucci.

Effect upon Magnetization of Traction along the Lines of Magnetization.—Matteucci[11] seems to have been the first to discover that when a bar subject to a magnetizing force in the direction of its length is stretched in the same direction its temporary magnetization increases. When the stretching force is removed the magnetization again diminishes. Wertheim[12] confirmed Matteucci's observation.

Villari.

Villari,[13] however, found that, after the first effect, which is always increase, the application of the traction will cause increase if the intensity of magnetization is not beyond a certain critical value, but decrease if that value is surpassed; the removal of the traction causes in each case the opposite effect to the application.

The effect of the first traction on the permanent magnetization, whether of iron or steel, is a diminution; the effect of subsequent tractions in steel is a diminution on application, with increase on removal; in soft iron an increase on application, a diminution on removal. Partial demagnetization of a steel bar by an opposite magnetic force causes it to behave like soft iron; when the demagnetizing force is sufficient to reverse its polarity, the effect of even the first traction may be to increase the magnetization.

Thomson.

Sir W. Thomson[14] has carefully studied the phenomena in question, as exhibited in a very soft iron wire ·075 cm. in diameter permanently stretched by a weight of 1 lb, and alternately stretched by weights of 7 lb, 14 lb, or 21 lb, and unstretched (so that there was no permanent elongation). As the magnetizing force was increased, the increase of magnetization caused by the application of traction increased to a maximum, then diminished, and became zero for a certain critical value of the magnetizing force; after the critical value was passed, the traction caused a diminution of the magnetization, which increased asymptotically towards a fixed limit as the magnetizing force was increased more and more. The following table will give an idea of the results.

I denotes the maximum increase, and D the limit of the decrease, roughly estimated in the same arbitrary unit; $\mathfrak{H}'$ is the force corresponding to I, and $\mathfrak{H}_0$ the critical force, each expressed in terms of the earth's vertical force at Glasgow as unit; T is the traction, t the temperature.

T	t	I	D	$\mathfrak{H}'$	$\mathfrak{H}_0$
7	Ord.	+31	–6	5·9	34
...	100°	+26	–3	6·4	35
1	Ord.	+35	–14	4·8	25
...	100°	+32	–9	4·5	25
21	Ord.	+54	–21	4·5	26
...	100°	+51	–15	5·0	29

Bars of nickel and cobalt were also examined; and it was found that after the first effect the result of applying traction in the direction of magnetization was in both cases to *diminish* the magnetization. The effect appeared to increase up to a maximum, and then to diminish as the magnetizing force increased; but the critical value was not reached with the largest forces employed.

Traction perpendicular to the lines of magnetization was found by Thomson to diminish the magnetic susceptibility. The experiment was made by means of a gun barrel magnetized longitudinally, and subjected to internal hydrostatic pressure.

The effect of pressure along or perpendicular to the magnetization would in all probability be opposite (and equal?) to that of an equal amount of traction; but no experiments have as yet been made on the subject.[15] The effect of traction is therefore to produce magnetic æolotropy, the susceptibility being increased in the direction of the stress and diminished in the perpendicular direction so long as the intensity of magnetization is not above a certain critical value; above that value the effects are reversed. The effect of pressure would be opposite in every particular. Hence the effect of a shearing stress would be increase of magnetic susceptibility along the principal axis of elongation, and decrease (to an equal extent?) along the principal axis of compression.

[1] In the case of a bar of hard steel he found a considerable increase in length every time the magnetizing current was interrupted. This he attributes to a state of "tension" in the hardened steel.

[2] *Ann. d. Chim. et d. Phys.*, 1848.

[3] Cited by Wiedemann, *Galv.*, ii. § 504.

[4] *Pogg. Ann.*, 1866.

[5] *Diamagnetism and Magnecrystallic Action*, 1870.

[6] *Phil. Mag.*, 1873.

[7] *Nuov. Cim.*, 1880.

[8] *Comptes Rendus*, 1880.

[9] See Wiedemann's remarks, *Galv.*, ii. § 503.

[10] *Nature*, vol. xxvi., 1882.

[11] *Comptes Rendus*, 1847; *Ann. d. Chim. et d. Phys.*, 1858.

[12] *Ann. d. Chim. et d. Phys.*, 1857, 1858.

[13] *Pogg. Ann.*, 1868, also 1865, 1869.

[14] *Phil. Trans.*, 1876 and 1879, p. 55.

[15] Pressure applied outside Thomson's gun barrel would enable us to observe the effect of transverse pressure; and by magnetizing the barrel circularly the effect of pressure along the lines of force could be determined.

Wiedemann. Torsion and magnetization.

Relations between Torsion and Magnetization.—These were investigated by Matteucci,[1] and after him by Becquerel and Wertheim.[2] The whole subject was carefully studied by G. W. Wiedemann,[3] who has done more than any living physicist both in discovering new facts in this interesting field and in coordinating those formerly known. We extract from his *Galvanismus* [4] the following series of parallel statements, which will serve the double purpose of making the reader acquainted with the principal facts, and of drawing his attention to the close analogy between the mechanical and magnetic properties of bodies, and to the almost perfect reciprocity of their experimental laws.

Parallel statements for strain and magnetization.

1. The permanent torsion of iron wires is diminished by magnetization in a proportion decreasing with increasing magnetization.	I. The permanent magnetization of steel bars is diminished by torsion in a proportion decreasing with increasing torsion.
2. Repetition of magnetization in the same direction diminishes permanent torsion very little farther; but magnetization in the opposite direction causes a fresh and considerable diminution.	II. Repetition of torsion in the same direction diminishes permanent magnetization very little farther; but torsion in the opposite direction causes a fresh and considerable diminution.
3. When the permanent torsion of a wire has been removed as far as it can be by magnetizations within certain limits repeated alternately in opposite directions, it takes a maximum of torsion when magnetized in one direction, a minimum when magnetized in the other direction.	III. When the permanent magnetization of a bar has been removed as far as it can be by twisting within certain limits repeated alternately in opposite directions, it takes a maximum of magnetization when twisted in one direction, a minimum when twisted in the other direction.
4. A permanently twisted wire partially untwisted loses less of its twist when magnetized than an ordinary permanently twisted wire. If the untwisting has been considerable, feeble magnetization causes an increase of torsion, which rises to a maximum and then decreases as the magnetization is increased. The greater the untwisting the stronger the magnetization corresponding to this maximum, and, when the untwisting is very great, the maximum may not be reached at all.	IV. A permanently magnetized bar partially demagnetized loses less of its magnetization when twisted than an ordinary permanently magnetized bar. If the demagnetization has been considerable, feeble twist causes an increase of magnetization, which rises to a maximum and then decreases as the twist is increased. The greater the demagnetization the greater the twist corresponding to this maximum, and, when the demagnetization is very great, the maximum may not be reached at all.
5. If a wire under the influence of a twisting stress is magnetized, the twist increases with weak but decreases again with strong magnetization. The first effect of magnetization is usually to increase the twist; but, if the wire be jarred beforehand, the magnetization at once causes untwisting, which disappears when the magnetization ceases.	V. If a bar under the influence of a longitudinal magnetizing force is twisted, the magnetization increases with small twists but decreases again with large twists. The first effect of twisting is usually to increase the magnetization; but, if the bar be jarred beforehand, the twist at once causes a decrease, which disappears when the twist ceases.
6. If we magnetize an iron wire so that its free end has north polarity, and then pass a current from the fixed to the free end, or first pass the current and then magnetize, the free end of the wire as seen from the fixed end twists in the direction of the hands of a watch. The reversion of current or of magnetization reverses the twist; reversion of both leaves it unaltered.	VI. If we twist the free end of a wire in the direction of the hands of a watch as seen from the fixed end, while a current from fixed end to free end either is passing through it or has passed through it, the wire becomes longitudinally magnetized so that its free end has north polarity. The reversion of current or of twist reverses the magnetization; reversion of both leaves it unaltered.
[It would appear that when the magnetizing force and the current are both in action the twist tends to a maximum when either is increased, the other remaining constant.]	

The alterations of the longitudinal and circular magnetization of iron wires may be shown by the induced currents thereby caused in a coil surrounding the wire or in the wire itself. For example, if an iron wire be circularly magnetized by passing a current through it, and then twisted in either direction, an induction current flows through the wire in the same direction as the original current; and an opposite current is observed when the wire is untwisted again. This shows that twisting the wire diminishes the permanent circular magnetization, while untwisting partially restores it.[5]

The relation between bending stress and magnetization has been studied by Guillemin,[6] Wertheim,[7] Ader,[8] and Kimball;[9] but the results are not of sufficient interest to be cited here. The question has also been raised whether magnetization affects the elasticity of bodies, and has been answered by Wertheim and Wartmann in the negative. Both Kimball[9] and Piazzoli[10] find that the breaking tension of iron wires is increased by longitudinal magnetization; the former puts the increase at 0·9 per cent. when the wire is saturated.

Magnetic sounds.

This is the place to mention the so-called "magnetic sounds" which accompany the magnetization and demagnetization of the strongly magnetic metals. It is now established beyond all doubt that these sounds have their origin partly at least in the mechanical strains accompanying magnetization. In many cases direct magnetic or electromagnetic action, and even electrostatic and thermal actions, concur in producing them, and it is often difficult to say how much is due to each of these several causes. This is especially to be observed where the sounds are produced by the passage of interrupted or undulatory currents through wires of the strongly magnetic metals. A full discussion of the matter belongs more properly to the subject of electric telephony; but a few notes on the history and literature of the subject may be given here.

Page[11] seems to have been one of the first to notice phenomena of the kind; but Joule[12] appears to have first stated clearly that magnetic-mechanical strain was a specific cause. He says that the magnetic extension in the core of an electromagnet takes place so suddenly that the shock is sensible to the touch, and is accompanied by a musical note arising from vibration in the metal. Marrian,[13] Matteucci,[14] Beatson, and Wertheim[15] all took up the matter; and De la Rive[16] published many investigations concerning it. In 1861 Reiss published the invention of an electric telephone for the transmission of music and speech, which depended essentially on the magnetic sounds produced by a varying current in an iron core. This instrument was the prototype of the telephone of Gray, and of the still more famous instrument of Bell, whose action, although often described as purely electromagnetic, is no doubt in part due to the magnetic strains. Among the more recent investigations on this subject may be mentioned Ferguson, *Proc. Roy. Soc. Edin.*, 1878 and 1880; Ader, *Comptes Rendus*, 1879; Du Moncel, *Ib.*; Chrystal, *Nature*, vol. xxii., 1880; Hughes, *Proc. Roy. Soc. Lond.*, xxxi. and xxxii., 1881.

Effects complex.

General Remarks.—Wiedemann has remarked with justice that most of the effects of strain upon magnetization and *vice versa* are complex. Apart from the possible admixture of direct magnetic action, we must distinguish (1) the mere disturbing effect of jarring: thus the first application of a mechanical stress has the same effect as a shock, *i.e.*, it loosens the molecules of the body, as it were, and renders them more ready to follow any inductive magnetic force, while the first effect of magnetization upon a body under stress is precisely similar, and may in fact be imitated by mechanical jarring pure and simple; (2) after-effect, whether mechanical or magnetic, the consequence of which is that the effect due to any mechanical stress or magnetizing force is affected by pre-existing stress and magnetization; (3) the proper effect of mechanical stress or magnetic force, which appears at once where one or the other is applied, and disappears when it is removed.

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[1] *Comptes Rendus*, 1847. [2] *Comptes Rendus*, 1852.
[3] *Pogg. Ann.*, 1858, 1859, 1860. [4] Bd. ii. § 492.

[5] See Wiedemann and Villari, *l.c.*; also Gore, *Phil. Trans.*, 1874; H. and F. Strenitz, *Wien. Ber.*, 1877; Hughes, *Proc. Roy. Soc. Lond.*, 1881.
[6] *Comptes Rendus*, 1846. [7] *Ib.*, 1846, &c.
[8] *Ib.*, 1879. [9] *Sill. Jour.*, 1879.
[10] *Wied. Beibl.*, 1880; see also Hoffmann, *Ib.*
[11] *Pogg. Ann.*, 1838.
[12] Sturgeon, *Ann. El.*, 1842; *Phil. Mag.*, 1847.
[13] *Phil. Mag.*, 1844. [14] Wied., *Galv.*, ii. § 515. [15] *Ib.*
[16] *Comptes Rendus*, 1845; *Phil. Trans.*, 1847, &c.

heory mole- lar agnets.

In his excellent analysis of the phenomena, Wiedemann coordinates them throughout by means of an extension of Weber's theory of "molecular magnets" (*Drehbare Molecularmagnete*). This of course involves an attempt to pass beyond the mere results of experience; and there can be no question that, on the whole, this theory explains the facts in a highly instructive and suggestive manner. The main defect in it is the multitude of assumptions and the want of clearness and definiteness in its conclusions. Thus it is sometimes not easy to see why exactly the opposite conclusion should not be drawn; and it appears hopeless to bring it to the test of a quantitative comparison with experiment.

ossible on- exion etween ne ifferent he- omena.

Without entering into the ultimate causes of magnetism, we might endeavour to reduce the phenomena to the smallest number of experimental facts. Thus, assuming merely the effects of longitudinal and transverse traction upon magnetization and the magnetic extension and compression along and perpendicular to the lines of magnetization, we might explain many of the results concerning the relation between torsion and magnetization.

Let us take for example No. VI. of Wiedemann's parallel statements. In fig. 44 let the upper end of the wire be the fixed end, and let P be a point in any of the thin coaxal cylindrical shells into which the wire may be supposed divided. First suppose the wire to be circularly magnetized by the action of a downward current, the resultant magnetic force at P being in the horizontal direction PB. If now the wire be twisted in the direction of the arrow T, it acquires two axes of greatest and least magnetic susceptibility P*e* and P*r*. The resultant magnetic force PB being resolved along these axes will induce more magnetism along P*e* than along P*r*; hence the æolotropy will cause the resultant magnetization to take the direction PB′; it will therefore have a positive vertical component downwards, which agrees with statement VI. In fact the twisting converts the circular lines of magnetization into right-handed helices.

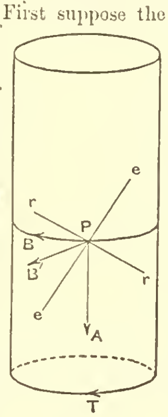

Fig. 44.

Next let us suppose the wire untwisted to begin with, but magnetized both circularly and longitudinally, the components being PB and PA. The resultant magnetization will then have some direction such as P*e*, but, by Joule's principle, this will cause extension along P*e* and compression along the perpendicular direction P*r*; consequently the wire will twist in the direction of the arrow T, which agrees with statement 6. Moreover, since magnetization along PB alone would simply cause the tube to expand along a horizontal section, and magnetization along PA alone would simply cause longitudinal extension, it is clear that when either A or B is given the twisting reaches a maximum and then diminishes when the other is increased.[1]

It does not seem unreasonable to expect that a general mechanical theory of this kind will yet be found to coordinate all the facts; although there are difficulties in its way at present.[2] The phenomena will then be reduced to two or three experimental facts at the utmost, which it will be the business of some ultimate dynamical theory of magnetism to explain.

Effect of Temperature.—Some information on this subject has been given incidentally above, p. 256. We collect here a few additional facts; but a complete account of all that has been done could not be compressed within our available space, owing to the great diversity of opinion upon the subject. That the question is a very difficult one will appear at once, if we reflect that variations of temperature influence the density and molecular structure of magnetic bodies to a remarkable degree, and that thus secondary influences arise in addition to the proper effect of temperature.

That very high temperatures destroy both the magnetic susceptibility and the power of retaining magnetism altogether has been known since the infancy of magnetic science. Thus Gilbert found that a loadstone and a piece of iron equally lost their power of affecting the magnetic needle when heated very hot, and remarks that the magnetic property returns to the iron after it has cooled a little, but that the magnetic virtue of the loadstone is altogether destroyed.[3] Similar results were obtained by Brugmans, Boyle, Cavallo, Barlow and Bonnycastle, Christie, Ritchie, Erman, Scoresby, Seebeck, and others. Faraday[4] found that a steel magnet lost its permanent magnetism rather suddenly at a temperature a little under the boiling point of almond oil; it behaved like soft iron till it was raised to an orange-red heat, and then it lost its magnetic susceptibility and became indifferent. The temperature at which retentive power for permanent magnetism was lost appeared to vary in steel with the hardness and structure; in fragments of loadstone it was very high: they retained their permanent magnetism until just below visible ignition in the dark, but, on the other hand, they lost their susceptibility at dull ignition, *i.e.*, at a much lower temperature than iron. Nickel was found to lose its magnetic susceptibility at a much lower temperature than iron, viz., about 330° to 340° C.[5] Cobalt is much more refractory, for it retains its susceptibility, according to Faraday, nearly up to the melting point of copper, *i.e.*, to a white heat. The writer had occasion to verify these results in the course of some experiments on the magnetic sounds in wires of iron, nickel, and cobalt traversed by an interrupted current of electricity.[6]

Destruction of magnetism by very high temperature.

The effect of extreme cold, produced in the ordinary way by means of solid carbonic acid and ether, was, according to Trowbridge,[7] to diminish the moment of a steel magnet (magnetized at 20° C.) by about 60 per cent.

Effect of extreme cold.

The effect of moderate alteration of temperature varies greatly according to circumstances. We shall consider separately the effect upon the magnetic susceptibility and upon the permanent magnetism; but it must be noticed that no such separation is possible in actual experiment.

Moderate variations of temperature.

The temporary magnetism of bars of cast iron, smithy iron, soft iron, soft steel, and hard steel magnetized by the earth's vertical force was found by Scoresby[8] to be insensible at a white heat, but to be much greater at a dark red heat than at the temperature of the air. The difference was most marked in the case of hard steel, no doubt partly because of the softening of the bar. Similar experiments were made by Barlow, Seebeck, and others. Kupfer[9] experimented on the subject using variations of temperature between 0° and 100° C., and found the susceptibility of soft iron to increase with the temperature. Wiedemann's conclusion is that the first alteration of temperature, whether increase or decrease, increases the temporary magnetism of iron or steel, whatever the temperature at starting. If the temperature be repeatedly altered and brought back to its initial value, the magnetization continues to increase, but after a time becomes more and more nearly constant at the initial temperature. After this state has been reached, an increase of temperature causes increase of magnetization in very hard steel bars, a decrease of temperature a decrease of magnetization; the behaviour of soft steel bars is exactly opposite.

Effect on magnetic susceptibility.

Wiedemann's results.

[1] According to the results of Villari and Thomson, if the magnetization were beyond a certain critical value, P*e* would become an axis of compression and P*r* an axis of extension, in which case the wire would twist in the opposite direction.

[2] See Thomson, *Phil. Trans.*, 1879, p. 73. Not the least of these arise from gaps in our experimental knowledge; *e.g.*, regarding the effects of *permanent set* caused by traction and compression.

[3] *De Magnete*, lib. ii. cap. 3.

[4] *Exp. Res.*, vol. ii. p. 220, 1836.

[5] According to Becquerel about 400° C., according to Pouillet about 350° C.

[6] *Nature*, vol. xxii., 1880.

[7] *Sill. Jour.*, 1881.

[8] *Phil. Trans. Roy. Soc. Edin.*, vol. ix.

[9] Wied., *Galv.*, ii. § 521.

Baur's results.

Baur[1] and Wassmuth[2] have recently taken up the matter with all the advantages of modern experience. The former concludes from his experiments on iron by the ring method, at temperatures between 0° and 150° C., that the magnetic susceptibility for a given magnetizing force increases with the temperature if the force be below a certain critical value (3·6 or so), but decreases as the temperature increases if the force be above that value.[3] The smaller the magnetizing force the greater the influence of temperature on the magnetic susceptibility. The result of his experiments at very high temperatures is that, for small magnetizing forces, the susceptibility at first increases rapidly as the temperature increases, reaches a maximum at red heat, and then falls suddenly to zero. For large forces, the susceptibility decreases gradually until red heat, and then falls suddenly to a very small value. According to him, if a bar be cooled from white heat the first traces of susceptibility are observed at a very bright red, the brighter the greater the magnetizing force. He gives a variety of interesting results concerning the phenomenon of Gore,[4] all in accordance with what we have just stated.

Diamagnetism of flame.

In his earlier researches Faraday was unsuccessful in obtaining any evidence of the influence of temperature on the susceptibility of weakly magnetic bodies, such as the chlorides of the magnetic metals or of diamagnetic bodies.[5] His earliest results were obtained with gases, and that too, strange to say, before the magnetic character of gases was fully investigated. It was Bancalari's discovery of the extraordinary behaviour of flame between the poles of an electromagnet that led Faraday to resume his magnetic experiments on gases. Flames of all descriptions are strongly repelled from the axial line of a heterogeneous magnetic field,—so much so that it is impossible to induce the flame of a candle to go between the pointed poles of a powerful electromagnet when they are placed at a short distance apart. The flame is blown aside, or even downwards, as if by a strong current of air issuing from between the poles. If a flat pointed flame is placed with its centre a little below the axial line, when the magnet is excited it drops down and spreads out below and around the axial line, assuming a fish-tail shape. It appears that the effect is not due to the solid matter in the flame but simply to the hot gases in it; for the upper and cooler part of the stream of smoke from a freshly extinguished taper is scarcely affected, while the lower and hotter part is most powerfully acted upon, being blown aside and often split into two independent streams. A careful investigation led Faraday to the conclusion that oxygen, carbonic acid, and coal gas are rendered more diamagnetic, or, what is the same thing so far as the resultant differential action is concerned, less magnetic by heat,[6] and that this effect was much greater than could be accounted for by the mere rarefaction of the gas. He likewise obtained an increase of the susceptibility of oxygen by cooling it with ether and solid carbonic acid. Nitrogen appeared to be altogether indifferent.

Bancalari.

Faraday's experiments on heated gases.

Effect of heat on susceptibility in weak magnetics.

He found in a later series[7] of experiments that the magnecrystallic property of bismuth was destroyed at a temperature a little below its melting point, and that the same thing happened to crystalline antimony a little below red heat. In the thirtieth series of his experimental researches he states that between 35° and 142° C. the susceptibility of a specimen of spathic iron ore perpendicular to its magnetic axis decreased by ·333 per cent. per degree centigrade of rise of temperature; this agrees very closely with the formula which was found by Wiedemann to represent very approximately the temperature effect for salt solutions, viz., $k_t = k_0(1 - \cdot 00325\, t)$. For the decrease in the magnecrystallic couple, or, which is the same thing, in the difference between the susceptibilities along and perpendicular to the magnetic axis, he found for the spathic iron ore ·482 per cent. between 0° and 138° C., and the percentage of decrease was four times as great between −14° and 0° as between 129° and 143°. The corresponding decrease in the case of crystalline bismuth between 36° and 137° C. was ·53 per cent. The experiments of Plücker and Matteucci led them to conclude that the susceptibility of diamagnetics diminishes with increase of temperature; in the case of bismuth the decrease between ordinary temperatures and its melting point is said to be about one-sixth or more.

Effect of heat on permanent magnetism.

Canton seems to have been one of the first to study the effect of moderate variations of temperature on the permanent magnetism of iron and steel. The results of his and Hallström's experiments went to show that permanent magnetization decreases when the temperature rises, and increases again when the temperature falls. In reality, however, as was shown by Kupffer, Riess and Moser, G. Wiedemann, and others, the phenomenon is complicated; for, if we repeatedly heat a magnet and allow it to cool to its initial temperature, the magnetization lost at each heating is only partially recovered on cooling, and thus a progressive loss goes on, until at last a constant state is reached, in which the magnetization lost on heating is completely recovered on cooling. In this respect, as well as in the effect on the magnetic susceptibility already discussed, there is an analogy between the effect of temperature and the effect of strain; *i.e.*, there is a first or permanent effect and a proper or temporary temperature effect. The permanent effect is that any alteration of temperature, be it increase or decrease, diminishes the permanent magnetization just as a shock or a jar would do, and probably for a similar reason. The proper or temporary effect consists in a decrease of magnetization with increase of temperature, which is completely recovered on decrease of temperature and *vice versa*.[8] If this be borne in mind, together with what has already been said above, it will not be difficult for the reader to see that the order and amount of the temperature variations, the hardness and form of the bar, and its magnetic history will all influence the temperature coefficient.

First and permanent effect.

Proper temporary effect.

To take one example, Wiedemann found that a bar magnetized at 0° C. and then partially demagnetized by an opposite force, lost magnetism when heated; if the demagnetization was not carried too far, it did not when cooled again to 0° wholly recover what it had lost. If the demagnetization was carried a certain length, it recovered all that it had lost; if farther still, more than it had lost. It was in fact found possible to demagnetize a bar, so as to render it apparently unmagnetic, and then to restore part of its original magnetism by merely heating and cooling it again. Similar phenomena were observed with a bar magnetized and demagnetized at 100°, and then alternately cooled and heated. Unverdorben,[9] who arrived somewhat later at similar results, represents the matter by saying that the bar in this case has two magnetizations superposed, each having its own temperature coefficient.

The following are a few additional references to sources of information concerning the present subject: Mauritius, *Pogg. Ann.*, 1863, and *Phil. Mag.*, 1864; Jamin and Gaugain, *Comptes Rendus*, *passim*; Favé, *Ib.*, 1876; Poloni, *Wied. Beibl.*, 1878.

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[1] *Wied. Ann.*, xi., 1880. [2] *Wien. Ber.*, 1880, 1881, 1882.
[3] See the results of Faraday, *Exp. Res.*, ser. xxx. 3424, &c.
[4] *Phil. Mag.*, 1869, 1870.
[5] *Exp. Res.*, 2359, 2397, 1845. [6] *Exp. Res.*, vol. iii. p. 486.
[7] *Exp. Res.*, 2570 *sq.*, 1848.

[8] To give the reader an idea of the magnitude of this effect, we may mention that Whipple in determining the temperature corrections for magnetometer magnets at Kew, according to the formula

$$K_t = K_0\{1 - q(t - t_0) - q'(t - t_0)^2\},$$

found for the coefficient q values varying from ·000762 to ·000044, with a mean of ·000161; and for q from ·00000398 to ·00000001, with a mean of ·00000048 (*Proc. Roy. Soc. Lond.*, 1877).

[9] Quoted in Lamont, *Handb. d. Mag.*, § 82. An account of Lamont's own researches will be found in the same place.

om- r's iclu- ns.

Development of Heat during Magnetization.—Reasoning on purely thermodynamic principles from the results of Faraday, as to the influence of temperature on the magnetic properties of bodies, Thomson[1] has concluded—(1) that a piece of soft iron at a moderate or low red heat, when drawn gently away from a magnet, experiences a cooling effect, and, when allowed to approach, a heating effect, and that nickel at ordinary temperatures and cobalt at high temperatures (between the melting point of copper and some lower temperature) experience the same kind of effect; (2) that cobalt at ordinary temperatures and up to the temperature of maximum permeability experiences a cooling effect when allowed to approach a magnet, and heating when drawn away; (3) that a crystal in a magnetic field experiences cooling when the axis of greatest paramagnetic or of least diamagnetic susceptibility is turned from along to across the lines of force, and *vice versa*.

xperi- ental ffi- ılties.

Besides these considerations, the fact that those who adopt the molecular magnet theory are obliged to assume something of the nature of a frictional resistance to the turning of the magnetic molecules, and generally, without reference to any particular theory, many of the phenomena of coercive force,[2] lead us to suppose that some specific development of heat may accompany magnetization and demagnetization. The experimental verification of this suspicion is, however, a matter of great difficulty, owing to the enormous generation of heat arising secondarily from induced currents in the mass of the metal. The development caused by magnetization and demagnetization was taken advantage of by Joule in one of his determinations of the mechanical equivalent of heat, but he makes no attempt to separate the effect of the two causes, indeed it did not concern his purpose to do so.[3] Notwithstanding that several experimenters have attacked the problem, it cannot be said that it is yet completely solved. It will therefore be best simply to call the reader's attention to some of the papers that have been published on the subject, and leave him to form his own judgment.

See Von Breda, *Pogg. Ann.*, 1846; Grove, *Phil. Mag.*, 1849; Edlund, *Pogg. Ann.*, 1864; Villari, *N. Cim.*, 1870; Cazin, *Comptes Rendus*, 1874; Herwig, *Wied. Ann.*, iv., 1878; Trowbridge, *Wied. Beibl.*, 1879.

'hermal onduc- ivity.

Miscellaneous Relations of Magnetism to other Physical Properties.—According to Maggi[4] the thermal conductivity of magnetized iron is less along the lines of force than across them. Naccari and Bellati[5] were unable to verify this result; Tomlinson,[6] however, found that the conductivity of iron and steel bars was diminished by longitudinal and increased by transversal magnetization.

Electric onduc- ivity.

Abraham, Edlund, Mousson, and Wartmann all made experiments in search of a magnetic alteration of the electric conductivity of iron. Thomson seems, however, to have been the first to arrive at any definite result.[7] He found the conductivity to be diminished along the lines of magnetization and increased across them. Beez[8] verified the former result, but doubts the latter, which he is inclined to explain as a secondary effect caused by the compression of the iron arising from the external magnetic action on the plates used in Thomson's experiments.

Thermo-electro-motive force.

Thomson also found[9] that the thermoelectric quality of iron was affected by magnetization; the thermoelectric current flowed from unmagnetized to longitudinally magnetized, and from transversely magnetized to unmagnetized or longitudinally magnetized iron through the hot junction. In the case of nickel, the current flowed from longitudinally magnetized to unmagnetized through the hot junction, *i.e.*, nickel behaved oppositely to iron. Thomson's results have been in part confirmed by a recent investigation of Strouhal and Barus.[10]

Magnetism and light.

A relation between magnetism and light was first established by Faraday's discovery of the magnetic rotation of the plane of polarization of a ray passing along the lines of force. This subject belongs more properly to physical optics, but there is one magnetic phenomenon apparently closely connected with it which falls to be mentioned here. This is Hall's discovery[11] that, if an electric current flow in a thin metallic strip in a direction AB, the effect of placing the strip in a magnetic field with its plane perpendicular to the lines of force is to cause a transverse electromotive force perpendicular to AB, which changes in sign when the direction either of the current or of the magnetic field is changed. This transverse electromotive force is proportional to the product of the current intensity and the strength of the magnetic field; *cæteris paribus*, its direction in the case of iron is opposite to that in other metals, and its magnitude is also greatest with iron. This discovery establishes the existence of the rotatory coefficient of resistance mentioned by Maxwell[12] in his discussion of æolotropic conductivity; and Rowland has shown that the phenomenon is probably due to the same cause as the magnetic rotation of the plane of polarization.[13]

Hall's phenomenon.

Effect of time.

If, as modern physicists suppose, magnetism be a dynamical phenomenon, time must enter as a conditioning element. The question has been raised how long any magnetizing force takes to develop the maximum magnetization that it is capable of producing. There are many facts that go to prove that this time is very small, or, at all events, that any force develops a very large fraction of the total magnetization due to it in a very short period of time. Perhaps the most wonderful evidence on this head is the fact that the telephone, which depends essentially on varying magnetic action, can reproduce the sounds of human speech even to the consonants.[14] Experiments bearing directly on the subject have been made by Villari.[15] A flat circular disk of flint glass was placed between the poles of a Ruhmkorff's apparatus for measuring the magnetic rotation of the plane of polarization. The axis of the disk was perpendicular to the axial line, so that rotation brought the different radii successively into the line of sight. When the disk was at rest the magnetic action in one experiment caused a rotation of 19 divisions; spinning the disk at the rate of 110, 121, 143, and 180 turns per second reduced the magnetic rotation of the plane of polarization by 2, 5, 10, and 17 divisions respectively; the reduction was less the greater the magnetic force. From this Villari concluded that in flint glass not less than 0·001244 second is required to produce such a diamagnetic intensity as can be observed by the rotation of the plane of polarization, and that 0·00241 second at least is required to develop the greatest diamagnetization of which this substance is capable; he also states that the diamagnetism lasts for less than 0·00018 second after the inducing force is withdrawn. A series of interesting experiments on the oscillation of the plane of polarization caused by the oscillatory discharge from a Leyden jar recently made by Bichat and Blondlot[16] led them to a different conclusion, viz., that if any lagging of the induced magnetization behind the magnetizing force

[1] *Phil. Mag.*, 1878; or Nichol's *Cyclopædia*, 2d ed., 1860.
[2] See the paper of Warburg quoted above, p. 260.
[3] Joule, *Phil. Mag.*, 1843.
[4] *Archives de Genève*, 1850; or Wied., *Galv.*, ii. § 510.
[5] *Wied. Beibl.*, 1877.
[6] *Proc. Roy. Soc. Lond.*, 1878.
[7] *Phil. Trans.*, 1856.
[8] *Pogg. Ann.*, 1866.
[9] *Loc. cit.*
[10] *Wied. Ann.*, xiv., 1881.
[11] *Phil. Mag.* [5], ix. and x., 1880.
[12] *El. and Mag.*, vol. i. § 303. See also Stokes, *Camb. and Dub. Math. Jour.*, vi., 1851; and Thomson, *Trans. R.S.E.*, vol. xxi. p. 165, 1854.
[13] *Am. Jour. of Math.*, 1880; *Phil. Mag.* [5], x., 1880, and xi., 1881.
[14] See also an article by the writer, *Phil. Mag.* [5], ii. 1876.
[15] *Pogg. Ann.*, 1879.
[16] *Comptes Rendus*, 1882.

exists it is less than 0·000033 second. No explanation has been given of the discrepancy of these results.

Direct influence of light upon magnetization. In the early part of this century there was an animated controversy as to whether light exerted a direct influence upon magnetization, in which Morichini, Mrs Somerville, Christie, Riess and Moser, and many others took part. Nothing definite, however, was established. A similar fate befell the attempts to trace the influence of magnetic force upon crystallization, and to detect a relation between magnetism and gravity,[1] although both quests at one time or another engaged the skill of Faraday.

Forms, Construction, and Preservation of Magnets.

This subject occupied a large portion of most of the earlier treatises on magnetism. Much of the information given, however, either has now been recognized to be of questionable value or has been superseded by recent progress, and retains a merely antiquarian interest; a few brief remarks, mainly historical, will therefore be sufficient.

Loadstones. The oldest form of magnet was a piece of magnetic iron ore or loadstone. The power of these natural magnets varied exceedingly from one specimen to another. An elaborate discussion of the various kinds of loadstone will be found in Gilbert's *De Magnete.*[2] In order to increase the carrying power, the loadstone was usually fitted with armatures of soft iron upon its polar regions; figure 45, taken from Gilbert, represents one of the oldest arrangements.

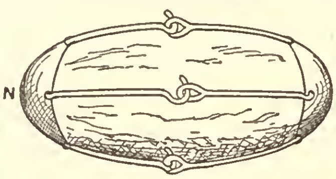

Fig. 45.

Figure 46 is taken from a loadstone in the collection of physical apparatus belonging to the university of Edinburgh, the carrying power of which is 205 ℔. A loadstone in the Teylerian Museum at Haarlem has a carrying power of 230 ℔; and one at Lisbon, presented by the emperor of China to King John V. of Portugal, is said to support as much as 300 ℔. Small loadstones are often very powerful in proportion to their weight; *e.g.*, Newton is said to have worn in a ring one that weighed only 3 grains, and yet was able to carry about 746 grains; and one in the physical collection at Edinburgh, formerly belonging to Sir John Leslie, weighing itself $3\frac{1}{2}$ grains, had at one time a carrying power of 1560 grains.

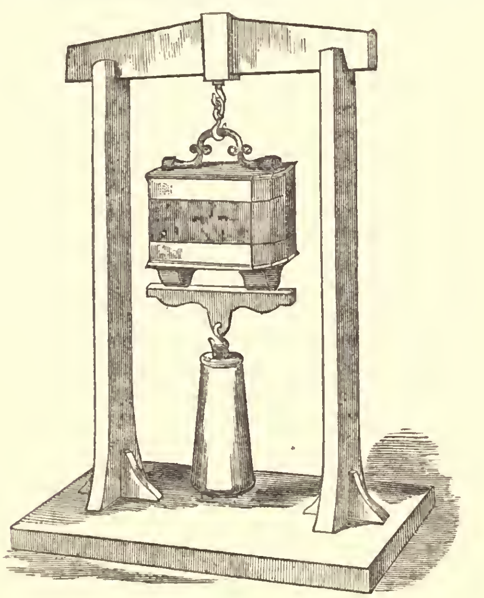

Fig. 46.

Steel magnets. The introduction of steel magnets, and the perfection to which they were gradually brought, caused the loadstone to fall into disuse. It is said that Galileo possessed the art of making steel magnets about the beginning of the 17th century. It was early discovered that the earth's force could be utilized in magnetizing steel. Gilbert was aware that a feeble magnetization could be produced in this way; and Michell, in his treatise on artificial magnets, minutely describes how weak magnets may be made by means of the earth's force, then combined into bundles or "magazines" and used in turn to produce stronger magnets, these used to produce still stronger, and so on.

Single touch. The earliest process of all was no doubt the method of rubbing or touching by another magnet. This method of making magnets was studied with much attention by the natural philosophers of the 18th century, among whom we may mention Savery, Knight, Duhamel, Le Maire, Canton, Michell, Æpinus, Coulomb, and Euler. The method of single touch consists simply in stroking the bar to be magnetized alternately on its two halves with the south and north poles of a loadstone or bar magnet, the stroke beginning always at the middle and ending at the end. According to Lamont, the best plan is to lay the magnet flat, overlapping one half of the bar to be magnetized, and then draw it off; when the magnet is held perpendicular to the bar during the process, the result is apt to give an irregular magnetization: *e.g.*, we may even get a magnet with its two ends north poles and with a south pole in the middle, or one with four poles, a north and south pole at the two ends and a south and north pole in the middle.[3]

Double touch. The first improvement on single touch was double touch with separate magnets. This consists in using two magnets simultaneously on the two halves of the bar undergoing magnetization. The north pole of one and the south pole of the other are placed either close together, or at a small distance apart near the middle of the bar, and then each is drawn towards the end of the half on which it lies; according to Lamont, here, as in single touch, the magnets should be laid flat on the bar.[4] Michell introduced the further improvement of using two bar magnets (or bundles of such) fastened together and kept parallel at a small distance apart by means of small pieces of wood, the north pole of one being conterminous with the south pole of the other. This pair is placed vertical with one end on the middle of the bar, drawn towards one end and slipped off, then replaced on the middle and drawn to the other end, and so on alternately until the moment of the bar ceases to increase any farther. Instead of the pair of bar magnets a horse-shoe magnet might of course be used.

Le Maire[5] introduced the essential improvement of placing the bar to be magnetized upon a larger bar, and then magnetizing the two together. The advantage of this is best seen in the form of the same device adopted by Canton[6] and Duhamel,[5] who magnetized steel bars in pairs, connecting them up parallel to each other by means of two pieces of soft iron, and then magnetizing them in opposite directions. It is easy to see that the magnetization of the one reacts on the magnetization of the other and strengthens it. Michell[7] obtained a similar advantage by magnetizing a number of bars placed end to end in a line; he found, as was to be expected, that the end bars were weaker, but this defect he remedied by repeating the process with the bars arranged in a different order. Coulomb's method was to place the ends of the bar on the north and south poles of two bar magnets arranged in line at the proper distance apart. This process of connecting up the bars to be magnetized in a closed magnetic circuit is sometimes called circular touch; it can be applied to horse-shoe magnets by placing a pair of them with their ends together, and then passing round and round upon them a horse-shoe magnet or a pair of bar magnets arranged as already described.[8]

Electromagnets. Immediately after Œrsted's discovery of the magnetic action of the galvanic current, Arago,[9] Boisgiraud,[10] and Davy almost simultaneously applied this property to the magnetization of iron and steel.[11] Powerful electromagnets, with cores of soft iron, were first constructed a few years later by Sturgeon and Brewster. Pohl, Moll, and Pfaff in Germany, and Henry and Ten Eyck in America, may be mentioned as the most successful of the early constructors. One of the electromagnets of Henry and Ten Eyck reached a carrying

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[1] For the literature, see Wied., *Galv.*, §§ 688, 689.

[2] See also Gehler's *Physikalisches Wörterbuch*, art. "Magnetismus."

[3] Poles situated abnormally in this way are called "consecutive points."

[4] This method appears to have been invented by Knight (about 1740), and used in producing the powerful magnets for which he was famous. The secret of his process was never divulged by himself, but was published by Wilson after his death. See art. Magnetism, 8th edition of *Encyclopædia Britannica.*

[5] *Mém. d. l'Acad. d. Paris*, 1745 and 1750.

[6] *Phil. Trans.*, 1751.

[7] *Treatise of Artificial Magnets*, 1750.

[8] For fuller information on the present subject, see Gehler's *Physikalisches Wörterbuch*, art. "Magnetismus," xv.

[9] *Ann. d. Chim. et d. Phys.*, 1820.

[10] *Phil. Trans.*, 1820–21.

[11] The anomalous magnetization of needles by the discharge from Leyden jars had been observed earlier, but not properly understood. See art. Electricity, vol. viii. p. 82.

power of 2061 lb; but magnets specially constructed for carrying power have surpassed this limit. As a specimen of scientific toys of this description may be mentioned the electromagnet of Roberts (fig. 47), which consists of a square block of iron deeply slotted with four parallel grooves into which three layers of copper wire cable are wound in zigzag fashion so that the current converts the flanges alternately into north and south poles; the armature is a square block planed to fit the face of the magnet. The carrying power of a machine of this kind was 2949 lb, *i.e.*, more than $1\frac{1}{2}$ tons!

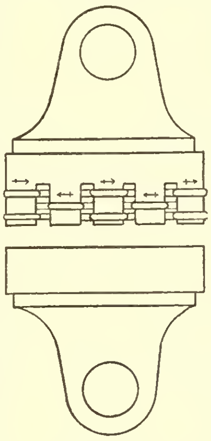

Fig. 47.

The forms of electromagnet used in the arts, *e.g.*, in electric bells, fire alarms, telegraphs, telephones, electric light regulators, dynamo machines, &c., are simply innumerable. It will be sufficient to allude to those constructed for the purpose of producing an intense magnetic field, uniform or non-uniform, over a larger or smaller area; these find their practical application in the construction of dynamo-electric machines, but they are mainly interesting to purely scientific men on account of their use in the investigation of the properties of weakly magnetic bodies. Figure 40 shows the usual arrangement adopted for large laboratory magnets. In considering the greatest available strength of such magnets, it is necessary to bear in mind the fact that magnetic saturation of iron is practically reached with magnetic forces much under the greatest that we can command. The strength of field in a narrow crevasse perpendicular to the lines of magnetization in saturated iron is less than 18,000 C.G.S. units;[1] and this is practically the utmost at present attainable, for any addition to the strength of the field, arising from direct action of the magnetizing helix, would not under ordinary circumstances affect the hundreds in this number. Further increase of magnetizing current after we have reached within a small percentage of the limit of saturation is a waste of power.

[Magnet]ization [by el]ectric [cur]rent. Elias[2] of Haarlem seems to have been the first who applied the electric current directly with success in the manufacture of powerful permanent magnets. He used a short flat magnetizing coil which was pushed backwards and forwards along the bar, the ends of which were caused to abut against two pieces of iron, which becoming inductively magnetized reacted on the bar, and also served to keep the magnetization at the ends more uniform. The famous Logeman magnets were constructed by this process.

[Ma]gnet[iza]tion [by me]ans [of a]n [ele]ctro-[ma]gnet. By far the most convenient way of magnetizing steel is to use an electromagnet.[3] The bar to be magnetized may be laid flat on the pole of the magnet before it is excited, and after excitation drawn slowly off. By repeating this process several times, with the north pole of the electromagnet for one half and the south pole for the other half, saturation can be very quickly obtained. Perhaps a better plan is to lay the bar with its ends on the two poles, and then excite the electromagnet. For reasons already sufficiently explained, it is advisable to hammer the bar with a mallet while the magnetizing force is in action, and to turn the current off and on several times in succession.[4]

[La]mi[nat]ed [ma]gnets. On account of the difficulty of tempering steel to any great depth from the surface, and for specific magnetic reasons as well, it has been customary in constructing powerful permanent magnets to build them up of thin laminæ of steel, each of which is separately magnetized. Figure 48 represents an arrangement of this nature

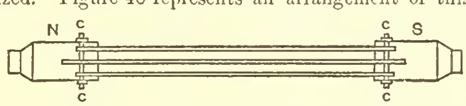

Fig. 48.

adopted by Coulomb, and figure 49 a horse-shoe magnet constructed in the same way. It will be observed that the ends of the laminæ are not exactly conterminous, the middle ones projecting more than the others; this arrangement was adopted with the view of getting rid to some extent of the weakening effect which the induction of one lamina has upon the other. That such an effect exists and is very great was conclusively shown by Coulomb; how far the modification in question cures it is another matter; much no doubt depends on the purpose for which the magnet is required; but it is scarcely worth while to discuss the subject here. We may call attention to a farther point in the construction of Coulomb's magnet, viz., that the ends of the laminæ are embedded in two soft iron terminals N and S; there can be no doubt that, for some purposes at least, this is an advantageous arrangement. Among the famous modern makers of permanent magnets Häcker of Nuremberg, Logeman and Wetteren of Haarlem,[5] Willward, and Jamin deserve to be specially mentioned.[6]

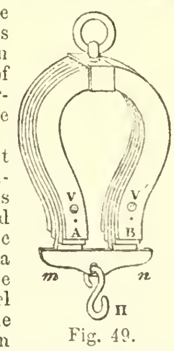

Fig. 49.

Preservation of magnets. In the preservation of permanent magnets it is essential to avoid extreme changes of temperature and shocks. When the magnet is laid aside it should be made part of a closed magnetic circuit; in the case of a horse-shoe magnet this is attained by simply laying a piece of soft iron, called the keeper, across the poles; bar magnets should be kept in parallel pairs, north pole to south pole and south pole to north pole, with two pieces of soft iron between the poles. When this is done the induced magnetism reacts on the magnets and diminishes the demagnetizing force; the action of shocks then ceases to destroy the permanent magnetism, and may even increase it.

Ultimate Theories of Magnetic Phenomena.

Stream theory. If we pass over the stream theory, which, although partially developed by Euler, has never taken root in modern physical science, the first great theory that we find proposed with a view to the explanation of magnetism is the two-fluid theory of Coulomb and Poisson. This is not an ultimate theory in the modern sense, inasmuch as it is not dynamical; but it was, doubtless, looked upon as ultimate in the days when the imponderable fluids had a recognized role in the physical sciences. In the two-fluid theory the imaginary positive and negative attractive agents (called magnetism in the empirical theory developed above) are regarded as imponderable fluids; but the essential point in the definite form of the theory due to Poisson is that he regards a body susceptible to magnetic induction as made up of an infinite number of particles of infinite permeability immersed in an impermeable medium.

Two-fluid theory. Poisson. After pointing out that, if the particles were of elongated form, and arranged so that the axes of elongation had one preponderating direction, or if they were arranged so that the linear density in different directions varied, the result would be æolotropy, he assumes that they are spheres uniformily distributed in the impermeable medium so that the volume of the magnetic particles in unit volume of the substance is the fraction k. The problem of magnetic induction under the influence of a uniform force is then the same as the problem of electric induction for an infinite number of perfectly conducting spheres uniformly distributed in a non-conducting medium. He finds for the permeability $\varpi = (1 + 2k)/(1 - k)$.

Maxwell has pointed out one fundamental objection to this theory, viz., that the value of k calculated from the formula just given by means of observed values of ϖ in the case of iron is greater than it would be even if the magnetic spheres were packed in the closest possible manner. Another objection is that the theory affords no explanation of the variability of k with different forces. We might of course modify the hypothesis, as was done by Plücker, by supposing that a resistance depending on the magnitude of the force opposes the separation of the fluids in the magnetic molecules, and that in certain cases a frictional resistance tends to prevent their reunion. We might in this way explain magnetic saturation and permanent magnetism; but the theory thus burdened has no more scientific value than the purely empiric theory, and, moreover, affords no clue to the phenomena of diamagnetism.

[1] See above, p. 256.

[2] *Pogg. Ann.*, 1844 and 1846.

[3] Frick, *Pogg. Ann.*, 1849, was one of the earliest who practised this method.

[4] It has been several times proposed to magnetize steel bars by heating them red hot, allowing them to cool to the proper temperature under the magnetizing force, and then tempering while the force is still acting. Gilbert, Knight, Robison, Haman, Gaugain, Aimé, and Holz (*Wied. Ann.*, vii., 1879) have all experimented with this method, but it does not appear to possess any advantage over the ordinary modern process, and need not be discussed here.

[5] Advised by Elias and Van der Willigen; see *Nature*, vol. xix. p. 552, 1879.

[6] Further details as to the advantages and disadvantages of various forms of magnets will be found in Wiedemann's *Galvanismus*, and Lamont's *Handbuch des Magnetismus*. See also a recent paper by W. Holz, *Wied. Ann.*, 1880, on hollow cylindrical magnets, and another by Gray on the moments attainable with hard steel bars, *Phil. Mag.*, 1878.

Molecular magnet theory.

In a very important class of modern theories, the fundamental assumption is that the molecules, or at all events a certain proportion of the molecules, of magnetic substances are small permanent magnets. In a body which is to outward appearance unmagnetized, the axes of these molecular magnets are turned indifferently in all directions; in a body which is magnetized in a certain direction a larger proportion than usual of the molecular magnets have their axes more or less in that direction. Magnetic induction is supposed to consist, not in any alteration of the molecular magnets themselves, but in the orientation of their axes under the action of the inducing force. The reader may figure to himself the nature of the action by imagining a line of small magnetic needles with their axes all horizontal, but all pointing in different directions; the whole system thus arranged will have no determinate magnetic moment, and will represent an unmagnetized body. Next, suppose a magnetizing force to act parallel to the line joining the centres of the needles, they will then arrange themselves in that line, and the magnetic moment of the system will be the sum of the moment of the different parts; we have thus an image of a body magnetized by induction.

Weber's form.

The notion of molecular magnets seems to have been suggested by Kirwan; but it was not until a definite form was given to it by Weber that it acquired any importance. The mathematical problem presented is one of great complexity. In the position of equilibrium any molecule is acted on by the magnetizing force, by a magnetic force due to the combined action of the other molecules, and possibly by a force arising from the displacement as well. Weber assumes that the couple tending to restore the molecule to its original position is that due to a constant magnetic force D, parallel to the original direction of its axis. If m be the magnetic moment of a molecule, and there be n molecules in a unit of volume, then the magnetic intensity $\mathfrak{I}$ due to the magnetizing force $\mathfrak{H}$ is given by $\mathfrak{I}=2mn\mathfrak{H}/3\mathrm{D}$, if $\mathfrak{H}<\mathrm{D}$; and by $\mathfrak{I}=mn(1-\mathrm{D}^2/3\mathfrak{H}^2)$, if $\mathfrak{H}>\mathrm{D}$. In other words, the curve ($\mathfrak{I}$, $\mathfrak{H}$) is straight till it reaches the point ($\frac{2}{3}mn$, D), it then becomes concave towards the axis of $\mathfrak{H}$, and rises towards an asymptote parallel to the axis of $\mathfrak{H}$; the maximum value of $\mathfrak{I}$ is mn. The theory does, therefore, give a general explanation of the phenomena of magnetic induction. The reader will be able by comparison with the experimental data given above to see how far it falls short of a complete explanation.

If the magnetic substance be devoid of coercive force, we must suppose that the molecules return to their original positions when the magnetizing force is removed. In substances capable of being permanently magnetized, we must imagine something of the nature of a frictional resistance to the motion of the magnetic molecules; so that, when they are deflected through more than a certain angle, they retain a permanent set after removal of the magnetizing force.

Maxwell's form.

Maxwell has worked out the particular hypothesis that each molecule which is deflected through an angle less than β_0 returns when the magnetizing force ceases to act, but that a molecule deflected through an angle $\beta>\beta_0$ retains the deflexion $\beta-\beta_0$. Denoting $\mathrm{D}\sin\beta_0$ by L, he finds as the result of the above supposition that the curve of temporary magnetization is a straight line from $\mathfrak{H}=0$ to $\mathfrak{H}=\mathrm{L}$; after that it is concave to the axis of $\mathfrak{H}$, and rises to an asymptote, the maximum value of $\mathfrak{I}$ being mn as before. The curve of residual magnetization begins when $\mathfrak{H}=\mathrm{L}$; it is concave to the axis of $\mathfrak{H}$, and rises to an asymptote corresponding to the maximum $\mathfrak{I}'=\frac{1}{4}mn\{1+\sqrt{1-\mathrm{L}^2/\mathrm{D}^2}\}^2$. It results from the hypothesis that, when a bar is permanently magnetized by a positive force $\mathfrak{H}_1$, its magnetism cannot be increased by a positive force $<\mathfrak{H}_1$, but may be diminished by a negative force $<\mathfrak{H}_1$; and, when the bar is exactly demagnetized by a negative force $\mathfrak{H}_2$, it cannot be magnetized in the opposite direction without the application of a force $>\mathfrak{H}_2$; but a positive force $<\mathfrak{H}_2$ is sufficient to begin to remagnetize the bar in the original direction.

Ampère's hypothesis.

Behind the molecular magnet theory there arises the question, What is the nature of the magnetic molecule? One answer to this question is given by the hypothesis of Ampère, that around each such molecule a current circulates in planes perpendicular to the axis of the molecule. That such an arrangement will be equivalent to an infinitely small magnet in the axis of the molecule, so far as external action is concerned, we know from the laws of electrodynamics. It remains only to inquire what the nature and properties of these molecular currents must be, to trace the full logical consequences of the assumption, and to compare them with experience. This was first done by Weber, and afterwards more completely by Clerk Maxwell.

It is obvious in the first place that the circuits in which the molecular currents flow must be perfectly conducting; for otherwise the electrokinetic energy of the molecular currents would be continually transformed into heat, and a constant supply of energy from without would be necessary to support the magnetism of a permanent magnet, which is contrary to experience. Let A be the effective area of a molecular circuit, L its coefficient of self-induction, θ the inclination of its axis to the inducing force $\mathfrak{H}$, γ_0 the primitive current, and γ the current after the inducing force is in action. Then $\gamma=\gamma_0-\mathfrak{H}\mathrm{A}\cos\theta/\mathrm{L}$; and the component of the moment parallel to $\mathfrak{H}$ will be $\mathrm{A}(\gamma_0-\mathfrak{H}\mathrm{A}\cos\theta/\mathrm{L})\cos\theta$. There are three different cases to consider.

1. Let either γ_0 be so great, or $\mathfrak{H}\mathrm{A}/\mathrm{L}$ be so small, that the effect due to the electromagnetic induction may be neglected in comparison with the effect due to the deflexion of the molecule; putting $m=\mathrm{A}\gamma_0$, we have thus merely the theory of molecular magnets already explained.

Weber theory of diamagnetism.

2. Let the force resisting the turning of the molecules be infinitely great, we then find for the magnetic susceptibility the value $\kappa=-\frac{1}{2}n\mathrm{A}^2/\mathrm{L}$. This is the theory originally proposed by Weber to explain diamagnetism.

3. If the effects due to deflexion of the molecules and to electromagnetic induction in the molecular circuits be both considered, we have a theory intermediate to (1) and (2), inclining to the one or the other according to the assumptions made as to the relative values of γ_0, A, and L.

The reader will find a full discussion of the different cases in Maxwell's *Electricity and Magnetism*, vol. ii. chap. xxii.

Maxwell's molecular vortex theory.

The most important attempt that has yet been made to realize a mechanism affording a dynamical explanation of magnetic phenomena is the theory of molecular vortices, published by Clerk Maxwell in the *Philosophical Magazine* for 1861 and 1862 (4th ser., vols. 21 and 23). The general results, stripped of all particular assumptions, will be found embodied in his great treatise on *Electricity and Magnetism*; but the following summary, taken from the original paper, may be of some interest.

1. Magnetoelectric phenomena are due to the existence of matter under certain conditions of motion or of pressure in every part of the magnetic field. The substance producing these effects may be a certain part of ordinary matter, or it may be an æther associated with matter.

2. The condition of any part of the field through which lines of magnetic force pass is one of unequal pressure in different directions, the pressure being least along the lines of force, so that they may be considered as lines of tension.

3. This inequality of pressure is due to vortices coaxial with the lines of force. The density of the revolving matter is proportional to the magnetic permeability of the medium. The direction of rotation is related to the direction of the line of force; and the velocity at the circumference of the vortex is proportional to the resultant magnetic force.

4. The vortices are separated from each other by a single layer of round particles; so that a system of cells is formed, the partitions being layers of these particles, and the substance of each cell being capable of rotating as a vortex.

5. The particles forming the layer are in rolling contact with both the vortices which they separate, but do not rub against each other. They are perfectly free to roll between the vortices and so to change their place, provided they keep within one *complete molecule* of the substance; but in passing from one molecule to another they experience resistance and generate irregular motions which constitute heat. These particles play the part of electricity. Their motion of translation constitutes an electric current; their rotation serves to transmit the motion of the vortices from one part of the field to another; the tangential pressures thus called into play constitute electromotive force; and the elastic yielding of the connecting particles constitutes electric displacement.

Maxwell deduces without difficulty all the principal electrical and magnetic phenomena from this theory; and he points out that its general conclusions have a value which does not depend upon the somewhat intricate kinematical arrangements supposed to exist in the magnetic medium. The theory certainly affords us a most instructive dynamical picture of the phenomena of electricity and magnetism; and it remains, so far as we know, the only successful attempt of its kind. (G. CH.)

MAGNETISM, Animal. The terms *animal magnetism*, *electro-biology*, *mesmerism*, *clairvoyance*, *odylic* or *odic force*, and *hypnotism* have been used to designate peculiar nervous conditions in which the body and mind of an individual were supposed to be influenced by a mysterious force emanating from another person. With the exception of *mesmerism*, a name given to the phenomena in honour of one of their earliest investigators, F. A. Mesmer, each of these terms implies a theory. Thus the phenomena of *animal magnetism* were supposed to be due to some kind of magnetic force or influence peculiar to living beings and analogous to the action of a magnet upon steel or certain metals; *electro-biology*, a more modern term, introduced in 1850 by two American lecturers, referred the phenomena to the action of electrical currents generated in the living body, and capable of influencing electrically the bodies of others; *clairvoyance* implied a power of mental vision or of mental hearing, or of a mental production of other sensations, by which the individual became aware of events happening in another part of the world from where he was, or could tell of the existence of objects which could not affect at the time any of his bodily senses; *odylic force* was a term given to a force of a mysterious character by which all the phenomena of animal magnetism might be accounted for; and *hypnotism*, from ὕπνος, sleep, was a name applied to a condition artificially produced in which the person was apparently asleep and yet acted in obedience to the will of the operator as regards both motion and sensation.

History.—It was natural that the apparent power of influencing the bodies and minds of others should attract much attention and be eagerly sought after for purposes of gain, or from a love of the marvellous, or for the cure of diseases. Hence we find that, whilst not a few have investigated these phenomena in a scientific spirit, more have done so as quacks and charlatans who have thrown discredit on a department of the physiology of man of the deepest interest. Recently, however, as will be shown in this article, physiologists and physicians have set about investigating the subject in such a manner as to bring it into the domain of exact science, and to dispel the idea that the phenomena are due either to any occult force or to supernatural agency. It would appear that in all ages diseases were alleged to be affected by the touch of the hand of certain persons, who were supposed to communicate a healing virtue to the sufferer. It is also known that among the Chaldæans, the Babylonians, the Persians, the Hindus, the Egyptians, the Greeks, and the Romans many of the priests effected cures, or threw people into deep sleeps in the shades of the temples, during which the sleeper sometimes had prophetic dreams, and that they otherwise produced effects like those now referred to animal magnetism. Such influences were held to be supernatural, and no doubt they gave power to the priesthood. In the middle of the 17th century there appeared in England several persons who said they had the power of curing diseases by stroking with the hand. Notable amongst these was Valentine Greatrakes, of Affane, in the county of Waterford, Ireland, who was born in February 1628, and who attracted great attention in England by his supposed power of curing the king's evil, or scrofula. Many of the most distinguished scientific and theological men of the day, such as Robert Boyle and R. Cudworth, witnessed and attested the cures supposed to be effected by Greatrakes, and thousands of sufferers crowded to him from all parts of the kingdom (see Colquhoun's *History of Magic*, &c., vol. ii. p. 146).

Phenomena of a marvellous kind, more especially such as imply a mysterious or supernatural power exercised by one person over another, not only attract attention, but take so firm a hold on the imagination that belief in them breaks out now and again with all the intensity of an epidemic. Thus since the time of Greatrakes, at short intervals, men have arisen who have led the public captive at their will. About the middle of the 18th century John Joseph Gassner, a Roman Catholic priest in Swabia, took up the notion that the majority of diseases arose from demoniacal possession, and could only be cured by exorcism. His method was undoubtedly similar to that followed by Mesmer and others, and he had an extraordinary influence over the nervous systems of his patients. Gassner, however, believed his power to be altogether supernatural and connected with religion.

Friedrich (or Franz) Anton Mesmer was born at Weil, near the point at which the Rhine leaves the Lake of Constance, on May 23, 1733. He studied medicine at Vienna under the eminent masters of that day, Van Swieten and De Haen, took a degree, and commenced practice. Interested in astrology, he imagined that the stars exerted an influence on beings living on the earth. He identified the supposed force first with electricity, and then with magnetism; and it was but a short step to suppose that stroking diseased bodies with magnets might effect a cure. He published his first work (*De Planetarum Influxu*) in 1766. Ten years later, on meeting with Gassner in Switzerland, he observed that the priest effected cures without the use of magnets, by manipulation alone. This led Mesmer to discard the magnets, and to suppose that some kind of occult force resided in himself by which he could influence others. He held that this force permeated the universe, and more especially affected the nervous systems of men. He removed to Paris in 1778, and in a short time the French capital was thrown into a state of great excitement by the marvellous effects of mesmerism. Mesmer soon made many converts; controversies arose; he excited the indignation of the medical faculty of Paris, who stigmatized him as a charlatan; still the people crowded to him. He refused an offer of 20,000 francs from the Government for the disclosure of his secret, but it is asserted that he really told all he knew privately to any one for 100 louis. He received private rewards of large sums of money. Appreciating the effect of mysterious surroundings on the imaginations of his patients, he had his consulting apartments dimly lighted and hung with mirrors; strains of soft music occasionally broke the profound silence; odours were wafted through the room; and the patients sat round a kind of vat in which various chemical ingredients were concocted or simmered over a fire. Holding each others' hands, or joined by cords, the patients sat in expectancy, and then Mesmer, clothed in the dress of a magician, glided amongst them, affecting this one by a touch, another by a look, and making "passes" with his hand towards a third. The effects were various, but all were held to be salutary. Nervous ladies became hysterical or fainted; some men became convulsed, or were seized with palpitations of the heart or other bodily disturbances. The Government appointed a commission of physicians and members of the Academy of Sciences to investigate these phenomena; Franklin and Baillie were members of this commission, and drew up an elaborate report admitting many of the facts, but contesting Mesmer's theory that there was an agent called animal magnetism, and attributing the effects to physiological causes. Mesmer himself was undoubtedly a mystic; and, although the excitement of the time led him to indulge in mummery and sensational effects, he was honest in the belief that the phenomena produced were real, and called for further investigation. For a time, however, animal magnetism fell into disrepute; it became a system of downright jugglery, and Mesmer himself was denounced as a shallow empiric and impostor. He withdrew from Paris, and died at Meersburg in Switzerland on 5th March 1815. He left many disciples, the most distinguished of whom was the Marquis de Puysegur. This nobleman revolutionized the art of mesmerism by showing that many of the phenomena might be produced by gentle manipulation causing sleep, and without the mysterious surroundings and violent means resorted to by Mesmer. The gentler method was followed successfully by Deleuze, Bertrand, Georget, Rostan, and Foissac in France, and by Dr John Elliotson in England up to about 1830.

In 1845 considerable attention was drawn to the announcement by Baron von Reichenbach of a so-called new "imponderable" or "influence" developed by certain crystals, magnets, the human body, associated with heat, chemical action, or electricity, and existing throughout the universe, to which he gave the name of *odyl.* Persons sensitive to odyl saw luminous phenomena near the poles of magnets, or even around the hands or heads of certain persons in whose bodies the force was supposed to be concentrated. In Britain an impetus was given to this view of the subject by the translation in 1850 of Reichenbach's *Researches on Magnetism, &c., in relation to Vital Force*, by Dr Gregory, professor of chemistry in the university of Edinburgh. These *Researches* show many of the phenomena to be of the same nature as those described previously by Mesmer, and even long before Mesmer's time by Swedenborg. The idea that some such force exists has been a favourite speculation of scientific men having a mental bias to mysticism, and it makes its appearance not unfrequently.

The next great step in the investigation of these phenomena was made by James Braid, a surgeon in Manchester, who in 1841 began the study of the pretensions of animal magnetism or mesmerism, in his own words, as a "complete sceptic" regarding all the phenomena. This led him to the discovery that he could artificially produce "a peculiar condition of the nervous system, induced by a fixed and abstracted attention of the mental and visual eye on one object, not of an exciting nature." To this condition he gave the name of *neuro-hypnotism* (from νεῦρον, nerve, ὕπνος, sleep); for the sake of brevity, *neuro* was suppressed, and the term hypnotism came into general use. Braid read a paper at a meeting of the British Association in Manchester on 29th June 1842, entitled *Practical Essay on the Curative Agency of Neuro-Hypnotism*; and his work *Neurypnology, or the Rationale of Nervous Sleep considered in relation with Animal Magnetism, illustrated by numerous cases of its successful application in the relief and cure of disease*, was published in 1843. It is necessary to point this out, as certain recent Continental writers have obtained many of Braid's results by following his methods, and have not adequately recognized the value of the work done by him forty years ago. Braid was undoubtedly the first to investigate the subject in a scientific way, and to attempt to give a physiological explanation. In this he was much aided by the physiologist Herbert Mayo, and also by Dr William B. Carpenter,—the latter being the first to recognize the value of Braid's researches as bearing on the theory of the reflex action of the ganglia at the base of the brain and of the cerebrum itself, with which Carpenter's own name is associated.

Recently the subject has been reinvestigated by Professor Weinhold of Chemnitz, and more particularly by Dr. Rudolf Heidenhain, professor of physiology in the university of Breslau, who has published a small but interesting work on animal magnetism. In this work Heidenhain attempts to explain most of the phenomena by the physiological doctrine of inhibitory nervous action, as will be shown hereafter.

Phenomena and Physiological Explanation.—The usual method of inducing the mesmeric or hypnotic state is to cause the person operated on to stare fixedly at a faceted or glittering piece of glass held at from 8 to 15 inches from the eyes, in such a position above the forehead as will strain the eyes and eyelids. The operator may stand behind the patient, and he will observe that the pupils are at first contracted from the effort of accommodation of each eye for near vision on the object; in a short time the pupils begin to relax, and then the operator makes a few "passes" over the face without touching it. The eyelids then close; or the operator may gently close them with the tips of the fingers, at the same time very gently stroking the cheeks. Often a vibratory motion of the eyelids may be observed when they are closed, or there may be slight spasm of the eyelids. The eyes may afterwards become widely opened. The patient is now in a sleep-like condition, and the limbs often remain in almost any position in which the operator may place them, as in a cataleptic condition. At the same time the patient may now be caused to make movements in obedience to the commands of the operator, and to act according to ideas suggested to him. Thus, he may eat a raw onion with gusto, apparently under the impression that it is an apple; he may make wry faces on drinking a glass of water when told that what he is taking is castor oil; he may ride on a chair or stool as in a horse race; he may fight with imaginary enemies, or show tokens of affection to imaginary friends; in short, all kinds of actions, even of a ridiculous and a degrading nature, may be done by the patient at the command of the operator. Another class of phenomena consists in the production of stiffness or rigidity of certain muscles or groups of muscles, or even of the whole body. For example, on stroking the fore arm it may become rigid in the prone or supine condition; the knee may be strongly bent, with the muscles in a state of spasm; the muscles of the trunk may become so rigid as to allow the body to rest like a log, head and heels on two chairs, so stiff and rigid as to bear the weight of the operator sitting upon it; or various cataleptic conditions may be induced and as readily removed by a few passes of the hand. Many disorders of sensation have been observed, such as defective colour perception, the hearing of special sounds which have no objective existence, or deafness to certain tones, or perverted sensations, such as tingling, prickling, rubbing, &c., referred to the skin. The patient may remain in this condition for an hour or more, and may then be roused by holding him for a few minutes and blowing gently into the eyes. Usually the patient has a vague recollection, like that of a disturbed dream, but sometimes there is an acute remembrance of all that has happened, and even a feeling of pain at having been compelled to do ridiculous actions. Certain persons are more readily hypnotized than others, and it has been observed that, once the condition has been successfully induced, it can be more easily induced a second time, a third time more easily than a second, and so on until the patient may be so pliant to the will of the operator that a fixed look, or a wave of the hand, may throw him at once into the condition. Such are the general facts in artificially induced hypnotism, and they belong to the same class as those referred to animal magnetism, electro-biological effects, odylic influences, &c., according to the whim or theory of the operator.

It is not surprising that such phenomena have been the cause of much wonder and the basis of many superstitions. Some have supposed that they were supernatural, others that they indicated the existence of a specific force exerted by the experimenter upon the passive subject. Many operators have no doubt believed they possessed such a force; such a belief would not affect the success of their experiments except to make them more likely to be successful, as the operator would readily comply with all the conditions; but most of these phenomena can be explained physiologically, and those which cannot be so accounted for will remain hidden until we get further light on the physiology of the nervous system.

The symptoms of the hypnotic state, as shown by Heidenhain, may be grouped under four heads:—(1) those referable to conditions of the sensorium or portion of the brain which receives nervous impulses, resulting in movements of a reflex and imitative character; (2) insensibility to pain, and various forms of perverted sensation; (3) increased irritability of the portion of the nervous system devoted to reflex actions; and (4) states of the nervous centres controlling the movements of the eye, the accommodation of the eye to objects at various distances, and the movements of respiration, &c.

1. *The State of the Sensorium.*—By the sensorium is meant that portion of the nervous system which receives impulses from the nerves coming from the organs of sense, such as those from the eye, ear, nose, tongue, and skin. Each of these nerves brings its message to a portion of the central nervous system in intimate connexion with the rest of the nervous system. This message may possibly arouse nervous actions associated with consciousness, or it may not; or the nervous actions of consciousness may be so transient as to leave a faint impress on the memory, so that it can be revived only if no great interval has elapsed since the impression was made on the sense organ. If, however, the impression be vivid, then it may be revived long afterwards. This impression may be consciously perceived, and then any apparent effect may end; but it may set up a set of actions, resulting in motion, which are apparently of a reflex character. Thus, suppose a person in the dark; light is suddenly brought before the eye; this affects the retina, and through the changes in it the optic nerve and central organ; there may be consciousness or there may not; if the person be wide awake he will see the light; if he be asleep he will not see it, at all events he will give no indication of seeing it; on awaking, he may have a recollection of a dream in which light has a place, or his memory may be blank; but nevertheless the light will cause the pupil of the eye to contract by reflex action without his consciousness; and perhaps, also, without consciousness, the sleeping person may make an effort to avoid the light, as has been noticed in the case of somnambulists.

Now, when a patient has been thrown into a weak hypnotic state, there may be a vivid recollection on awaking of all that happened during the apparent sleep. This implies, of course, that conscious sensory perceptions took place during the condition. Memory depends on the direction of the attention to sensations. If the effort of attention be strong, the recollection will probably be vivid, and the converse is true. But this does not preclude the supposition that sensory perceptions may come and go, like the shadows of clouds on a landscape, without any attempts at fixing them, and consequently with no recollection following their occurrence. The sensory perceptions may have existed for so short a time as to leave no impress behind. This may explain how it is that in the deeper forms of hypnotism there is either no recollection of what occurred or the recollection can only be aroused by hints and leading questions. Attention is necessary, therefore, to form a conscious idea arising out of a sensation.

It is generally admitted by physiologists that the cerebral hemispheres are the seat of the higher mental operations, such as attention, &c., although the interdependence of these hemispheres with the lower sensory ganglia, which receive all sensory impressions in the first instance, and with motor ganglia, which are, in like manner, the starting-points of motor impulses, is not understood. The one portion of the nervous system may work without the other. Thus, during free cerebral activity we pay little attention to what we see or hear, and consequently we remember nothing. A man in a reverie may have many impressions of sight or of hearing of which he has been really unconscious. On the other hand, the cerebral apparatus may be so attuned with the recipient portion that if the latter receives a message the former sympathetically responds. For example, a mother sound asleep is disturbed by the slightest cry of her child, although loud sounds of other kinds may not awake her.

It would appear then that impressions on the senses and the consciousness of impressions are two separate states which may occur in a manner independently; that is to say, there may be purely sensory operations, in which consciousness is not involved, or there may be the conscious repetition of old impressions, or what is called memory. Now it is a law of nervous action that processes which at first are always of a conscious kind may by repetition become so habitual as to be performed without consciousness. Thus a child learns to perform a piece of music on the pianoforte by conscious efforts, often of a painful kind; each note has to be recognized, and the appropriate muscular movements required for its production on the instrument executed with precision and delicacy; but by and by the music may be performed accurately even while the attention is directed to something else. In like manner, all movements which are the results of sensory impressions may become unconscious movements; the sensory impressions are at first paid attention to; but as they become habitual the mind becomes less and less engaged in the process, until the movements resulting from them are practically unconscious. A familiar illustration is that of a man in deep reverie walking along a street. Immersed in thought, he pays little or no attention to passers by; as his eyes are open, their images, or those of adjacent objects, must affect his visual apparatus, but they arouse no conscious impression, and still those impressions, evanescent as they are, are sufficient to excite the appropriate movements of locomotion. These movements are in all respects like voluntary movements, but they are not really voluntary, showing that, by the machinery of the nervous system, movements like voluntary movements may be executed without volition. It is important to observe, however, that these movements are the result of sensory impressions. A man in the deepest reverie, with his eyes blindfolded, could not execute the requisite movements; and when we see the blind walking in the streets, they afford no contradiction to this view, as their minds are busily engaged in noticing another set of sensory impressions derived from the sense of touch, muscular movement, and hearing, a set of impressions of the greatest importance to them, although of little importance comparatively to ordinary people, who are guided chiefly by visual impressions.

A person in a state of hypnotism may be regarded as in a condition in which the part of the nervous apparatus associated with conscious perception is thrown out of gear, without preventing the kind of movements which would result were it really in action. Impressions are made on the sensory organs; the sensory nerves convey the impression to a part of the brain; in the deepest condition of hypnotism these impressions may not arouse any consciousness, but the result may be the kind of movement which would naturally follow supposing the person had been conscious. The movements made by the hypnotic are chiefly those of an imitative kind. It has often been noticed that the mere suggestion of the movement may not be enough to excite it; to secure success, the movement must be made before the eyes of the person. For example, it is a common part of the exhibition of such persons for the operator to clench his fist; the patient at once clenches his; the operator blows his nose; the patient does likewise; but if the operator performs these actions behind the back of his patient the chances are that the patient will not repeat the movements.

The condition seems to be one in which the sensory impression leads to no conscious perception and to no voluntary movement, but is quite sufficient to arouse those nervous and muscular mechanisms which lead to unconscious imitation. The patient is in a sense an automaton played upon by the operator through the medium of the patient's sensory organs. It is important to observe that in deep hypnotism the patient has no idea corresponding to the movements he makes in obedience to the example of the operator. For example, suppose he is swallowing a glass of water and the operator tells him it is castor oil, at the same time making the requisite grimaces, the patient will imitate these grimaces without having any idea either of water or of castor oil. The grimaces are purely imitative, without any connexion with the idea which would naturally excite them. This is the case only with those deeply hypnotized. In some cases, however, the hypnotism is so deep as to resemble coma, and in these there is no trace of any sensory impressions or of movements. In cases where the hypnotism is slight, there may be a curious mixture of effects. Here the patient may be partially conscious of the requests made to him, and of the imitative movements executed before his eyes; to some extent he may resist the commands of the operator, he may feel he is being fooled, and yet he may perform many ridiculous actions; and when he awakes he may have a vivid recollection of the events in which he participated. A hypnotized person, in fact, is in a state similar to that of the somnambulist, who acts the movements of a disturbed dream. There are many degrees of the sleeping state, from the profound condition resembling coma to that of the light sleeper who starts with every sound. In some sleeps there are dreams in which the sleeper is so occupied with the phantoms of thought as to pay no attention to external impressions, unless these be sufficiently powerful to awake him, whilst there are other sleeps in which the boundary between the conscious reception of new impressions and the reproduction of old ones is so thin as to permit of a blending of the two. In this kind of sleep, a spoken word, a familiar touch, the suggestion of something in keeping with the thoughts of the dreamer, are sufficient to change the current of the dream, and even to excite movements. When the ideas of the dreamer cause movements corresponding to these ideas, then the dreamer becomes a somnambulist. He acts the dream; according to the depth of the semi-conscious state will be his capacity for responding to external impressions. Some somnambulists respond to external suggestions readily, others do not; and in all there is almost invariably no recollection of the state. Artificial hypnotism is a condition of the same kind, though usually not so profound.

The question now arises as to how this artificial state may be induced. In one awake and active, all sensory impressions as a rule are quick, evanescent, and constantly renewed. New successions of images and thoughts pass rapidly before the mind during walking, working, eating, or in the leisure hours of social life; but none last so long as to cause fatigue of any particular part of the body. By and by there is a general feeling of fatigue, and then sleep is needed to restore exhausted nature. But if the attention be fixed on one set of sensory impressions, fatigue is much sooner experienced than if the impressions are various in kind and degree. Thus one or two hours spent at a picture gallery or at a concert, if the attention be devoted to the impressions on the eye or ear, usually cause fatigue. It would appear that the method of exciting hypnotism by causing the patient to gaze at a bit of glass or a bright button depends in the first place on the feeling of fatigue induced. At first there is a dazzling feeling; then the eyes become moist; images become blurred and indistinct, and seem to swim in the field of vision; the field of vision becomes unsteady, and just about this period ideas do not pass in the mind in orderly sequence, but irregularly, as in the few minutes immediately before passing into sleep. At this stage also the pupils become widely dilated, and the eyeballs become more prominent than usual. The innervation of the iris must be understood, so as to appreciate the physiological meaning of these changes. The muscular structure of the iris is supplied by two nerves, the third cranial nerve and the sympathetic nerve. If the third nerve be cut the pupil dilates; if the distal end of the nerve be irritated the pupil contracts. On the other hand, if the sympathetic nerve be cut the pupil contracts, whilst if the distal end be irritated the pupil dilates. These experimental facts show that the radiating fibres of the iris which dilate the pupil are under the control of the sympathetic nerve, whilst the circular fibres which contract the pupil are supplied by the third. Further it can be shown that the corpora quadrigemina, two ganglionic masses in the brain, are the reflex centres for the regulation of these movements. The optic nerve from the retina supplies the sensory stimulus which causes the pupil to contract. Thus, suppose light to be brought before the eye while the pupil is dilated; the retina is affected, a stimulus is sent to the corpora quadrigemina along the fibres of the optic nerve, and from the corpora quadrigemina a nervous influence passes along the fibres of the third nerve to the circular fibres of the iris, causing the pupil to contract. It is also very probable that the corpora quadrigemina act as reflex centres for nervous impulses regulating the calibre of the blood-vessels of the eye, the vaso-motor nerves. If we apply these facts to the case of a hypnotized person, we find that (1) the pupil of a hypnotized person contracts energetically when light falls upon the eye, showing that the reflex mechanism is still intact; (2) just before the hypnotic state is induced the pupil dilates, indicating feeble nervous impulses passing along the third from the corpora quadrigemina; (3) at first, the eyeballs seem to sink in, but when hypnotism is complete they project in a manner similar to what has been observed in an animal when the arteries supplying the head have been compressed so as to make the brain anæmic or bloodless; and (4) the ophthalmoscope has not shown any change in the calibre of the blood-vessels of the retina in the hypnotic state. From a consideration of these facts and inferences Heidenhain was at first inclined to believe that hypnotism might be due to a reflex influence on the vessels of the brain, causing them to contract so as to permit the passage of only a small quantity of blood, and make the brain anæmic. This view, however, had to be abandoned, as the faces of hypnotized persons are usually red, and not pale, as they would be were the arterioles contracted. Further, Heidenhain performed a crucial experiment by giving to his brother nitrite of amyl, which causes dilatation of the vessels by vaso-motor paralysis, when he still found hypnotism could be readily induced, showing that the state was not caused by deficient blood supply.

Heidenhain has advanced another and more probable hypothesis. During the past twenty years a new mode of nervous action, known as inhibitory action, has been discovered by physiologists. A good example is supplied by the innervation of the heart. This organ has nervous ganglia in its substance by which its rhythmic contractions are maintained. Further it is supplied by the vagus or pneumogastric nerve and by the sympathetic. Section of the vagus is followed by quickening of the heart's action, and stimulation of the lower end causes slowing and, if the stimulation be strong enough, stoppage of the heart, not, however, in a tetanic state (which would be the case if the fibres of the vagus acted directly on the muscular structure of the heart, as a motor nerve), but in a state of complete relaxation or diastole. Opposite results follow section and stimulation of the sympathetic fibres. It has been clearly made out that the terminal fibres of both nerves do not act on muscular fibres but on ganglion cells, those of the vagus "inhibiting" or restraining, whilst those of the sympathetic "accelerate" the action of the cells. Inhibition is now known to play an important part in all nervous actions, and it would seem that any powerful impression in a sensory nerve may inhibit or restrain motion. This is strikingly seen in some of the lower animals. A ligature applied loosely round the thigh of a frog whilst it lies on its back apparently deprives it of all power of motion. The weak sensory stimulation in this case seems to stop voluntary motion. Pressure on the internal organs of such animals as the rabbit, although gentle, sometimes causes paralysis of the lower or hinder limbs. Again, it has been ascertained that, whilst the spinal cord is the chief reflex centre, the reflex activity can be inhibited by impulses transmitted to it from portions of the cerebral hemispheres which are in a state of high activity. It would appear then that, if we suppose one set of sensory or recipient cells in the brain to be brought into a state of exalted irritability by the preliminary operations of hypnotism, the result might be inhibition of the parts devoted to voluntary movement. In like manner, the activity of sensory nerve cells may become inhibited. Thus stimulation of a certain cutaneous area, say the arm, by a mustard plaster, has been found to lower the sensibility of the corresponding portion of skin on the opposite arm. The theory then offered is that "the cause of the phenomena of hypnotism lies in the inhibition of the activity of the ganglion-cells of the cerebral cortex, . . . the inhibition being brought about by gentle prolonged stimulation of the sensory nerves of the face, or of the auditory or optic nerve."

According to this view, the portion of the brain devoted to voluntary movements is as it were thrown out of gear, and the movements that follow, in the hypnotic state, are involuntary, and depend on impressions made on the senses of the patient. To understand how this is possible, we must now consider shortly some of the views presently held as to the action of the brain. The researches of Hitzig, Fritsch, Ferrier, Hughlings Jackson, and many others indicate that certain movements initiated as a consequence of perception, and of the ideas thereby called forth, are due to nervous actions in the grey matter in certain areas on the surface of the cerebral hemispheres, and that there is another class of movements which do not require the agency of the cortex of the brain, but depend on the activity of deeper centres. These deeper centres are the optic thalami, which receive sensory impressions from all parts of the skin; the corpora quadrigemina, which receive luminous impressions from the retina; and the corpora striata, which are the motor centres whence emanate influences passing to the various groups of muscles. No doubt other sensory centres exist for hearing, taste, and smell, but these have not been clearly ascertained. In the case of conscious and voluntary movements carried out as the result of external impressions, the excitation would pass first to the thalami optici (tactile) or corpora quadrigemina (visual), thence to the cerebral hemispheres, where ideas would be called forth and volitional impulses generated; these would then be transmitted downwards through the corpora striata (motor) to the crura cerebri and spinal cord, and from thence to special groups of muscles, thus causing specific movements. Suppose now that the portions of cerebral hemispheres connected with ideation and volition were thrown out of gear, and that a similar sensory impression was made on the person; again the path of nervous impulses would be to the thalami optici (tactile) or corpora quadrigemina (visual), and from thence directly through corpora striata (motor) to crura cerebri and spinal cord, then passing out to muscles, and causing movements as precise as those in the first instance, and apparently of the same character. The difference between the two operations, however, would be this:—in the first there would be movements following perception, ideation, and volition; in the second the same class of movements would be effected by an automatic mechanism without any of the psychical operations above alluded to. This theory has the merit of simplicity, and is in accordance with most of the facts. The chief difficulty in the way of accepting it is to understand why, if hypnotism be so induced, it is not induced much oftener. One would suppose that, if gazing at a coin and having a few passes made with the hand were sufficient to bring about physiological changes of such importance, men would be oftener hypnotized in daily life than they are. But it is to be remembered that attention is seldom fixed on one object so long as in the experiment of producing hypnotism. The first occasion the experiment is made, even with so-called susceptible persons, the time occupied may be from 10 to 20 minutes, and during all that time the attention is on the strain, and feelings of fatigue are excited in the way above described. Again it is well known that sudden and strong sensory impressions often paralyse voluntary action for a time, even in ordinary life, and what is called "presence of mind" really means that power of self-control which prevents the bodily energies being paralysed by strong sensory impressions. A carriage bearing down on a nervous lady in a crowded street may deprive her of all power of movement, or she may automatically run here or there in obedience to the shouts of the bystanders; but one with coolness can thread her way among the vehicles without fear or trouble.

A hypnotized person is therefore to be regarded as an automaton. "To cause him to move his arm, the image of a moving arm must pass over his retina, or an unconscious sensation of motion must be induced through passive movement of his arm."

2. *Insensibility to Pain.*—It has often been noticed that in the mesmerized or hypnotized person there may be complete insensibility to pain, so that deep pricks with a needle are not felt. During deep hypnotism a pin may be run into the hand without pain, but pain will be felt on awaking, and pulling out the pin in the waking state will cause acute pain. It would appear that certain nerves may convey tactile sensibility whilst others convey only painful impressions, and in certain forms of paralysis the patient may have tactile sensibility without pain, or the reverse. In hysterical women, as has been shown by Charcot and others, disorders of sensibility of this kind are not uncommon, indicating changes in the nervous centres.

3. *Increased Reflex Spasm of Muscles.*—One of the most striking phenomena of the hypnotic state is the ease with which certain voluntary muscles may be rendered stiff. For example, if the operator stroke the skin over the biceps muscle in the upper arm, the limb will be at once powerfully flexed, and the biceps can be felt stiff and rigid. To understand the physiological explanation offered of this

phenomenon it will be necessary shortly to describe the mechanism of reflex acts. If a sensory nerve be irritated at its periphery, say in the skin, a nervous impulse is transmitted to a central nervous organ, such as the spinal cord, and through the agency of nerve cells in this organ impulses are then transmitted by motor nerves to muscles, causing movements, without any operation of the will. Thus a particle of food getting into the larynx irritates sensory nerves of the vagus, and there is a reflex spasm of various muscles of expiration, causing a violent cough. That such reflex acts not only can occur without the will, but in spite of it, is shown by the want of control over a sneeze when the nostril is irritated by snuff. Now these reflex centres in the cord are partially under the control of higher centres in the brain. If the agency of the latter be removed, the activity of the cord-centres is increased, and reflex actions are more easily induced. This we have assumed to be the state of the hypnotic. If a portion of his skin be stroked, first one muscle, say the one immediately under the skin stroked, will become stiff, then in obedience to a law regulating reflex actions,—namely, that they tend to become diffused according to the strength and duration of the stimulus,—other muscles become rigid, and so on until the whole trunk becomes cataleptic. This phenomenon is so well described by Heidenhain that we quote as follows (pp. 23, 24):—

"With slight increase of reflex irritability, those muscles alone contract which lie immediately under the area of skin which has been stroked. In this condition it is easy to bring single muscles and groups of muscles into isolated action, and thus demonstrate their special motor function. Stroking the ball of the thumb causes adduction of the thumb (towards the palm). Stimulating the skin over the sterno-mastoid causes the head to assume the well-known oblique position which it has when one has got a "stiff neck"; stroking the skin at one corner of the mouth leads to distortion of the mouth on that side, owing to the contraction of the muscles inserted there. When the irritability is somewhat more increased, we are able, by continuous irritation of a defined group of skin, to set in activity neighbouring and distant groups of muscle, according to the degree of irritation. Thus, when I gently stroke the ball of the thumb, only the flexors and the adductors of this member are set in activity. If I stroke somewhat harder, the forearm muscles, especially the flexors of the fingers, contract. Our patient can, however, still bend and stretch his arm at the elbow, the upper arm muscles being still unaffected. Through further increase of the irritation, the latter too and the shoulder muscles are thrown into spasm, so that the whole limb appears immovably fixed. But the highest degree of reflex irritability is not yet attained. Mr A. Heidenhain sits quietly here on a chair. I now once stroke the ball of his left thumb. Please observe the exact succession in which the spasm slowly spreads from one part of the body to the other. You will see the following muscle groups successively affected, some seconds intervening in the passage from one group to another:—left thumb, left hand, left forearm, left upper arm and shoulder, right shoulder and arm, right forearm, right hand, left leg, left thigh, right thigh, right leg, muscles of mastication, muscles of the neck. But now I must put an end to it. I strike forcibly the left arm, and the rigor at once disappears. Instant relaxation of the whole body occurs also when I forcibly extend a finger of the clenched fist. Probably the reflex excitement would extend still farther, but I naturally consider it out of the question to try whether the muscles of respiration would become affected. It is easily understood that such experiments require the greatest caution, and may be very seldom carried out."

This condition of the muscles is exactly like that in catalepsy, a peculiar nervous disease; and hypnotism may be regarded as an artificial catalepsy.

4. *Other Peculiar Nervous Phenomena of the Hypnotic State.*—The changes in the eyes have been already alluded to. The pupils dilate, the eyelids open widely, and the eyeballs protrude. Occasionally the upper eyelid droops, so that the eyelids seem closed. It has often been asserted that clairvoyants see with the eyelids closed, but they are really partially open. The movements of respiration are often quickened from 16 to 30 or 35 per minute, indicating stimulation of the respiratory centres in the medulla oblongata. Sometimes the flow of saliva is increased. Hallucinations of sense may occur, though they are rare. One man in the hypnotic state experienced a strong odour of violets.

There is a class of phenomena referred to the hypnotic state of a very doubtful character, inasmuch as we have to depend entirely on the statements of the person operated on, and no objective tests can be employed. Such, for example, are various disturbances of sensation, hearing with the pit of the stomach more acutely than when the sound is made in the usual ways towards the ear, and the application of the hand of the operator to the body giving rise to profound sleep or dreams, induced dreaming, &c. Again it is asserted by Heidenhain and Grützner (*Breslauer Aerztl. Zeitsch.*, No. 4, 28th February 1880) that unilateral hypnosis is possible. Thus stroking the left forehead and temple caused immobility of the right arm and leg.

"Stroking on both sides causes catalepsy of all four limbs; no facial paralysis or aphasia. Unilateral stroking causes crossed catalepsy and facial paralysis, accompanied when on the left by aphasia. If in addition to unilateral stroking, and this being still maintained, the other side be stroked, then the same result is brought about as if both sides had been stroked from the beginning. . . . Measurement of the volume of the arm by means of Mosso's volumeter [an instrument for estimating the bulk of the limb by displacement of water and movements of a recording lever] proves that in the cataleptic arm the quantity of blood (in consequence of the vascular contraction) sinks enormously, whilst it simultaneously rises in the other arm. When the catalepsy is gone by, the quantity of blood in the cataleptic arm increases, whilst in the other arm it sinks" (Heidenhain, p. 91).

Charcot has pointed out that in certain kinds of hysteria in women there are remarkable unilateral disturbances or perversions of sensory impressions of colour. Phenomena of the same kind have been observed by Cohn, Heidenhain, and others in hypnotized persons. Thus A. Heidenhain became completely colour blind in the eye of the cataleptic side. All colours appeared grey in different degrees of brightness, from a dirty dark grey to a clear silver grey.

"If one eye be treated with atropin, whilst the effect of the latter is making its appearance, the phenomena of colour blindness are changed as follows:—red and green still appear as different shades of grey; blue and yellow, on the other hand, do not appear grey. They appear differently in the different stages of atropin action:—*first stage*, yellow appears grey, with a glimmer of blue; *second stage*, yellow appears pure blue; *third stage*, yellow appears blue with a slight tinge of yellow, somewhat as in the so-called struggle of the fields of vision,—yellow is seen, as it were, through a blue mist; *fourth stage*, yellow appears mostly yellow, with a tinge of blue. When blue is tried, the corresponding result is obtained; that is, at last blue with a slight yellow tinge is seen. During the action of atropin the sensation of yellow or blue passes from grey through the contrast colour to the right colour, whilst red and green only appear as different shades of grey" (Heidenhain, p. 95).

These facts are interesting as showing perverted sensation in the particular individual affected, but they throw no light on the condition of hypnotism.

It is evident then that animal magnetism or hypnotism is a peculiar physiological condition excited by perverted action of certain parts of the cerebral nervous organs, and that it is not caused by any occult force emanating from the operator. Whilst all the phenomena cannot be accounted for, owing to the imperfect knowledge we possess of the functions of the brain and cord, enough has been stated to show that just in proportion as our knowledge has increased has it been possible to give a rational explanation of some of the phenomena. It is also clear that the perverted condition of the nervous apparatus in hypnotism is of a serious character, and therefore that these experiments should not be performed by ignorant empirics for the sake of gain, or with the view of causing amusement. Nervous persons may be seriously injured by being subjected to such experiments, more especially if they undergo them repeatedly; and it should be illegal to have public exhibitions of the kind alluded to. The medical profession has always been rightly jealous of the employment of hypnotism in the treatment of disease, both from fear of the effects of such operations on the nervous systems of excitable people, and because such practice is in the border land of quackery and of imposture. Still in the hands of skilful men there is no reason why the proper employment of a method influencing the nervous system so powerfully as hypnotism should not be the means of relieving pain or of remedying disease.

Literature.—A very complete bibliography will be found appended to the article "Mesmérisme," *Dictionnaire Encyclopédique des Sciences Médicales* (deuxième série, 1873). In addition, see Braid, *Neurypnology*, London, 1843; Elliotson, *Human Physiology*, London, 1840; Colquhoun, *History of Magic, Witchcraft, and Animal Magnetism*, London, 1851; Mayo, *Letters on the Truths contained in Popular Superstitions, with an Account of Mesmerism*, Edinburgh, 1851; Scoresby, *Zoistic Magnetism*, London, 1849; Hughes Bennett, *Lecture on the Mesmeric Mania of* 1851, Edinburgh, 1851; Reichenbach, *Researches in Magnetism, Electricity, Heat, Light, Crystallization, and Chemical Attraction, in their relation to Vital Force* (translated by Dr Gregory, London, 1850; in this volume the doctrine of odylic force is set forth); Andrew Buchanan, *Darlingism, misnamed Electro-Biology*, London, 1851; Alexander Wood, *What is Mesmerism?* Edinburgh, 1851; Weinhold, *Seven Lectures on Somnambulism*, translated by J. C. Colquhoun, Edinburgh, 1845; John Forbes, *Illustrations of Modern Mesmerism*, London, 1845. See also Maudsley, *Physiology of Mind*, London, 1876; and especially Carpenter, *Mental Physiology*, p. 547 *sq.* (where the author attempts to account for many of the phenomena by the theory of a dominant idea influencing and governing all other mental operations), London, 1874. The most recent account of these phenomena will be found in Heidenhain's *Animal Magnetism*, translated by Wooldridge, with a preface by G. J. Romanes, London, 1880. For a short and clear account of hysteria as bearing on the phenomena of hypnotism, see Rosenthal, *Clinical Treatise on the Diseases of the Nervous System*, vol. ii. p. 29 *sq.*, London, 1881. (J. G. M.)

MAGNOLIA, L., the typical genus of the order *Magnoliaceæ*, named from Pierre Magnol, professor of medicine and botany at Montpellier. It contains about fourteen species, distributed in Japan, China, and the Himalayas, as well as in North America and Mexico (De Candolle, *Prod.*, i. 79; Bentham and Hooker, *Gen. Pl.*, i. 18; A. Gray, *Gen. Ill.*, xxiii., xxiv.).

Magnolias are trees or shrubs with evergreen or deciduous foliage. They bear conspicuous, and often large, fragrant, white, rose, or purple flowers. The sepals are three in number, the petals six to twelve, in two to four series of three in each, the stamens and carpels being numerous. The fruit consists of a number of follicles which dehisce (contrary to the rule) along the outer edge to allow the scarlet or brown seeds to escape, but which are suspended by a long slender thread. Of the Old-World species, the earliest in cultivation appears to have been *M. Yulan*, Desf. (*conspicua*, Salisb.), of China, of which the buds were preserved, as well as used medicinally and to season rice (Pickering, *Chron. Hist. of Pl.*, p. 600). It, together with *M. fuscata*, Andr., was transported to Europe in 1789 (Paxton's *Bot. Dic.*) and thence to North America, and is now cultivated in the middle States. Of the Japanese magnolias, *M. Kobus*, DC., and the purple-flowered *M. obovata*, Thim., were met with by Kaempfer in 1690. They were introduced into England in 1709 and 1804 respectively. The species *M. pumila*, Andr., the dwarf magnolia, from the mountains of Amboyna, is nearly evergreen, and bears deliciously scented flowers. It was introduced in 1786. The Indian species are three in number, *M. globosa*, H. f. et T., allied to *M. conspicua* of Japan; *M. sphenocarpa*, Roxb., and the most magnificent of all magnolias, *M. Campbellii*, H. f. et T., which forms a conspicuous feature in the scenery and vegetation of Darjiling. It was discovered by Dr Griffith in Bhutan. It is a large forest tree, abounding on the outer ranges of Sikkim, 80 feet high, and from 6 to 12 feet in girth. The flowers are 6 to 10 inches across, appearing before the leaves. They vary from white to a deep rose colour (Hook. fil., *Ill. Him. Pl.*, pls. iv. and v.).

The first of the American species brought to Europe (in 1688, by Banister) was *M. glauca*, L. It is found in low situations near the sea from Massachusetts to Louisiana, —more especially in New Jersey and Carolina. In 1712 Catesby visited Virginia and found *M. acuminata*, L., the so-called cucumber tree, from the resemblance of the young fruits to small cucumbers. It ranges from Pennsylvania to Carolina. The wood is yellow, and used for bowls; the flowers are rather small. It was introduced into England in 1736. He also found *M. umbrella*, Lam. (*tripetala*, L.), called the umbrella tree. The flowers are very large, white, and highly scented. It was brought to England in 1752. *M. pyramidata*, Bart., discovered by Bartram in 1773, is a native of the western parts of Carolina and Georgia. The most beautiful species of North America is *M. grandiflora*, L., discovered by Catesby in 1719 in South Carolina and Florida, and introduced into England in 1734. It grows a straight trunk 2 feet in diameter, and upwards of 70 feet high, bearing a profusion of large powerfully lemon-scented creamy-white flowers. In England it is customary to train it against a wall; and the original species is surpassed by the Exmouth varieties, which originated as seedlings at Exeter from the tree first raised in England by Sir John Colliton, and which flower much more freely than the parent plant. The remaining North-American species are *M. auriculata*, Lam., *M. macrophylla*, Michx., and *M. cordata*, Michx. The Mexican species is *M. mexicana*, DC. The tulip tree, *Liriodendron tulipifera*, L., frequently cultivated in England, is also a member of the same family. It is the sole species, and is a native of North America.

For a description of the principal species of magnolia under cultivation see Hemsley's *Handbook of Hardy Trees, &c.*, p. 24; Loudon's *Arboretum*, vol. i. p. 260.

MAGNUS, Heinrich Gustav (1802–1870), an eminent German chemist and physicist, was born at Berlin May 2, 1802. He early showed a strong scientific bias, which was well fostered and strengthened by his education. Six years of thorough study at Berlin university were supplemented by a year's course at Stockholm in Berzelius's laboratory (1828). After some time spent in Paris under Gay-Lussac and Thénard, Magnus settled at Berlin in 1831 as lecturer on technology and physics in the university. In 1834 he was elected extraordinary and in 1845 ordinary professor of these subjects. He died April 4, 1870. His numerous papers, which appeared chiefly in *Poggendorff's Annalen* and in the publications of the Berlin Academy of Sciences, cover a wide range of chemical and physical subjects. His first memoir, published in 1825, while he was yet a student, was a discussion of the spontaneous inflammability of finely divided iron, nickel, and cobalt. From 1827 to 1833 he was occupied mainly with chemical researches, which resulted in the discovery of sulphovinic, ethionic, and isethionic acids and their salts, and, in conjunction with Ammermüller, of periodic acid. The absorption of gases in blood (1837–45), the expansion of gases by heat (1841–44), the vapour pressures of water and various solutions (1844–54), thermo-electricity (1851), electrolysis (1856), induction of currents (1858–61), conduction of heat in gases (1860), and polarization of heat (1866–68) are some of the many subjects of which he treated. From 1861 onwards he devoted much attention to the still vexed question of diathermancy in gases and vapours, especially to the behaviour in this respect of dry and moist air, and to the thermal effects produced by the condensation of moisture on solid surfaces. Many of his papers were translated and published in the *Philosophical Magazine*.

MAGNUSSON, Arni (1663-1730), a scholar to whom we are largely indebted for the preservation of the old Icelandic literature, was born in the west of Iceland in 1663. In his youth he resided for a time at Hvamm, then the residence of his mother's father, Ketil the priest, who was a well-known copyist of manuscripts. In 1683 he came to Copenhagen, and was employed by Bartholinus at first as a copyist, and afterwards to investigate the monuments and ancient customs of Norway. In 1697 he was appointed secretary of the archives of the kingdom. Before this he had begun to collect Icelandic manuscripts, his earliest acquisition (*Hulda*) being in 1687. From that time he steadily persevered, but his great acquisitions were chiefly made in Iceland, whither he went in connexion with the royal survey in 1702-12. The old and important manuscripts were by that time falling into neglect, and it is more than probable that without Arni's intervention the greater part would have been lost to us. On his return from Iceland he was appointed professor of history and Danish antiquities in the university of Copenhagen. He is said never to have recovered the shock caused by the mischief done to his library by the great fire of Copenhagen in 1728. He himself had never the courage to ascertain exactly what he had lost; but it appeared afterwards that scarcely any MS. of real importance had perished. On his death on 6th January 1730, he bequeathed his property to the university of Copenhagen for the purpose chiefly of publishing Icelandic manuscripts (Arna-Magnæan Bequest). The first volume published under the bequest was *Njala*, which appeared in 1772, and was succeeded by a number of valuable publications of the same class. Arni left behind him no literary work of any consequence, and his notes and historical material were mostly destroyed in the conflagration. The signal service which he rendered to Icelandic literature lay in his judicious and extensive collection of the old manuscripts, and investigation of their history so far as attainable, at a time when they were rapidly being superseded and disappearing through neglect.

MAGO was one of the most common Carthaginian names, borne among others by the reputed founder of the military power of Carthage, and the Punic admiral in the war with the elder Dionysius (see Carthage). The most famous of the name was the youngest of the three sons of Hamilcar Barca. He accompanied his brother Hannibal on his expedition into Italy, and held important commands in the great victories of the first three years. After the battle of Cannæ he marched through southern Italy and sailed to Carthage to report the successes gained. He was about to return to Italy with strong reinforcements for Hannibal, when the Government ordered him to go to help his other brother, Hasdrubal, who was hard pressed in Spain. He maintained war there with varying success in concert with the two generals Hasdrubal, until, in 209 B.C., his brother marched into Italy to help Hannibal. Mago remained in Spain with the other Hasdrubal. In 207 he was defeated by M. Silanus, and in 206 the combined forces of Mago and Hasdrubal were scattered by Scipio in the decisive battle of Silpia. Mago maintained himself for a long time in Gades, but afterwards received orders to carry the war into Liguria. He wintered in the Balearic Isles, where the fine harbour Portus Magonis, Port Mahon, still bears his name. Early in 204 he landed in Liguria, where he maintained a desultory warfare till in 203 he was defeated in Cisalpine Gaul by the Roman forces. He received orders soon after to return to Carthage, but on the voyage home he died of wounds received in the battle.

The name of Mago—but which Mago is uncertain—is attached to a great work on agriculture which was brought to Rome and translated by order of the senate after the destruction of Carthage. The book was regarded as a standard authority, and is often referred to by later writers.

MAGPIE, or simply Pie (French, *Pie*), the prefix being the abbreviated form of a human name (Margaret[1]) applied as in so many other instances to familiar animals, as this bird once was throughout Great Britain, though of late years almost exterminated in many parts, and now nearly everywhere scarce. Its pilfering habits have led to this result, yet the injuries it causes are unquestionably exaggerated by common report; and in many countries of Europe it is still the tolerated or even the cherished neighbour of every farmer, as it formerly was in England if not in Scotland also. There is ample evidence[2] to prove that it did not exist in Ireland in 1617, when Fynes Morison[3] wrote his *Itinerary*, and that it had appeared there within a hundred years later, when Swift mentions its occurrences in his *Journal* to Stella, under date of 9th July 1711. It is now common enough in that country, and there is a widespread but of course unfounded belief that it was introduced by the English out of spite. It is a species that when not molested is extending its range, as Wolley ascertained in Lapland, where within the last century it has been gradually pushing its way along the coast and into the interior from one fishing-station or settler's house to the next, as the country has been peopled.

Since the persecution to which the Pie has been subjected in Great Britain, its habits have undoubtedly altered greatly in character. It is no longer the merry, saucy hanger-on of the homestead, as it was to writers of former days, who were constantly alluding to its disposition, but is become the suspicious thief, shunning the gaze of man, and knowing that danger may lurk in every bush. Hence opportunities of observing it fall to the lot of few, and most persons know it only as a curtailed captive in a wicker cage, where its vivacity and natural beauty are lessened or wholly lost. At large few European birds possess greater beauty, the pure white of its scapulars and inner web of the flight-feathers contrasting vividly with the deep glossy black on the rest of its body and wings, while its long tail is lustrous with green, bronze, and purple reflexions. The Pie's nest is a wonderfully ingenious structure, placed either in high trees or low bushes, and so massively built that it will stand for years. Its foundation consists of stout sticks, turf, and clay, wrought into a deep, hollow cup, plastered with earth, and lined with fibres; but around this is erected a firmly-interwoven, basket-like outwork of thorny sticks, forming a dome over the nest, and leaving but a single hole in the side for entrance and exit, so that the whole structure is rendered almost impregnable. Herein are laid from six to nine eggs, of a pale bluish-green freckled with brown and blotched with ash-colour. Superstition as to the appearance of the Pie still survives even among many educated persons, and there are several versions of a rhyming adage as to the various turns of luck which its presenting itself, either alone or in company with others, is supposed to betoken, for some of these versions contradict one another in details, though all agree in this that the sight of a single Pie unquestionably presages sorrow.

The Pie belongs to the same Family of birds as the Crow (vol. vi. p. 617), and is the *Corvus pica* of Linnæus, the *Pica caudata*, *P. melanoleuca*, or *P. rustica* of modern

[1] "Magot" and "Madge," with the same origin, are names frequently given in England to the Pie; while in France it is commonly known as *Margot*, if not termed, as it is in some districts, *Jaquette*.

[2] A compendious summary of this will be found in Yarrell's *British Birds*, ed. 4, ii. pp. 318-320.

[3] His predecessor Derricke, in 1578, said:—

"No Pies to plucke the Thatch from house,
are breed in Irishe grounde:
But worse then Pies, the same to burne,
a thousande maie be founde."

—*The Image of Irelande*, London, 1581.

ornithologists, who have recognized it as forming a distinct genus, but the number of species thereto belonging has been a fruitful source of discussion. Examples from the south of Spain differ slightly from those inhabiting the rest of Europe, and in some points more resemble the *P. mauritanica* of north-western Africa; but that species has a patch of bare skin of a fine blue colour behind the eye, and much shorter wings. No fewer than five species have been discriminated from various parts of Asia, extending to Japan; but only one of them, the *P. leucoptera* of Turkestan and Tibet, has of late been admitted as valid. In the west of North America, and in some of its islands, a Pie is found which extends to the upper valleys of the Missouri and the Yellowstone, and has long been thought entitled to specific distinction as *P. hudsonia*; but its claim thereto is now disallowed by some of the best ornithologists of the United States, and it can hardly be deemed even a geographical variety of the Old-World form. In California, however, there is a permanent race if not a good species, *P. nuttalli*, easily distinguishable by its yellow bill and the bare yellow skin round its eyes; and it is a curious fact that on two occasions in the year 1867 a bird apparently similar was observed in Great Britain (*Zoologist*, ser. 2, pp. 706, 1016). (A. N.)

MAHÁBALESHWAR, a hill station in Satára district, and the principal sanatarium in the Bombay presidency, India (17° 58′ N. lat., 73° 42′ E. long.), occupies the summit of a range of the Western Gháts, with a general elevation of 4500 feet above sea-level. It was established by Sir John Malcolm, the governor in Bombay in 1828, who obtained the site from the rájá of Satára in exchange for another patch of territory. The superior elevation of Mahábaleshwar renders it much cooler than Mátherán (2460 feet), but its heavy rainfall (about 240 inches) makes it almost uninhabitable during the rainy season. It forms the retreat usually during spring, and occasionally in autumn, of the governor of Bombay, the commander-in-chief of the Bombay army, and the chief officers of their establishments, and has the usual public buildings of a first-class sanatarium. The population was returned in 1872 at 2759.

MAHABHARATA. See SANSKRIT LITERATURE.

MAHÁNADI, or MAHANUDDY ("The Great River"), a river of India, rising in 20° 10′ N. lat., 82° E. long., 25 miles south of Ráipur town, in a wild mountainous region of the Central Provinces. At first an insignificant stream, it flows in a tortuous easterly course through the hills in a rocky bed until it reaches Dholpur in Orissa. From this point it rolls its unrestrained waters straight for the outermost line of the Eastern Gháts. This mountain line it pierces by a gorge about 40 miles in length, overlooked by hills, shaded by forests, deep and tranquil, and navigable at all seasons. It pours down upon the Orissa delta at Naráj, about 7 miles west of Cuttack town; and after traversing Cuttack district from west to east, and throwing off numerous branches (the Kátjuri, Paika, Birúpá, Chitartalá, &c.), it falls into the Bay of Bengal at False Point by several channels.

The Mahánadi has an estimated basin of 43,800 miles, and its rapid flow renders its maximum discharge in time of flood second to that of no other river in India. During unusually high floods 1,800,000 cubic feet of water pour every second through the Naráj gorge, one-half of which, uncontrolled by the elaborate embankments, pours over the delta, filling the swamps, inundating the rice-fields, and converting the plains into a boundless sea. In the dry weather the discharge of the Mahánadi dwindles to 1125 feet per second. Efforts have been made to husband and utilize the vast water supply thrown upon the Orissa delta during seasons of flood. Each of the three branches into which the parent stream splits at the delta head is regulated by a weir. Of the four canals which form the Orissa irrigation system, two take off from the Birúpá weir, and one, with its branch, from the Mahánadi weir. On the 31st December 1868 the Government took over the whole canal works from the East Indian Irrigation Company, at a cost of £941,368, since which time the gradual prosecution of the Orissa scheme to completion has been sanctioned. The canals thus taken over and since completed, or carried to an advanced stage of construction, are the High-Level Canal, the Kendrápárá Canal, the Táldandá Canal, and the Máchhgáon Canal, with their distributaries, designed to irrigate a total of 1,600,000 acres.

MAHANOY CITY, a post borough of the United States, in Mahanoy township, Schuylkill county, Pennsylvania, lies at a height of 1211 feet above the sea, 56 miles north-east of Harrisburg, with a station both on the Lehigh Valley and on the Philadelphia and Reading Railway. It was founded in 1859, and owes its existence to the great anthracite mines in the neighbourhood. Two public halls, a public library, two weekly newspapers, and the increase of its population from 5533 in 1870 to 7181 in 1880, betoken its prosperity.

MAHASEER, or MAHSEER (*Barbus mosal*), a kind of barbel, abundant in the rivers of India, especially in pools of the upper and more rapid streams where they issue from the mountainous part of the country. It is one of the largest species of the family of carps, attaining to a length of from 3 to 5 feet, and exceeding sometimes a weight of 70 lb. Its body is well-proportioned, rather elongate, and somewhat like that of the European barbel, but covered with very large scales, of which there are only twenty-five or twenty-seven placed along the lateral line; the dorsal fin is armed with a long and strong spine, and the mouth provided with four slender and short barbels. The lips are sometimes produced into fleshy lobes. To the fisherman in India the mahaseer affords the same kind of sport as the salmon in the British Isles, and it rivals that fish as regards size, strength, and activity. Its flesh is likewise much esteemed.

MAHDÍ, *i.e.*, "he who is guided aright," the third caliph of the house of 'Abbás (see MOHAMMEDAN EMPIRE). The name of Mahdí is also that which the Shí'ite Mohammedans give to their Messiah, the last of the Imáms of the house of 'Ali. It was under the name of al-Mahdí that Mokhtár proclaimed 'Ali's son Mohammed as the opponent of the caliph 'Abd al-Malik, and, according to Shahrastani, p. 111, the doctrine of the Mahdí, the hidden deliverer who is one day to appear and fill the oppressed world with righteousness, first arose in connexion with a wild notion that this Mohammed had not died but lived concealed at Mount Radwá, near Mecca, guarded by a lion and a panther. The hidden Imám of the common Shí'ites is, however, the twelfth Imám, Mohammed Abu'l-Kásim, who disappeared mysteriously 879 A.D. The belief in the appearance of the Mahdí readily lent itself to imposture. Of the many pretendants to this dignity known in all periods of Moslem history down to the present day[1] the most famous was the first caliph of the Fatimite dynasty in North Africa, 'Obaid-alláh al-Mahdí, who reigned 909–934 A.D. From him was named the capital of the dynasty, the once mighty city of Mahdíya, the port and entrepôt of Kairawán (see MOHAMMEDAN EMPIRE under the reign of Moktadir). Another great historical movement, headed by a leader who proclaimed himself the Mahdí (Mohammed ibn Abdallah ibn Túmrut), was that of the ALMOHADES (*q.v.*).

MAHÉ, a French settlement and town, in the Malabar district, Madras, India, is situated in 11° 41′ 50″ N. lat. and 75° 34′ 25″ E. long., to the south of the river Mahé, with an area of 1445 acres. It is the only French possession on the west coast of India, and is in charge of a *chef-de-service*, subordinate to the governor-general at Pondicherri. It is now a decaying place, with most of its chief buildings

[1] Thus there are at the present date (1882) three actual pretendants to the dignity of Mahdí, Sheikh Mohammed of Dongola in the Egyptian Súdán, the Sheikh El-Senúsí in Tripoli, and a third in the vilayet of Aídín.

picturesquely situated close to the river mouth. The population in 1871 was 8492. It contains a Román Catholic chapel, a school, and a British post-office; and a long wooden bridge maintained by the British Government gives access to the British territory beyond the river.

MAHI KANTHÁ, THE, a group of native states forming a political agency under the Government of Bombay, India, lying between 23° 14′ and 24° 28′ N. lat. and 72° 40′ and 74° 5′ E. long., with an area of about 4000 square miles, and an estimated population of 447,056. It is bounded on the N.E. by the Rájput states of Udáipur and Dunyarpur, on the S.E. by Rewa Kanthá, on the S. by Kaira district, and on the W. by the native states of Baroda and the Pálanpur agency. The Mahi Kanthá territory is divided among a number of chiefs, of whom the rájá of Edar is by far the most important. In May 1877 these chiefs were classified in seven divisions, according to their importance and the extent of their jurisdiction. There are two states of the second class, three of the third, nine of the fourth, nine of the fifth, fourteen of the sixth, and fourteen of the seventh class. The entire revenues amount to about £110,000.

MAHMÚD OF GHAZNI (971-1030), known also as Mahmúd, son of Subuktigín, was born October 2, 971. His fame rests chiefly on his successful wars, in particular his numerous invasions of India. His military capacity, inherited from his father, Nasír-ud-din Subuktigín, was strengthened by youthful experience in the field. Subuktigín, a Turki slave of Alptigín, governor of Khorásán under Abd' ul Malik Núh, king of the Sámáni dynasty of Bokhára, early brought himself to notice. He was raised to high office in the state by Alptigín's successor, Abú Isḥák, and in 366 A.H. (977 A.D.), by the choice of the nobles of Ghazni, he became their ruler. He soon began to make conquests in the neighbouring countries, and in these wars he was accompanied by his young son Mahmúd. On one occasion, when Mahmúd was fourteen years of age, his advice with respect to a military operation in the hills was approved and adopted by the generals. Before he had reached even this age he encountered in two expeditions under his father the Indian forces of Jaipál, raja of Lahore, whom Subuktigín defeated on the Punjab frontier.

In 994 Mahmúd was made governor of Khorásán, with the title of *Saif-ed-daulah* ("Sword of the State"), by the Sámáni emir, Abd' ul Malik Núh. Two years later, his father Subuktigín died in the neighbourhood of Balkh, having declared his second son, Ismáil, who was then with him, to be his successor. As soon as Ismáil had assumed the sovereignty at Balkh, Mahmúd, who was at Nishápúr, addressed him in friendly terms, proposing a division of the territories held by their father at his death. Ismáil rejected the proposal, and was immediately attacked by Mahmúd and defeated. Retreating to Ghazni, he there yielded, and was imprisoned, and Mahmúd obtained undisputed power as sovereign of Khorásán and Ghazni (997).

The Ghaznavi dynasty is sometimes reckoned by native historians to commence with Subuktigín's conquest of Búst and Kusdár (978). But Subuktigín, throughout his reign at Ghazni, continued to acknowledge the Sámáni suzerainty, as did Mahmúd also, until the time, soon after succeeding to his father's dominions, when he received from the caliph of Baghdad, Al Kádir Billah, a *khilat* or robe of honour, with a letter recognizing his sovereignty, and conferring on him the titles *Yamín-ed-daulah* ("Right Hand of the State"), and *Amín-ul-Millat* ("Guardian of the Faith"). From this time it is the name of the caliph that is inscribed on Mahmúd's coins, together with his own new titles.[1] Previously the name of the Sámáni sovereign, Mansúr bin Núh (successor of Abd' ul Malik) is given along with his own former title, Saif-ed-daulah Mahmúd. The earliest of those of the new form gives his name Mahmúd bin Subuktigín. Thereafter his father's name does not appear on his coins, but it is inscribed again on his tomb.

The new honours received from the caliph gave fresh impulse to Mahmúd's zeal on behalf of Islam, and he resolved on an annual expedition against the idolaters of India. He could not quite carry out this intention, but a great part of his reign was occupied with his Indian campaigns. In 1000 A.D. he started on the first of these expeditions, but it does not appear that on this occasion he went farther than the hill country near Peshawar. The hostile attitude of Khalaf ibn Ahmad, governor of Sístán, called Mahmúd to that province for a short time. He was appeased by Khalaf's speedy submission, together with the gift of a large sum of money, and further, it is said, by his subdued opponent addressing him as *sultán*, a title new at that time, and by which Mahmúd continued to be called, though he did not formally adopt it, or stamp it on his coins. Four years later Khalaf, incurring Mahmúd's displeasure again, was imprisoned, and his property confiscated.

Mahmúd's army first crossed the Indus in 1001, opposed by Jaipál, raja of Lahore. Jaipál was defeated, and Mahmúd, after his return from this expedition, is said to have taken the distinctive appellation of *Ghází* ("Valiant for the Faith"), but he is rarely so called.[2] On the next occasion (1005) Mahmúd advanced as far as Bhera on the Jhelum, when his adversary Anang-pál, son and successor of Jaipál, fled to Kashmir. The following year saw Mahmúd at Multan. When he was in the Punjab at this time, he heard of the invasion of Khorásán by Ilak Khan, ruler of Transoxiana (whose daughter Mahmúd had married). After a rapid march back from India, Mahmúd repelled the invaders. Ilak Khan, having retreated across the Oxus, returned with reinforcements, and took up a position a few miles from Balkh, where he was signally defeated by Mahmúd.

Two years had elapsed since his last visit to India when Mahmúd again entered the Punjab (1008), this time for the express purpose of chastising Séwah Pál, who, having become a Mussulman, and been left by Mahmúd in charge of Multan, had relapsed to Hinduism. The Indian campaign of the following year (1009) was a notable one. Near the Indus Mahmúd was opposed again by Anang-pál, supported by powerful rajas from other parts of India. After a severe fight, Anang-pál's elephants were so terror-struck by the fire-missiles flung amongst them by the invaders that they turned and fled, the whole army retreating in confusion and leaving Mahmúd master of the field.[3] Mahmúd, after this victory, pushed on through the Punjab to Nagar-kót (Kangra), and carried off much spoil from the Hindu temples to enrich his treasury at Ghazni. In 1011 Mahmúd, after a short campaign against the Afghans under Mohammed ibn Súr in the hill country of Ghor, marched again into the Punjab. The next time (1014) he advanced to Thanésar, another noted stronghold

[1] Even before succeeding his father he struck coins in his own name at Nisábúr (Nishápúr), when he was governor of Khorásán.

[2] The emperor Bábar gives him this title (1526). He himself was the second Mohammedan king who had conquered India, the first being Sultan Mahmúd Ghází.

[3] The terms in which native historians have described the effects of these missiles—not unlike the account given by De Joinville of the Greek fire which caused such consternation to the army of St Louis something more than two centuries later—gave rise at one time to the idea that something like modern artillery was meant. The fact that naphtha is distinctly mentioned as having been used by Mahmúd on a later occasion, and the knowledge that petroleum is found at several places on both sides of the Indus near the scene of the fight with Anang-pál, furnish the most probable explanation.

of Hinduism, between the Sutlej and the Jumna. Having now found his way across all the Punjab rivers, he was induced on two subsequent occasions to go still farther. But first he designed an invasion of Kashmir (1015), which was not carried out, as his progress was checked at Lóh-kót, a strong hill-fort in the north-west of the Punjab. And then before undertaking his longer inroad into Hindustan he had to march north into Khwárizm (Khiva) against his brother-in-law Mamún, who had refused to acknowledge Mahmúd's supremacy. The result was as usual, and Mahmúd, having committed Khwárizm to a new ruler, one of Mamún's chief officers, returned to his capital. Then in 1018, with a very large force, he proceeded to India again, extending his inroad this time to the great Hindu cities of Mathra on the Jumna and Kanauj on the Ganges. To the glory of reducing the one and receiving the submission of the other he added, as was his custom, the further satisfaction of carrying back great stores of plunder from both to his own country. Three years later he went into India again, marching over nearly the same ground, to the support, this time, of the raja of Kanauj, who, having made friendship with the Mohammedan invader on his last visit, had been attacked by the raja of Kalinjar. But Mahmúd found he had not yet sufficiently subdued the idolaters nearer his own border, between Cabul and the Indus, and the campaign of the year 413 (1022 A.D.) was directed against them, and reached no farther than Peshawar. Another march into India the following year was made direct to Gwalior.

The next expedition (1025) is the most famous of all. The point to which it was directed was the temple of Somnath on the coast of the Gujerát peninsula. After an arduous journey by Multan, and through part of Rajputana, he reached Somnath, and met with a very vigorous but fruitless resistance on the part of the Hindus of Gujerát. Moslem feet soon trod the courts of the great temple. The chief object of worship it contained was broken up, and the fragments kept to be carried off to Ghazni. The story is often told of the hollow figure, cleft by Mahmúd's battle-axe, pouring out great store of costly jewels and gold. But the idol in this Sivite temple was only a tall block or pillar of hewn stone, of a familiar kind. The popular legend is a very natural one. Mahmúd, it was well known, made Hindu temples yield up their most precious things. He was a determined idol-breaker. And the stone block in this temple was enriched with a crown of jewels, the gifts of wealthy worshippers. These data readily give the Somnath exploit its more dramatic form. For the more recent story of the Somnath gates see GHAZNI, vol. x. p. 560.

After the successes at Somnath, Mahmúd remained some months in India before returning to Ghazni. Then in 1026 he crossed the Indus once more into the Punjab. His brilliant military career closed with an expedition to Persia, in the third year after this, his last visit to India. The Indian campaigns of Mahmúd and his father were almost, but not altogether, unvarying successes. The Moslem historians touch lightly on reverses. And, although the annals of Rajputana tell how Subuktigín was defeated by one raja of Ajmír and Mahmúd by his successor, the course of events which followed shows how little these and other reverses affected the invader's progress. Mahmúd's failure at Ajmír, when the brave raja Bisal-deo obliged him to raise the siege but was himself slain, was when the Moslem army was on its way to Somnath. Yet Mahmúd's Indian conquests, striking and important in themselves, were, after all, in great measure barren, except to the Ghazni treasury. Mahmúd retained no possessions in India under his own direct rule. But after the repeated defeats, by his father and himself, of two successive rajas of Lahore, the conqueror assumed the right of nominating the governors of the Punjab as a dependency of Ghazni, a right which continued to be exercised by seven of his successors. And for a time, in the reign of Masáúd II. (1098–1114), Lahore was the place of residence of the Ghaznavi sovereign. Certain silver coins of Mahmúd's reign bear inscriptions in Sanskrit characters as well as Arabic, betokening sovereignty in India. They are dated 418 and 419 A.H., the two years immediately following his last visit to the Punjab, and are struck at a place called by his name, Mahmúdpúr, supposed to be Lahore. There are also copper coins struck at Lahore (now retaining legible dates) bearing Mahmúd's name and the caliph's, in Arabic characters only. Mahmúd's coins are numerous and historically important. They were issued from mints at Nisábúr, Hirát, Ghaznah (a common alternative form of the name), Farwán, and Balkh, besides Mahmúdpúr and Lahore, just mentioned. Mahmúd died at Ghazni in 1030, the year following his expedition to Persia, in the sixty-first year of his age and thirty-third of his reign.

Mahmúd stands conspicuous for his military ardour, his ambition, strong will, perseverance, watchfulness, and energy, combined with great courage and unbounded self-reliance. But his tastes were not exclusively military. His love of literature brought men of learning to Ghazni. His acquaintance with Moslem theology was recognized by the learned doctors. Mahmúd is accused of avarice. It has been said that the prospect of booty was as strong a motive power in these repeated invasions of India as his love of military glory and desire to shine as a champion of the faith. An illustration commonly given of his want of liberality is his treatment of the poet Firdousi. Delighted with a portion which was read to him of the poet's metrical romance narrating the deeds of the early kings of Persia, Mahmúd presented him with a thousand *dínárs*, one for each couplet, with an implied promise, or at least expectation on the part of the author, of payment on the same scale for the rest. The completed *Sháh Námah*, presented in due course, contained no less than sixty thousand couplets, and the reward this time was given in *dirhems* instead of *dínárs*. Firdousi retired in disgust to his native place, Tús, and satirized the sultan. At a later time, it is said, Mahmúd sent him the larger sum; but the poet died just before it arrived. Mahmúd had the general reputation of giving liberal and discerning encouragement to learned and literary men. Among those who took up their abode at Ghazni in his time, the most noted, after Firdousi, were the poet Unsuri of Balkh, whose compositions were largely devoted to the praise of the sultan Mahmúd; another poet, Asjudi of Merv, who wrote a grand ode on the Somnath expedition; El Utbi of Khorásán, author of the *Kitáb-i-Yamíni*, a history of Subuktigín and of Mahmúd (to about the middle of his reign); and the accomplished historian, Abú Rihán, called Al Biríni, author of the *Taríkh ul Hind*, as well as of a number of scientific works. The sultan established large educational institutions at Ghazni.

Mahmúd also found time to bestow attention on other arts of peace, and did not neglect his capital and the country around. Large sums were devoted to important public works. The building of the great Jama Masjid of Ghazni is described by El Utbi in admiring terms. A splendid palace which Mahmúd built induced wealthy nobles at Ghazni to erect great mansions for themselves. Two fine towers or minarets at Ghazni, 140 feet in height, bearing Mahmúd's name (though one is said to have been built by his successor) have attracted the attention of travellers. They are of a remarkable construction, the lower part with a zigzag or star-shaped outline, the upper part round, like the third and fourth stories of the Kutb Minar at Delhi, built two centuries later. Like the Kutb pillar too, they are isolated, and may, like it, have served as the minarets for a separate mosque or mosques. The dam called the *Band-i-Sultán*, which Mahmúd constructed to form an artificial lake for irrigation, appears to have been a really great and substantial work.

Mahmúd, besides being marked by small-pox, had an ill-favoured countenance, and knew it. Courtiers met his allusions to his personal appearance by the familiar complimentary remarks about inward graces more than counterbalancing outward defects. He himself is said to have observed, after looking in the glass, that he saw so many faults in himself he was ready to excuse those of others.

Mahmúd's tomb stands in a garden a short distance from Ghazni, called *Rauzat-i-Sultán* ("the sultan's tomb," or "garden"—the word means both). On one of the minarets is an inscription which gives all his titles. On the massive tombstone within the building he is named more briefly Nizám-ed-din Abu'l Kásim Mahmúd, son of Subuktigín. He was succeeded by his son Muhammad, who was soon displaced by his more vigorous brother Musáúd.

The principal histories of Mahmúd's reign are—*Kitáb-i-Yamíní* (Utbi); *Taríkh-us-Subuktigín* (Baihaki); *Tabakát i Násiri* (Minháj el-Siráj); *Rauzat-us-Safa* (Mir Khond); *Habib-us-Siyar* (Khondamir). See Elliot, *History of India*; Elphinstone, *History of India*; *Jour. Roy. As. Soc.*, vols. ix., xvii.; *Jour. As. Soc. Bengal*, vol. xii.; *As. Res.*, vols. xvi., xvii. (R. M'L*.)

MAHOGANY, a familiar dark-coloured wood largely used for household furniture, and supplied by a large tree indigenous to Central America and the Antilles. It was originally received from Jamaica; 521,300 feet were exported from that island in 1753. *Swietenia Mahogani*, L., is the sole species of the genus of the order *Meliaceæ* (Benth. and Hook., *Gen. Pl.*, i. 338). It bears imparipinnate leaves, like those of the ash, and panicles of small pentamerous flowers with 10 monadelphous stamens. The fruit is a pear-shaped woody capsule, with many winged seeds. The dark-coloured bark has been considered a febrifuge, and the seeds were used by the ancient Aztecs with oil for a cosmetic, but the most valuable product is the timber, first noticed by the carpenter on board Sir Walter Raleigh's ship in 1595, for its great beauty, hardness, and durability. Dr Gibbons brought it into notice as well adapted for furniture in the early part of the 18th century, and its use as a cabinet wood was first practically established by a cabinetmaker named Wollaston, who was employed by Gibbons to work up some mahogany brought to England by his brother. Since its introduction no wood has been more generally used for cabinet-making purposes, and none possesses like advantages of combined soundness, large size, uniform grain, durability, beauty of colour, and richness of figure.

In the trade the wood is generally classified under the two heads of Spanish Mahogany and Honduras Mahogany or Baywood. The former comprises the rich, solid, and heavy varieties, susceptible of a high degree of polish, and frequently showing rich wavy figuring, in which case the wood is enormously enhanced in value, and used only in the form of veneers. Under the name of Honduras mahogany or baywood is embraced the light open-grained and plain classes of mahogany, uniform in colour, and valuable for the ease with which they can be worked for an endless variety of uses where sound straight timber, free from all tendency to warp, is required. By importers, however, several classes of mahogany are recognized. The original Spanish mahogany is the produce of the island of San Domingo, whence only small supplies now come, and these mostly in logs of not more than 8 to 10 feet in length by 12 or 13 inches in thickness. Cuba mahogany is in richness of figure and other properties little inferior for ornamental purposes to San Domingo wood, while it possesses the advantage of being obtained in logs up to 35 feet long and 2 feet square in cross section. Squared Honduras logs are sometimes obtained 40 feet long and 2 feet thick, and, although the wood is generally plain in character, richly figured logs are occasionally got. It appears that the Honduras wood obtained in the north, near the Mexican boundary, is much more rich, dense, and solid than the soft swamp-grown timber, which commonly goes by the name of Honduras or baywood. In Mexico the mahogany tree attains its greatest dimensions, and thence logs squared to 40 and even 48 inches are sometimes obtained, whilst the common size of logs varies between 15 inches and 3 feet. The Mexican wood is cut into lengths of from 18 to 30 feet, for convenience of shipment, and, while in general the wood is plain and somewhat soft in the core, the produce of some provinces, Tabasco especially, is firm, solid, and not unfrequently richly figured. Occasionally the wood which has been floated in tropical seas is found to be badly "wormed" or attacked by marine borers. The cutting, squaring, and shipment of the wood in the tropical regions which are its home are conducted under circumstances of great difficulty. The tree has recently been introduced into the north-west provinces of India under very favourable conditions, and its successful cultivation there is likely to prove a matter of considerable economic importance. Mahogany is included among the second-class woods in Lloyd's list for ship-building purposes; it is a good deal employed in internal joiner work both in ships and houses; it is a favourite turnery wood, and is equally preferred by wood-carvers. The imports of mahogany into the United Kingdom during 1881 were 42,412 tons, of an estimated value of £390,418, fully one-half of which came from Mexico.

MAHOMET. See MOHAMMED.

MAHONY, FRANCIS (1804-1866), "Father Prout," Roman Catholic priest, scholar, journalist, song-writer, and humorist, was born at Cork of a respectable middle-class family in 1804. His classical education was chiefly obtained at a Jesuit college at Amiens, and after studying theology at Paris he received clerical ordination, and served in Switzerland and Ireland. He then came to London, and officiated for some time in the chapel of the Bavarian Legation. While there he fell in with the coterie of wits and men of letters who were then engaged on *Fraser's Magazine*, and, soon finding their society and pursuits more congenial to him than those of the Romish priesthood, he, about 1834, began to contribute his celebrated Prout papers to *Fraser*. These consist principally of translations of well-known English songs into Latin, Greek, French, and Italian verse, which he humorously represents as being the true originals from which the English authors had merely plagiarized them. The songs of France, and those of modern and ancient Italy (including among the latter many most felicitous renderings of Horace's odes), were then given in English versions, accompanied by a running commentary full of queer humour and often acute criticism. Prout's translations have been universally admired for the extraordinary command which they display of the various languages into which his renderings are made, and for their spirit and freedom both of thought and expression. Perhaps, however, the wonder at his polyglott learning has led to less attention than is deserved being paid to the remarkable excellence of many of his English versions of French and Latin odes. In happy abandon they are often almost unequalled, and most of them have all the unfettered character of original compositions. It might have been expected that with his great gift of poetical expression he would have left behind him more of what was exclusively his own. What he has given us in this line tends chiefly to show that with all his sarcastic and cynical wit his genius had also its tender, serious, and sentimental side. His "Bells of Shandon" have always been greatly admired; and "The Mistletoe," "The Redbreast of Aquitaine," "The Lady of Lee," and the "Legend of Arethusa" are not without a certain sweetness and beauty. In 1846 Mahony became "own correspondent" at Rome to the *Daily News*, and his letters from that capital gave very vivid pictures, and contain much valuable and interesting information, of the first years, so full of liberal promise, of the reign of Pius IX. The last twelve or fifteen years of his life were spent at Paris, from which he supplied the *Globe* with a series of piquant letters on the incidents of the day. His death took place in May 1866. Mahony was not less distinguished as a conversationalist than as a writer. He had great stores of very various knowledge, had seen much of the world, and had a quick power of repartee and no end of sharp cynical wit. It is difficult to suppose that he could ever have been in his true place as a priest of the Roman Catholic Church. Bohemian as he was, however, he never separated himself from it, or seems to have lost his attachment to it; and it is creditable to his character that, though living much among scorners and indifferentists, he would never suffer injurious reflexions either upon his church or upon Christianity to pass without sharp rebuke.

The *Reliques of Father Prout* were collected from *Fraser's Magazine* and published in two handsome volumes in 1836, a considerably enlarged edition appearing in 1860. A biographical notice of him by his friend Mr Sheehan was prefixed to the *Bentley Ballads*; and many additional details were given, with a considerable amount of his fugitive work contributed to the *Daily News* and the *Globe*, edited by Mr Blanchard Jerrold, in the *Final Reliques of Father Prout*, published in 1876.

MAHRATTAS. The Mahrattas inhabit that portion of India which is known by the ancient name of Mahârâshtra (Sanskrit for the great kingdom or region). This large tract, extending from the Arabian Sea on the west to the

Sâtpura mountains in the north, comprises a good part of western and central India, including the modern provinces of the Concan, Khandesh, Berar, the British Deccan, part of Nagpur, and about half the Nizam's Deccan. Its area amounts to about 120,000 square miles, and its population to about 12 millions of souls, or 100 to the square mile. The population has increased greatly in the 19th century under British rule; but there had been much decrease during the 17th and 18th centuries owing to war and devastation. Frightful depopulation occurred from the famine which was at its height in 1400 A.D., and was called the Dûrga Dévi or the goddess of destruction. Much mortality was also caused by famine between 1801 and 1803. There was probably a period of high prosperity during the first centuries of the Christian era, under a number of petty indigenous sovereigns, among whom these wide territories had become parcelled out before the first invasion of the Deccan by the Moslems about 1100.

The etymology of the word Mahratta (or Marhatta, as it is written in the vernacular) is uncertain. The name does not indicate a social caste, or a religious sect; it is not even tribal. It embraces the people of all races who dwell in the region of Mahàrâshtra, both high-caste and low-caste Hindus; it is applied, of course, to Hindus only. Thus there are Mahratta Brahmans, next Mahratta Kumbis or cultivators, and Mahratta Rajputs or warriors, though the latter have but a small infusion of real Rajput blood. The Mahrattas, then, are essentially Hindus in religion and in caste ordinances, not differing in these respects from the Hindus in other parts of India. They have a language of their own, called the Mahratti, a dialect of the Sanskrit, —a copious, flexible, and sonorous tongue.

But the Mahrattas have always been a separate nation or people, and still regard themselves as such, though nowadays they are almost all under British or Mohammedan jurisdiction; that is, they belong either to British India or to the Nizam's Dominions. A few states or principalities purely Mahratta,—such as Kolhapur and some lesser states clustering round it in the southern Deccan,—still survive, but they are under close supervision on the part of the British Government. There are indeed still three large native states nominally Mahratta, namely, that of Sindhia near the borders of Hindustan in the north, that of Holkar in Malwa in the heart of the Indian continent, and that of the gaekwar in Gujerat on the western coast. But in these states the prince, his relatives, and some of his ministers or employés only are Mahrattas; the nobility and the mass of the people are not Mahrattas at all, but belong to other sections of the Hindu race. These states then are not to be included in the Mahratta nation, though they have a share in the Mahratta history, and are concerned in the extraneous achievements of that people.

In general terms the Mahrattas, as above defined, may be described under two main heads, first the Brahmans, and secondly the humble or low-caste men. The Mahratta Brahmans possess, in an intense degree, the qualities of that famous caste, physical, intellectual, and moral. They have generally the lofty brow, the regular features, the spare upright figure, the calm aspect, the commanding gait, which might be expected in a race maintained in great purity yet upon a broad basis. In modern times they have proved themselves the most able and ambitious of all the Brahmans in the Indian empire. They are notably divided into two sections—the Concanast, coming from the Concan or littoral tract on the west coast below the Western Ghât mountains, and the Dèshast, coming from the uplands or Deccan, on the east of the mountains. Though there have been many distinguished Dèshasts, yet the most remarkable of all have been Concanasts. For instance, the pèshwas, or heads of the Mahratta confederation which at one time dominated nearly all India, were Concanast Brahmans. The birthplaces of these persons are still known, and to this day there are sequestered villages, nestling near the western base of the Ghâts, which are pointed to as being the ancestral homes of men who two centuries ago had political control over the Indian empire.

Apart from the Brahmans, the Mahrattas may be generally designated as Sùdras, or men of the humblest of the four great castes into which the Hindu race is divided. But, as indicated above, the upper classes among the Mahrattas claim to be Kshattriyas or Rajputs. They probably are aborigines fundamentally, with a mixture of what are now called the Scythian tribes, which at a very early time overran India. They have but a slight admixture of the Aryans, who victoriously immigrated from Central Asia and established the Hindu system.

These ordinary Mahrattas, who form the backbone of the nation, have plain features, an uncouth manner, a clownish aspect, short stature, a small but wiry frame. Their eyes, however, are bright and piercing, and under excitement will gleam with passion. Though not powerful physically as compared with the northern races of the Punjab and Oudh, they have much activity and an unsurpassed endurance. Born and bred in or near the Western Ghât mountains and the numerous tributary ranges, they have all the qualities of mountaineers. Among their native hills they have at all times evinced desperate courage. Away from the hills they do not display remarkable valour, except under the discipline which may be supplied by other races. For such organization they have never, of themselves, shown any aptitude. Under civilized authority, however, they are to be reckoned among the good soldiers of the empire. In recent times they enter military service less and less, betaking themselves mainly to cultivation and to the carrying business connected with agriculture. As husbandmen they are not remarkable; but as graziers, as cartmen, as labourers, they are excellent. As artisans they have seldom signalized themselves, save as armourers and clothweavers.

Those Mahrattas who dwell in the extreme west of Mahàrâshtra, within the main range of the Western Ghâts, and in the extreme north of Mahàrâshtra near the Sâtpura mountains, are blessed with unfailing rainfall and regular seasons. But those who dwell at a distance from these main ranges, or among the lower or subsidiary ranges, are troubled with variable moisture and uncertain seasons, frequently, too, with alternations of drought and of flood. Periodically they are afflicted by scarcity, and sometimes by severe famine. They have within the last half century largely extended their area of cultivation. Their industry, which is chiefly agricultural, has grown apace. Their tendency is undoubtedly to increase in numbers; and, despite occasional depopulation from disasters of season, they have increased considerably on the whole. But in some districts, owing to the famine of 1877, and the sickness which ensued when excessive rainfall followed the drought, the population has been stationary, while in others it has actually retrograded because epidemics and plagues of vermin were added to the misfortunes of season.

Among all the Mahrattas the land is usually held on the tenure technically known as "ryotwari." This tenure is now established under the British Government by surveying and assessing operations comprehended under the official term "settlement." It practically means peasant proprietorship. The proprietor, or ryot, is a cultivator also. His holding may be on the average 20 or 30 acres, divided into small fields. Of these fields he cultivates some, himself working at the plough, and his family weeding and cleaning the soil. He will also hire labour, and thus the farm-labourers become a considerable class. He pays to the Government direct the land tax, which is assessed on his holding for the long term of thirty years, so that he may have the benefit of his improvements. His property in the land is absolute; it descends according to the Hindu law of inheritance; it can be sold or otherwise transferred by private arrangement; it is pledged or mortgaged for debt, and money is largely borrowed on its security. It is liable to sale for default in regard to land revenue; and Government as a creditor has the first claim. Thus, as a peasant proprietary, the Mahrattas are in the best possible position, and have been so for many years since the completion of the British settlement. Their only fault is a disposition to live beyond their humble means. They have thus been of late years led into debt, which has produced disputes between them and the money-lenders, ending sometimes in agrarian disturbance.

In the Concan there are some superior proprietors termed Khotes. With this and perhaps some other exceptions, notably that of Nagpur, there are not in the Mahratta country many large landlords, nor many of the superior tenure-holders whose position relatively to that of the peasantry has caused much discussion in other parts of India. There are indeed many Mahratta chiefs still resident in the country, members of the aristocracy which formerly enjoyed much more wealth and power than at present. They are sometimes in the position of landlords, but often they are the assignees of the land revenue, which they are entitled under special grants to collect for themselves instead of for Government, paying merely a small sum to Government by way of quit-rent. Under them the cultivators are by British arrangements placed in the position of peasant proprietors. The village community has always existed as the social unit in the Mahratta territories, though with less cohesion among its members than in the village communities of Hindustan and the Punjab. The ancient offices pertaining to the village, as those of the headman (*patēl*), the village accountant, &c., are in working order throughout the Mahratta country.

The Mahratta peasantry possess manly fortitude under suffering and misfortune. Though patient and good-tempered in the main, they have a latent warmth of temper, and if oppressed beyond a certain endurable limit they would fiercely turn and rend their tormentors. Cruelty also is an element in their character. As a rule they are orderly and law-abiding, but traditions of plunder have been handed down to them from early times, and many of them retain the predatory instincts of their forefathers. The neighbourhood of dense forests, steep hill-sides, and fastnesses hard of access offers extraordinary facilities to plunderers for screening themselves and their booty. Thus gang robbery is apt to break out, gains head with rapidity, and is suppressed with difficulty. In time of peace it is kept under, but during war, or whenever the bands of civil order are loosened, it becomes a cause of anxiety and a source of danger. The women have frankness and strength of character; they work hard in the fields, and as a rule evince domestic virtue. Conjugal infidelity, however, is not unknown among them, and here, as elsewhere in India, leads to bloodshed.

The peasantry preserve a grave and quiet demeanour, but they have their humble ideas of gaiety, and hold their gatherings on occasions of births or marriages. They frequently beguile their toil with carols. They like the gossiping and bartering at the rural markets and in the larger fairs, which are sometimes held in strikingly picturesque localities. They are utterly superstitious, and will worship with hearty veneration any being or thing whose destructive agency they fear. They will even speak of the tiger with honorific titles. They are Hindus, but their Hinduism is held to be of a non-Aryan type. They are sincerely devout in religion, and feel an awe regarding "the holy Brahmans," holding the life and the person of a Brahman sacred, even though he be a criminal of the deepest dye. They of course regard the cow as equally sacred. There are two principal sects among the modern Hindus—those who follow Vishnu, and those who follow Siva. The Mahrattas generally follow Siva and his wife, a dread goddess known under many names. The Mahratta war-cry, "Hur Hur Mahadeo," which used to be heard above the din of battle urging the soldiers to onset with victorious *ēlan*, referred to Siva. All classes high and low are fond of the religious festivals, the principal of which, "the Dasserah," occurs in October, when the first harvest of the year has been secured and the second crops sown. This has always been held with the utmost pomp and magnificence at every centre of Mahratta wealth and power. The people frequently assemble in bowers and arbours constructed of leafy boughs to hear "kathas" recited. These recitations are partly religious, partly also romantic and quasi-historical. After them national resolves of just resistance or of aggressive ambition have often been formed.

Apart from the Mahratta Brahmans, as already mentioned, the Mahratta nobles and princes are not generally fine-looking men. Their appearance, notwithstanding jewellery and rich apparel, is still that of peasants. There certainly are some exceptions, but there is general truth in what was once said by a high authority to the effect that, while there will be something dignified in the humblest Râjpût, there will be something mean in the highest Mahratta. Bluff good-nature, a certain jocoseness, a humour pungent and ready, though somewhat coarse, a hot or even violent disposition, are characteristics of Mahratta chieftains. They usually show little aptitude for business or for sedentary pursuits; but, on the other hand, they are born equestrians and sportsmen. As a rule they are not moderate in living, and are not unfrequently addicted to intemperance. Instances of licentiousness and debauchery have always been found among them. They have generally sprung from a lowly origin, and they have been proud of this fact even after attaining greatness. For instance, three Mahratta chiefs, each of whom established a large kingdom—Sindhia, Holkar, and the gaekwar—declared the lowliness of their birth. Holkar was the descendant of a shepherd; Sindhia boasted of having begun life by keeping his master's slippers; and by his very title the gaekwar perpetuates the memory of his progenitor having tended the cow (gâe). Mahratta ladies and princesses have often taken a prominent part in public affairs and in dynastic intrigues; in some instances their conduct has been of the highest type, in others their influence has been exerted for evil.

Though they have produced some poetry, the Mahrattas have never done much for Oriental literature. Nor have they been distinguished in industrial art. Their architecture in wood, however, was excellent; and the teak forests of their country afforded the finest timber for building and for carving. They had also much skill in the construction of works for the supply of drinking water on a large scale, and for irrigation.

On the whole the Mahrattas will hardly be regarded by Europeans as being among the most interesting of the Indian races. The admirable *History of the Mahrattas*, by Captain Grant Duff (1826), may possibly awaken enthusiasm, as written under personal advantages and with a living knowledge which will never again be possessed by a historian of the later Mahratta times. At all events, a strange interest gathers itself around the Mahratta history.

In the first place the Mahratta country is for the most part strategically important as well as highly picturesque. Some parts of the Deccan are indeed almost irretrievably ugly. The stretches of low hill have long been disforested, and even laid bare of lesser vegetation, and the champaign tracts are treeless as far as the eye can reach. Still much of the Mahratta country lies in the bosom or near the skirts of mountains. The geological formations may be popularly described as consisting of trap, basalt, and indurated lava in magnificent layers. The black precipices, scarped for thousands of feet, and striped with marks of the layers, are superb. The summits, though generally flat with horizontal outlines, are often broken into towers and cones. The vapours from the Arabian Sea are propelled by the south-west monsoon against these mountain tops, and produce an excessive rainfall. Hence arise a luxuriant vegetation and the surprising spectacle (at certain seasons) of cascades tumbling down the perpendicular flanks of the mountains. The forests have suffered during ages from wasteful cutting; but of late years a system of conservancy has been established, and many great forests remain.

The mountains stand in the midst of a fertile and populous country; on both sides of them are rich valleys, cultivated plains, numerous villages, and large towns. Thus insurgents or warriors had here a complete military base, with sources whence supplies could be drawn, and strongholds for organizing power or for securing refuge. This hill country has been regarded by strategists as one of the strongest, in a military sense, to be found in India. It extends over nearly 500 miles from north to south, and has at least twenty fortresses which in uncivilized warfare were virtually impregnable if resolutely defended, and which, though of course unable to resist a scientific attack in these times, would yet prove difficult of approach. Several of these are surrounded with historic traditions. In former times there was no road worthy of the name across these mountains. No means of passage existed save steep rugged pathways for footmen and pack animals. Within the last generation the British Government has, in Oriental phrase, lifted up the veil of these mountains, piercing them with well-made roads and with railways. There are now seven of such roads, and two lines of railway open, a third being projected. Guns and troops as well as goods and produce can now be moved up and down these once impassable mountains.

It is the range of the Western Ghâts which enabled the Mahrattas to rise against their Mohammedan conquerors, to reassert their Hindu nationality against the whole power of the Mogul empire, and to establish in its place an empire of their own. It is often held that in India British conquest or annexation succeeded Mohammedan rule; and to a considerable extent this was the case. But, on the other hand, the principal power, the widest sovereignty, which the British overthrew in India was that of the Mahrattas.

During the earlier Moslem invasions in 1100 and in subsequent years, the Mahrattas do not seem to have made much resistance. They submitted to several Mohammedan kings under the changing circumstances of those times. They were despised by their conquerors, and were called "mountain rats" in derision. It was against the Mohammedan king of Bijapur in the Deccan that Sivaji, the hero of Mahratta history, first rebelled in 1657. Sivaji and his fighting officers were Mahrattas of humble caste, but his ministers were Mahratta Brahmans. When the Mogul empire absorbed that kingdom he defied the emperor. He imparted a self-reliant enthusiasm to his countrymen, formed them into an army, and organized them as a political community; his mountaineer infantry, though limited in numbers, proved desperately courageous; his cavalry was daring and ubiquitous. Having once overcome the Hindus in almost all parts of India, often after heroic resistance, the Moslems had not for centuries met with any noteworthy uprising. Sivaji, however, planned their expulsion, and before the end of his restless life made much progress in the execution of that design. The new Mahratta state which he founded was maintained under various vicissitudes after his death. Still Mahratta resistance, once aroused by him, was never extinguished, and the imperial resources were worn out by ceaseless though vain efforts to quell it. The great Mogul emperor's impoverished and enfeebled successor was fain to recognize the Mahratta state by a formal instrument. The Mahratta king, a descendant of Sivaji, was a *roi fainéant*, and the arrangement was negotiated by his Brahman minister, whose official designation was the pêshwa. The office of pêshwa then became hereditary in the minister's family, and grew in importance as the Mahratta kingdom rose, while the king sunk into the condition of a puppet. Thus the Mahratta power was consolidated throughout nearly the whole of Mahârâshtra under the Brahman pêshwa as virtual sovereign, with his capital at Poona, while the titular Mahratta raja or king had his court at the neighbouring city of Sattara. Despite his political importance, however, the raja was still venerated as the descendant of Sivaji.

Then several chiefs carved out principalities of their own from among the ruins of the Mogul empire. Thus Raghoji Bhônsla established himself in the tracts lying underneath the southern base of the Satpura range (namely, Nagpur and Berar), overran Orissa, and entered Bengal. Dammaji Gaekwar descended from the Western Ghâts upon the alluvial plains of Gujerat around Baroda; Takaji Holkar subdued the uplands of Malwa beyond the Vindhya range on the north bank of the Nerbudda; and Madhaji Sindhia obtained possession of large tracts immediately south of Agra and Delhi, marched into Hindustan, and became virtually the master of the Mogul emperor himself. Princes of Sivaji's own family founded a dominion at Tanjore, in the rich delta of the Kaveri south of Madras.

But these principalities, though really independent respecting internal administration, and making war or peace with their neighbours according to opportunity, yet owned allegiance to the pêshwa at Poona as the head of the Mahratta body. On state occasions heads of principalities would visit Poona by way of acknowledging the superior position of the pêshwa. On the other hand the pêshwa was careful to obtain the sanction of his nominal sovereign at Sattara to every important act of state. Thus a confederation was formed of which the Brahman pêshwa or head was at Poona, governing the adjacent territories, while the members, belonging to the lower castes of Mahrattas, were scattered throughout the continent of India. Such was the Mahratta empire which supplanted the Mogul empire. The Mahratta power grew and prospered till it embraced all India with certain exceptions. Its culminating point was reached about 1750, or about a century after Sivaji first rebelled against his Mohammedan sovereign.

Its armies drew soldiers from all parts of India. The infantry was not of good quality; but its cavalry was really an enormous force, numbering fully a hundred thousand in all. The horsemen were splendidly audacious in riding for long distances into the heart of a hostile country, without support, striking some terrific blows, and then returning rapidly beyond reach of pursuit. They could truly boast of having watered their horses in every Indian river from the Kaveri to the Indus. If attacked, however, in a competent manner they would not stand; and afterwards, in conflict with the British, whole masses of them behaved in a dastardly manner. As their ambition grew, the chiefs began to organize their troops after the system learnt from the English and French. In this way several Frenchmen—De Boigne, Perron, and others—rose in the Mahratta service to a position dangerous to the British. But the new system was unsuited to the Mahratta genius; it hampered the meteoric movements of the cavalry, which was obliged to manœuvre in combination with the new artillery and the disciplined battalions. Mahratta elders hence uttered predictions of military disaster which were in the end more than fulfilled.

While the Mahrattas collected vast quantities of treasure and valuables, the ordinary revenue of the confederation hardly exceeded ten millions sterling annually. Large amounts, however, were drawn by feudal tenure-holders, which never appeared in the public accounts. The area and population under the dominion or the control of the confederation could hardly have been less than 700,000 square miles and 90 millions of souls.

The rapid and amazing success of the Mahratta confederation rendered it the largest Hindu sovereignty that ever existed in India. But it lacked the elements of true greatness. It was founded by plundering expeditions, and its subsequent existence was tainted by the baseness of this predatory origin. With the exception of the pêshwas, its chiefs were little more than freebooting warriors, for the most part rude, violent, and unlettered. Their custom was to offer their neighbours or victims the alternative of paying "chouth," that is, one-fourth of the revenue, or being plundered and ravaged. Thus the Mahratta chouth came to have an ominous significance in Indian history. Desultory efforts were made to establish a civil government, but in the main there was no administration formed on statesmanlike principles. The pêshwas, on the other hand, as Brahmans, were men of the highest education then possible in India. But they were absorbed by the direction of military and political combinations, and by intrigues for the preservation of their own power; and, even allowing for all this, they failed to evince the civil capacity which might have been anticipated. While several displayed commanding abilities, and some possessed many virtues, one only attempted to conduct an administration in an enlightened manner, and he died prematurely.

There were at the same time powers existing in India to keep the Mahrattas in check, and it has just been mentioned that some parts of India were excepted from their depredations. The English power was rising at Calcutta, Madras, and Bombay. The nascent Sikh power prevented Mahratta incursions from being permanently successful in the Punjab. As the Mogul empire broke up, some separate Mohammedan powers rose upon its ruins. The nizam of the Deccan established himself at Hyderabad, comparatively near the headquarters of the pêshwa. Hyder Ali was proclaimed sultan of Mysore in the south. Ahmed Shah Abdali burst upon India from Afghanistan. The Mahrattas bravely encountered him at Panipat near Delhi in 1761, and were decisively defeated. The defeat, however, did not essentially shake the Mahratta empire. It was collision with the English that broke that wonderful fabric to pieces.

The first collision with the English occurred in 1780; it arose from a disputed succession to the pêshwaship. The English Government at Bombay supported one of the claimants, and the affair became critical for the English as well as for the Mahrattas. It was at this conjuncture that Warren Hastings displayed his political genius and rendered signal service to his country.

The next collision happened in 1803. The pèshwa had fallen into grave difficulties with some of the principal members of the Mahratta confederation, namely Sindhia, Holkar, and the Bhonsla raja of Nagpur. He therefore placed himself under British protection, and this led to the great Mahratta war, in which the Marquis Wellesley displayed those talents for military and political combination which have rendered him illustrious. It was during the campaigns which ensued that General Arthur Wellesley defeated Holkar and the Bhonsla raja at Assaye, and General Lake won the victories of Farrukhabad, Dig, and Laswari over Sindhia and Holkar. The three confederates, Sindhia, Holkar, and the Bhonsla, concluded peace with the British Government, after making large sacrifices of territory in favour of the victor, and submitting to British control politically. Thus the Mahratta empire was broken up. It was during these events that the British won the province of Orissa, the old Hindustan now known as the North-Western Provinces, and a part of the western coast comprising Gujerat.

The third collision came to pass between 1816 and 1818, through the conduct, not only of the confederates, but also of the pèshwa himself. During the previous war the pèshwa had been the protégé and ally of the British; and since the war he had fallen more completely than before under British protection and guidance, British political officers and British troops being stationed at his capital. He apparently felt encouraged by circumstances to rebel. Holkar and the Bhonslas committed hostile acts. The predatory Pindaris offered a formidable resistance to the British troops. So the pèshwa ventured to take part in the combination against the British power, which even yet the Mahrattas did not despair of overthrowing. After long-protracted menaces, he attacked the British at Kirki, but failed utterly, and fled a ruined man. Ultimately he surrendered to Sir John Malcolm, and was sent as a state pensioner to Bithûr, near Cawnpur. Thus the last vestige of the Mahratta empire disappeared. The British, however, released the raja of Sattara from the captivity in which he had been kept during the pèshwa's time, and reinstated him on the throne. Owing to these events the British Government became possessed of the Concan and of the greater part of the Deccan.

It remains to mention briefly the fortunes of each remaining member of the once imperial confederation. The principality of Sattara was held to have lapsed in 1849 by the death of the raja without lineal heirs, and was annexed by the British Government. The Bhonsla raja of Nagpur and Berar was obliged to surrender Berar to the nizam, as the ally of the British, in 1803. Berar then remained under the nizam till 1854, when it came under British administration, though it is still included in the nizam's dominions. The raja of Nagpur died without lineal heirs in 1853, and his territory, being held to have lapsed, was annexed to the British territories. The house of Holkar has, during the last sixty years, remained faithful to its engagements with the British Government, and its position as a feudatory of the empire is well maintained. In Sindhia's territory, by reason of internal feuds, the British had to undertake measures which were successfully terminated after the battles of Maharajpur and Panniar in 1843. But on the whole the house of Sindhia has remained faithful. Sindhia himself was actively loyal during the war of the mutinies. The gaekwar gradually fell under British control towards the close of last century, and his house has never engaged in hostilities with the British Government. The gaekwar Khande Rao signalized himself by loyalty during the war of the mutinies. His successor, Malhàr Rao, has recently been deposed by the British Government on account of gross maladministration. The ex-pèshwa lived to old age at Bithûr, and died in 1851. His adopted son grew up to be the Nana Sahib, of infamous memory, who took a leading part in the war of the mutinies. (R. T.)

MAḤZOR (מַחְזוֹר), or MAḤAZOR,[1] as some write the word (from the root חָזַר, to go round, to return), signifies a cycle. The term is used by the Jews in a threefold sense:—(1) astronomically, as *Maḥzor Ḳatan* for the cycle of nineteen years, *Maḥzor Gadol* for that of twenty-eight years, *Maḥzor Gadol lallebanah*[2] for the Metonic cycle; (2) liturgically, for the "Larger Prayer-Book," whether in its narrower or its wider meaning (see below); and (3) ritually, for a book containing religious laws and directions, as, for example, *Maḥzor Vitri* by R. Simḥah b. Shemuel of Vitri-le-Français, *Maḥzor Rabbenu Tam* by R. Ya'aḳob b. Meir of Rameru, &c. In the first sense the plural is either *Maḥazoroth*,[3] or *Maḥzorim*,[4] or *Maḥazorin*;[5] in the second and third it is exclusively *Maḥzorim*. As most ancient prayer-books contain more or less fully elaborate "tables," exhibiting calendar matter, in connexion with the fixing of feasts and fasts and of the lessons from the Pentateuch and the Prophets, we cannot be in doubt as to the true cause of the application of the word *Maḥzor* to the "Larger Prayer-Book." It is not applied because it is the equivalent of the Syriac *ḥudrâ*, as some think, but simply because *Maḥzor* is the equivalent of the Greek *cyclos* (κύκλος).[6]

The *Maḥzor*, meaning prayer-book, is capable of division from different points of view. According to its contents we may divide it into two parts,—the Smaller and the Larger. The Smaller Maḥzor contains the ordinary prayers, together with the poetical insertions and the lessons from the Pentateuch and the Prophets used on the *Yamim Noraim*, or "Awe-inspiring Days" (*i.e.*, New Year and the Day of Atonement), and those used on the *Yamim Tobim*, the three principal festivals (Passover, Pentecost, and Tabernacles). The Larger Maḥzor is, indeed, the only one which really deserves this name, since it embodies the ordinary prayers, together with the poetical insertions for the whole year, and the lessons from the Pentateuch and the Prophets for all feasts and fasts and the other extraordinary occasions. According to its various "uses" the Maḥzor may be divided into the Rabbanite and the Anti-Rabbanite. The Anti-Rabbanite Maḥzor comprises the Karaite,[7] used by the so-called Ḳaraites, or Scripturalists, inhabiting Russia (especially the Crimea), Galizia (Austrian Poland), Egypt, Palestine, &c., and the Semi-Karaite, adopted by the so-called "Reformed Jews" of England, in reality the "Congregations of British Jews" of London, Manchester, and Bradford.[8] The Rabbanite Maḥzor may be divided into that of the Ashkenazim, the Sepharadim, and the Italiani. The Italian Maḥzor, though embodying large Ashkenazic and Sepharadic elements, is yet a distinct "use." It branches out at home into three subdivisions—(1) the Roman,[9] (2) the Neapolitan[10] (now extinct), and (3) the Italian proper;[11] and abroad into (4) the Greek Rites of Kaffa,[12] Crete, &c. (Crete having very early received a large influx of immigrants from France and Germany, but chiefly from Italy), and (5) the Romanian,[13] *i.e.*, the "use" obtaining, among others, at Constantinople and other Byzantine cities. The Italians who, long before the year 1000, had given Jewish learning and poetry, not merely to

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[1] Targum Yonathan on Genesis i. 14 (וּמַחֲזוֹרִין), which is the plural of *Maḥazoro*, and mediately of *Maḥazor*.

[2] This must not be mistaken for *Maḥzor Gadol shel Lebanah*, which consists of twenty-one years. See *Pireḳe R. Eli'ezer*, cap. vii.

[3] See *Pireḳe R. Eli'ezer*, cap. vi.

[4] See *Pireḳe R. Eli'ezer*, cap. vi.

[5] See note [1] above.

[6] For the sake of completeness we may mention the term "Mahazorto," which occurs in the Massoreth. It is not so called, as some have thought, because the *Maḥzor Vitri* (or, indeed, any other Maḥzor), ever gave the text of the whole Bible. The *Maḥazorto* was a pattern *codex* of the Bible, and got its name simply from its containing the *cycle* of the sacred Scriptures,—the Law, the Prophets, and the Hagiographa. It (or a similar codex) is also sometimes called *Maḥazoro Rubbo*, in contradistinction to smaller codices, which contained only some part of the Bible. It should be also borne in mind that the Babylonian Jews (as we are distinctly told of those of Nehardea) used in olden times to read on Sabbaths in the synagogue not merely, as nowadays, the Pentateuch and portions of the Prophets, but, in the afternoon service, portions of the Hagiographa also (T. B., *Shabbath*, 116*b*).

[7] See *Daily and Festival Prayers*, in 4 vols., Venice, 1528–29, 4to; in 3 vols., Kale, 1806, 4to; in 4 vols., Eupatoria, 1836, 4to; do., Vienna, 1854, 8vo.

[8] *Forms of Prayer*, &c., in 5 vols., London, 1841–43, 8vo.

[9] *Soncinati*, Soncino, Casal Maggiore, 1485–86, Bologna, 1540, both in folio.

[10] Cambridge MS. Add. 491.

[11] *Prayers*, &c., Venice, 1545, 16mo, &c.

[12] Cambridge MS. Add. 542.

[13] *Prayers for the Whole Year*, &c., in 2 vols., Venice, 1517–49, folio; Constantinople, 1573–76, folio. The copies of both editions in the Cambridge University Library are, so far as we know, the finest to be found in England.

Germany, but to the whole Roman empire, received in the 14th century numerous immigrants from northern France,[1] in the 15th century from Spain and Portugal, and at all times from Germany. The "uses" of these immigrants are practically preserved side by side with the native Italian to this day. The pure Sepharadic Ritual[2] represents, in the first instance, of course, the "use" of the Jews formerly inhabiting Spain and Portugal, who now form the minority in Hamburg, Amsterdam, Manchester, London, Paris, Vienna, Budapest, Temesvár, Semlin, Bucharest, Venice, Rome, and some other Italian and Greek cities, as also in Canada and the United States, and the majority in India, Persia, Morocco, Leghorn, Corfu, Belgrade, all Bulgaria, Constantinople, Palestine, Egypt, South Arabia, and other parts of the Turkish empire, in the French possessions in Africa, and in the south of France. Some of these, although characteristically Sepharadic, are distinct enough to claim a ritual of their own, as those of "Catalonia,"[3] Algiers,[4] Tunis,[5] Tripoli,[6] Tlemcen,[7] Ceylon and Cochin in India,[8] the Comtat in France,[9] and Provence, as a whole, in bygone days.[10] The "use" of the Ashkenazim,[11] *i.e.*, of the majority of the Jews inhabiting Germany, the Austrian states, Hungary, Russia, Denmark, Sweden, France, Belgium, Holland, the British empire (India excepted), the United States, &c., branches out into two rituals, the German proper[12] and the Polish. This latter has some differences of use between Great Poland and Little Poland.[13] The German proper had in times past the separate rituals of Worms and other cities in the empire, which are all now extinct. Those of Frankfort-on-the-Main and of other towns are not sufficiently marked to deserve separate notice. It should, however, be mentioned that there are scattered everywhere, both at home and abroad, "Reformed congregations," whose separate uses and practices are more or less an imitation of the "Temple" (Reformed congregation) of Hamburg.[14] Some of these have only introduced choirs, others have introduced instrumental music, and others again have considerably curtailed not merely the poetical insertions, but the ordinary prayers themselves, and have introduced hymns and prayers in the vernacular. (S. M. S.-S.)

MAI, ANGELO (1782–1854), cardinal, well known as the discoverer and editor of numerous ancient texts, was born of humble peasant parentage at Schilpario, a mountain village in the province of Bergamo, Lombardy, on March 7, 1782. For the excellence of his early education, received at Bergamo, he was indebted to a Jesuit priest named Mozzi, whom the suppression of the order had caused to settle in the neighbourhood. He afterwards accompanied Mozzi to a college at Colorno, in the duchy of Parma, where the Jesuits had been permitted to re-establish themselves; and there he entered the noviciate of the society in 1799. In 1804, after the brief which restored the Jesuits to the Two Sicilies had been granted, he was removed to Naples as teacher of classics in the college there. Next, after completing his theological studies at the Collegium Romanum, he lived for some time at Orvieto, where he was admitted to priestly orders, and was engaged partly in teaching and partly in the palæographical studies for which he had already manifested a strong partiality. The political events of 1808 necessitated his withdrawal from Rome (to which he had meanwhile returned) to Milan, where he assumed the functions of a secular priest, and in 1813, through the influence of Mozzi, was made custodian of the Ambrosian library. He now threw himself with characteristic energy and zeal into the business of carefully exploring the numerous and valuable MSS. committed to his charge, and in the course of the next six years was able to restore to the world a considerable number of long-lost works. With the full approval of all concerned he now withdrew from his connexion with the Society of Jesus, and in 1819 he was invited to Rome as chief keeper of the library of the Vatican. Soon after his installation there he found the palimpsest from which he edited the *De Republica* of Cicero; this, probably the most important work of his life, was followed by the publication of a vast number of fragments of Greek and Latin fathers and historians. In 1833 Mai was transferred from the office of Vatican librarian to that of secretary of the congregation of the Propaganda; on February 12, 1838, he was raised to the dignity of cardinal. In this rank he successively discharged the functions of prefect of the congregation for the supervision of the Oriental press, prefect of the congregation of the council of Trent, and cardinal librarian of the Roman Church. He died at Castelgandolfo, near Albano, on September 9, 1854, bequeathing his valuable private library at half its estimated value to the Vatican, the proceeds to be applied to the relief of the poor of his native village.

To the period of his Milanese activity belong *M. T. Ciceronis trium orationum, pro Scauro, pro Tullio, pro Flacco, partes ineditæ* (1814, from a palimpsest containing the poems of Sedulius); *M. T. Ciceronis trium orationum, in Clodium et Curionem, de ære alieno Milonis, de rege Alexandrino, fragmenta inedita* (1814, from a MS. containing a Latin translation of the *Acta* of the council of Chalcedon); *M. Corn. Frontonis opera inedita, cum epistolis, item ineditis, Antonini Pii, Marci Aurelii, Lucii Veri et Appiani, necnon aliorum veterum fragmentis* (1815); portions of eight speeches of Quintus Aurelius Symmachus, fragments of Plautus, the oration of Isæus *De hereditate Cleonymi*, the last nine books of the *Antiquities* of Dionysius of Halicarnassus, and a number of other editorial labours. *M. Tullii Ciceronis de Republica quæ supersunt* appeared at Rome in 1822; *Scriptorum Veterum nova collectio, e Vaticanis codicibus edita* (10 vols. 4to), in 1825–38; *Classicorum Auctorum Collectio e Vaticanis codicibus edita* (10 vols. 8vo) in 1828–38; *Spicilegium Romanum* (10 vols. 8vo) in 1839–44; and *Patrum nova Bibliotheca* (6 vols. 4to) in 1845–53. His edition of the celebrated *Codex Vaticanus*, completed in 1838, but not published (ostensibly on the ground of inaccuracies) till four years after his death (1858, 5 vols. 4to), is unsatisfactory and has been superseded

[1] There are to this day three congregations in Italy (Asti, Fossano, Moncalvo), which use the ancient ritual of northern France (see MS. Add. 667, in the Cambridge University Library).

[2] *Seder Tephilloth*, &c., Amsterdam, 1642, 16mo; in 4 vols., 1644; in 6 vols., London, 1789–93; *Maḥzor*, &c., Vienna, 1820, 8vo.

[3] *Maḥzor*, &c., Salonika, 1863, 8vo.

[4] *Ḥokhmath Hammisken*, &c., 1793; קרובין, 1823; *Maḥzor Ḳatan*, &c., 1861, all at Leghorn, in 8vo.

[5] *Maḥzor*, &c., Pisa, 1794; *Seliḥoth*, 1845; *Pene Haragel*, 1856, all at Leghorn, and in 8vo.

[6] *Siphethe Renanoth*, &c., 2 vols., Venice, 1648, 1711, 4to, Leghorn, 1837; *Ḳisshurin Leya'aḳob*, Leghorn, 1858; *Readings*, Venice, 1736, all three in 8vo.

[7] *Maḥzor*, &c., 1842 and 1861, both at Leghorn, and in 8vo.

[8] *Order of Prayers*, &c., Amsterdam, 1757 and 1769, Leghorn, 1849, all in 8vo.

[9] Or Venaissin, *i.e.*, the four congregations of Carpentras, Avignon, Lisle, and Cavaillon. See *Seder Hattamid*, &c., Avignon, 1767, Aix, 1855, 8vo; *Seder leyamim Noraim*, &c., 1739; *Seder leshalosh Regalim*, 1759–1762, both at Amsterdam, and in 8vo; *Seder Hakunteris*, &c., Avignon, 1765; *Seder shel yom Kippur*, 1766, and *Seder Haashmuroth*, 1763, both at Amsterdam, and all three in 4to.

[10] It ought not to be omitted that in the old Provençal ritual and the South Arabian there are several points of contact existing. A teacher or teachers must have come from the one country and settled in the other. We will give but one example. The phrase, בבניניה דמקדשא ובשכלוליה דהיכלא, which occurs in the *Path-shegen* (on Genesis ii. 1), by an anonymous author, and published by Dr Nathan Adler, and which the editor modestly says he has not succeeded in finding, is in reality to be found in the service of the *Hosha'noth*, both in the old Provençal *Maḥzor* (Camb. MS. Add. 752, leaf 205*b*; only that, instead of דמקדשא, it reads דבית מקדשא) and in that of Yemen (Camb. MS. Add. 1200, leaf 62*b*), though in no other so far as we know.

[11] *Maḥzor*, Pesaro, 1520, Augsburg, 1536, Venice, 1567, all in folio; 6 vols., London, 1807, 1824, 1826, &c., 8vo.

[12] *Maḥzor*, 2 vols., Sulzbach, 1794, folio.

[13] These differences show themselves first in the prayer "El erekh appayim" in the service for Monday and Thursday.

[14] *Ordnung der öffentlichen Andacht*, &c., 1819; *Seder Ha'abodah*, &c., both at Hamburg, and in 8vo.

by the subsequent magnificent edition of Vercellone and Cozza (Rome, 1868), which in turn leaves much to be desired. Generally speaking, it may be said that the services rendered to scholarship by Mai (great though they were) were merely those of a laborious and persevering pioneer; as a textual critic he does not rank high, either for sagacity or for accuracy.

MAIA was the eldest and fairest of the Pleiades, the seven daughters of Atlas and the Oceanid Pleione. Her name marks her as the "fruitful mother"; and the seven sisters have no individuality except as the mothers of famous families. They were all born on Mount Cyllene in Arcadia, and are sometimes called mountain goddesses. In a cave of Cyllene, in the darkness of night, Maia became by Zeus the mother of the god Hermes. Maia bears one of the most characteristic names of the Phrygian mother, Cybele or Ma, the goddess whose home is on mountains and in caves; and in a common class of votive reliefs Hermes-Cadmilus is represented as a youth bearing a vase standing beside the throne on which Cybele sits. Maia was also an epithet of the Bona Dea, who is a form of Cybele, in Rome. See Conze, "Hermes-Cadmilos," in *Arch. Ztg.*, 1880.

MAIDENHEAD, a municipal borough and market-town in Berkshire, England, in the diocese of Oxford, 22½ miles from London, 13½ from Reading, and 6 from Windsor. It was formerly called *Maidenhythe*, a wharf for timber and a wooden bridge across the Thames having existed there from very early times. In 1352 Edward III. incorporated a guild to keep the bridge in repair. In 1400 the duke of Surrey and the followers of Richard II. held the bridge against the new king, Henry IV., and at nightfall made good their retreat. In July 1647 a meeting took place at the Greyhound Inn between Charles I. and his three children. The church, dedicated to St Andrew and St Mary Magdalene, was originally founded by Margaret of France in 1270, and it was rebuilt on the same site in 1724; but in 1826 it was entirely taken down, and a new church was erected at the east end of the High Street. A church dedicated to St Luke was erected in 1867, and enlarged in 1869. The town contains a small town-hall, a large hall recently erected for concerts and lectures, schools, almhouses, and Roman Catholic, Wesleyan, and Baptist places of worship. There are numerous charities for the education and maintenance of poor persons. The principal trades are in malt, meal, and timber. A fine stone bridge across the Thames was erected at a cost of £20,000 in 1772, connecting Berkshire with Buckingham. The scenery around Maidenhead is extremely picturesque, and several noblemen's seats are in the neighbourhood. Population in 1871, 6173; in 1881, 8219.

MAIDSTONE, a municipal and parliamentary borough, and the county town of Kent, England, situated almost midway between London and Dover. It lies principally on the eastern bank of the river Medway, the modern part spreading over the western slopes of a picturesque valley, which is intersected and environed by orchards and hop gardens. Although antiquaries have conjectured that Maidstone was a military station of the Romans, few Roman remains have been found in the neighbourhood. The Saxon spelling of the name was *Medwegestun*, "Medway's town." The manor, valued in Domesday Book at £35, 10s., had from a very early period belonged to the see of Canterbury. Archbishop Boniface in 1260 established a hospital here for poor pilgrims, the chapel of which, with modern additions, is again used for public worship. The parish church of St Mary, which had existed from Norman times, was demolished in 1395 by Archbishop Courtenay, who erected on the site thereof the present church of All Saints; he also, at a short distance, founded a college of secular canons, the ruins of which are an interesting specimen of 14th century architecture. From the reign of John until the Reformation the archbishops had here a residence, at which Stafford and Courtenay died; but the existing building known as the palace dates chiefly from Elizabethan times. The rectory, with the manor, passed into lay hands at the Reformation; and, having been a perpetual curacy for three hundred and twenty years, the living became a vicarage in 1866. All Saints is one of the largest parish churches in the kingdom, and contains, besides many excellent monuments, the richly carved sedilia and the twenty-eight oak seats used by the collegiate priests. The parish has, since 1837, been divided into nine ecclesiastical districts, each with a church. The grammar school was founded in 1549, and endowed with the estates of the local Corpus Christi fraternity, then dissolved; the hall in which the guild assembled still remains. Broadcloth and linen thread, introduced by Dutch settlers, were at one time manufactured here; but brewing and papermaking have long superseded these industries. Of the barges trading on the Medway, about sixty belong to Maidstone wharfingers. The river is crossed by a stone bridge of three arches, completed in 1879. A museum, with public library attached, was opened in 1858. The endowed charities yield an annual income of £3000. Since the beginning of the 17th century the Kent assizes have generally been held at Maidstone. From Saxon times down to 1830 condemned malefactors were executed, and all the great county meetings were held, on Penenden Heath, a common situated about a mile north-east of the town, and recently enclosed by the corporation. The area of the municipal borough is 4008 acres, of the parliamentary borough 4576 acres. The population has steadily increased during the present century; in 1801 it was 8027, in 1881 29,632.

With general history Maidstone has been intimately associated. Wat Tyler broke into the prison, liberated John Ball, the rebel preacher, and committed other depredations. Several of the leading inhabitants joined Jack Cade's rising. Sir Thomas Wyatt, who resided at Allington Castle, now an ivy-clad ruin a mile and a half north of the town, raised the standard of rebellion at Maidstone on 25th January 1554. As a punishment for their complicity with Wyatt, the burgesses were for the next five years deprived of their charter of incorporation. The rising of the Kentish royalists in 1648 collapsed at Maidstone, where, on the 1st June, Fairfax, after five hours' obstinate fighting, captured the town at midnight. Anciently governed by a portreve, Maidstone was first incorporated by Edward VI., and since the beginning of Elizabeth's reign it has sent two representatives to parliament. Andrew Broughton, one of its mayors, as clerk of the court which tried Charles I., read the fatal sentence to the king.

See Russell's *History of Maidstone*, and Poste's *History of the College of All Saints*.

MAIMANSINH, or MYMENSING, a district in the lieutenant-governorship of Bengal, India, lying between 23° 56′ and 25° 25′ N. lat., and 89° 43′ and 91° 18′ E. long., with an area of 6287 square miles, is bounded on the N. by the Gáro Hills, on the E. by Sylhet, on the S.E. by Tipperah, on the S. by Dacca, and on the W. by the river Jamuná, which separates it from Pabna, Bogra, and Rangpur districts. It is, for the most part, level and open, covered with well-cultivated fields, and intersected by numerous rivers. The Madhupur jungle is a slightly elevated tract, extending from the north of Dacca district into the heart of Maimansinh, almost as far as the Brahmaputra; its average height is about 60 feet above the level of the surrounding country, and it nowhere exceeds 100 feet. The jungle contains abundance of *sál*, valuable both as timber and for charcoal. During the cold season the open parts of the jungle afford grazing grounds for cattle. The only other elevated tract in the district is on the southern border, where the Susang hills rise. They are for the most part covered with thick thorny jungle, but in parts are barren and rocky. The Jamuná forms the western boundary of Maimansinh for a course of 94 miles. It is navigable for large boats throughout the year; and during the rainy season it expands in many places to 5 or 6 miles in breadth, overflowing a considerable portion of low-lying land. The Brahmaputra enters Maimansinh at its north-western corner near Karáibari, and flows south-east and south till it joins the Meghná a little below Bhairab Bázár. The gradual formation of *chars* and bars of sand in the upper part of its course has diverted the main volume of water into the present channel of the Jamuná, which has in consequence become of much more importance than the Brahmaputra proper. The Meghná only flows through the south-east portion of the district for a short distance. The eastern and south-eastern parts of the district abound in marshes. The wild animals include tigers, leopards, deer, bears, elephants, and an occasional rhinoceros. Small game is abundant.

The census of 1872 returned the population of Maimansinh at 2,349,917 (males, 1,187,962; and females, 1,161,955),—Mohammedans numbering 1,519,635; Hindus, 817,963; Christians, 124. Of aboriginal tribes the most numerous are the Hajongs (24,936) and Gáros (10,997). The semi-Hinduized aborigines number in all 205,592, of whom more than one-half are Chandáls (123,262), the most numerous caste in the district, employed as cultivators, fishermen, labourers, and menial servants. Among high-caste Hindus, Bráhmans number 33,414. Five towns contain upwards of 5000 inhabitants:—Maimansinh or Nasirábád, 10,068; Jamalpur, 14,302; Kisoriganj, 13,637; Sherpúr, 8015; and Dhanikhola, 6730. Ulákandi or Bhairab Bázár, although with only a population of 1500, is the most important commercial mart, with a large trade in jute and a well-supplied cattle-market. Rice, of which three crops are raised annually, forms the staple food crop of the district. Other agricultural products are wheat, oats, maize, pulses, linseed, mustard, *til*, indigo, tobacco, sugar-cane, *pán*, and jute. The last constitutes the chief commercial staple. Maimansinh suffers occasionally from blights and floods, but never to any serious extent. The chief imports are piece goods, raw cotton, wheat, betel nuts, chillies, sugar, and cattle; the exports consist of rice, jute, indigo, reed-mats, hides, brass and copper utensils, cheese, *ghí*, &c. Tobacco and muslins are also exported to a small extent. Besides a little muslin, the only manufactures are coarse silk cloth, *sitalpati* mats, cheese, and *ghí*. Apart from the rivers, means of communication are afforded by about 146 miles of good and 124 miles of inferior roads. Although the general revenue (£166,938 in 1880-81) has more than doubled in seventy-five years, the land revenue has remained almost stationary; in 1880-81 it was only £75,226, excise amounting to £23,652, and stamps to £48,680. Education in 1872-73 was afforded by 173 state-supported schools attended by 6372 pupils, besides 71 unaided schools, with 2425 pupils. Except towards the close of the rainy season, the climate is fairly healthy. The average annual rainfall is 105 inches.

MAIMBOURG, Louis (1610-1686), a French historical writer, was born at Nancy in 1610. At the age of sixteen he entered the Society of Jesus, and after completing his theological studies at Rome he became a classical master in the Jesuit college at Rouen. He afterwards devoted himself to preaching, but with only moderate success. After having taken some part in minor controversies he threw himself with energy into the dispute which had arisen as to the Gallican liberties; for his *Traité historique sur les prérogatives de l'Église de Rome* (1682) he was by command of Innocent XI. expelled from his order, but rewarded by Louis XIV. with a residence at the abbey of St Victor, Paris, and a pension. He died on August 13, 1686. His numerous works (exhaustively enumerated in the *Biographie Générale*) include histories of Arianism, the iconoclastic controversy, the Greek schism, Lutheranism, Calvinism, and of the pontificates of Leo I. and Gregory I.; they are mere compilations, written indeed in a very lively and attractive style, but inaccurate throughout, and wherever matters of controversy are touched on, specially untrustworthy.

MAIMONIDES (1135-1204). Among the great men to whom Mohammedan Cordova[1] has given birth—and these are not a few—the greatest is unquestionably Rabbenu Mosheh b. Maimun[2] Haddayyan.[3] Like the lives of so many great men, that of this "last of the *Geonim* as regards time and the first of them as regards worth"[4] is surrounded by a halo of fables, some of which, though fictitious, are instructive in many respects, whilst others are telling in dramatic effect and touching in the extreme. Some of these fables, however, are merely amusing, whilst others are simply ridiculous.[5] The present article confines itself to facts and a few criticisms founded on them.

"Rambam," or Maimonides, was born March 30, 1135, and died at Cairo, December 13, 1204; consequently he did not quite attain the age of seventy,[6]—a short space of life, when we take into consideration all the work he did for his contemporaries and all the works he left to posterity.

Like many other great and conscientious rabbis of all times, who considered it a sin to make of religious learning a means of gaining bread, Maimonides adopted the medical profession. That he must have greatly excelled in it is not merely known by the medical works he composed, but is best testified to by the fact that, although a Jew (and the times and the country he lived in were certainly not more tolerant than ours), he held the lucrative and important office of court-physician to Saladin of Egypt.

Maimonides was master of Greek-Arabic philosophy, as may be seen from his *Technical Terms of Logic*,[7] his *Guide*, and his other works. That he was a mathematician and astronomer of no mean standing appears from the *Maamar Ha'ibbur*[8] (calculations of the calendar, which he wrote at the age of twenty-two), the *Hilekhoth Kiddush Hahodesh* (in the book *Zemannim* of the *Mishneh Torah*), and the commentary on T. B., *Rosh Hasshanah*. That he was a great Talmudist we know from his commentary on the *Mishnah* and his *chef-d'œuvre* the *Mishneh Torah*. That he was, as philosopher and theologian, a profound thinker we know from his *Guide of the Perplexed* and his other works. To sum up in a few words the merits of Maimonides, we may say that, with all the disadvantages of the times in which he lived, he was the greatest theologian and philosopher the Jews ever produced, and one of the greatest the world has seen to this day. As a religious and moral character he is equalled only by a few and surpassed by none.

The works of Maimonides were composed by him partly in Hebrew and partly in the vernacular Arabic,—a portion of the latter eing translated into Hebrew by himself.

I. *Works composed by Maimonides in Hebrew.*

1. *Mishneh Torah*, *i.e.*, the systematic codification of the whole of the Jewish law, as it is to be found in the Bible, the *Mishnah*, *Tosephta*, *Mekhilta*, *Siphra*, *Siphre*, both *Talmudim*, the *Sheeltoth*, *Halakhoth Gedoloth*, the *Responsa* of the *Geonim*, the *Hilekhoth*, *Rab Al-phesi*, &c. This work is drawn up in fourteen (י״ד = *Yad*)

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[1] Hence he is called "Al-Kortubi" (and not al-Kordovi, or Hakordovi) by Arabic writers, and "Hassephardi" by himself (preface to *Mishneh Torah*).

[2] From the initials of his name, with "R" (for "Rabbenu") prefixed, and his father's name with "B" (for son of) prefixed, the Jews call him RaMBaM; among Christians he is, *more Græco*, called *Maimonides*, from his father's name *Maimun* or *Maimon*.

[3] See end of the commentary on the *Mishnah* ("*Ani Mosheh bar Maimun Haddayyan*").

[4] So Maimonides is designated by the famous Enbonet Abram (or Yeda'yah Happenini Bederesi, *i.e.*, of Beziers) at the end of his *Behinath 'Olam*.

[5] Whoever wishes to know more of these fables may gratify his desire, if he knows Rabbinic, by reading Ibn Yahya's *Shalsheleth Hakkabbalah*; if he understands German, by reading Jost's *Geschichte*; and if he understands only English, by reading Benisch, *Two Lectures*, &c., London, 1847, 8vo.

[6] Note at the end of the author's commentary on T. B., *Rosh Hasshanah*, by his grandson R. David (*Hallebanon*, ii. p. 60).

[7] This work was translated from the Arabic into Hebrew by R. Mosheh Ibn Tibbon, and printed for the first time at Venice, 1550, 4to. The third edition (Frankfort-on-the-Oder, 1761, 4to) has a commentary by Mendelssohn.

[8] See the collection *Dibere Hakhamim* (Metz, 1849, 8vo), p. 23. The translation is by R. Mosheh Ibn Tibbon.

books, with a view to which fact and to the author's name (*Mosheh*) admiring and grateful posterity called it, from Deut. xxxiv. 12, *Hayyad Haḥazakah,*—a title which has eclipsed, if it has not actually superseded, that given to it by the author himself. Great has been the success of this work. If Maimonides has not succeeded in superseding by it the Babylonian Talmud (as some think was his purpose[1]), he has certainly succeeded (probably against his will) in making of it a second Talmud of Babylon in the Talmudic acceptation of this term.[2] The *Mishneh Torah* has become an arena of endless, though happily bloodless, strife. It is to this day a place of tournament for all Talmudists. The hundreds of folios on Rabbinic literature, written since the author's time, constantly draw the *Rambam*,[3] naturally or artificially, into the discussions they contain. To clear up a difficult *Rambam*, or to "answer a *Rambam*," *i.e.*, to remove an apparent difficulty in the *Mishneh Torah*, is the great test of the fitness or learning of a rabbi to this day. Moreover, all Sepharadim have received its *dicta*, though only *cum grano*, whilst the congregations of Arabia (as those of Yemen and others) not only live absolutely according to its teachings, but have actually neglected the study of the *Talmudim* through it. The work itself is to be found in MS. in numerous libraries (probably one of the oldest MSS. lying in the University Library of Cambridge, Add. 1564). Printed editions are also numerous, some without "strictures" (*Hassagoth*) and without a commentary, others with the "strictures" of the great rabbi[4] of the little town of Pesquiers (in Provence), others with commentaries varying from four to eight, and even more. The earliest edition, which has neither place nor date, appeared somewhere in Italy, about 1480; the second at Soncino, 1490; the third at Constantinople, 1509; the fourth, fifth, sixth (with the *Sepher Hammisvoth*, &c.), and seventh editions at Venice, 1524, 1550, 1550–51, and 1574–75 respectively; the eighth (with the *Antichristiana*) at Amsterdam, 1702–3, all in folio; the most recent and incomplete edition being that of Leipsic, 1862, 8vo. The *Mishneh Torah* stands, and has stood for centuries, even among non-Jews, in such respect that "parts of books" (*Halakhoth*) have been rendered into other languages, notably into Latin. Extracts from this work have been translated into English by the late H. H. Bernard of Cambridge (Cambridge, 1832, 8vo) and E. Soloweyczik of Poland (London, 1863, 8vo).

2. Commentary on the treatise of *Rosh Hasshanah* according to the Babylonian Talmud. We know from Maimonides himself that he commented on almost the whole of the second, third, and fourth *Sedarim* and on one treatise (*Hullin*) of the fifth *Seder* of the Babylonian Talmud. But of all this none but his *Rosh Hasshanah* has been preserved. This commentary is extant in four MSS., one of which, however, is a mere transcript, whilst two of the others are imperfect. The only edition existing (*Hallebanon*, ii. p. 61, &c.) is from these imperfect MSS. The one perfect MS. copy known to us is preserved in the University Library of Cambridge (Add. 494).

3. Some of the numerous letters ascribed to Maimonides. These are inextricably mixed up both with letters written by him in Arabic and translated by others into Hebrew, and with letters addressed to him by others.

4. Religious poetry. There is a short liturgical piece (it is recited on the first day of New Year by the Arabic-speaking Jews of Algiers, Tunis, &c.) which begins *Eth Sha'are Ratzon*, and which bears the acrostic *Ani Mosheh biribbi Maimon Ḥazaḳ*. It is an "'*Akedah*." But because there is a composition of the same nature and beginning, but of greater length and by another author ('Abbas Yehudah Shemuel), this is, in contradistinction, called '*Akedah Ketannah*. Since the name of Mosheh, however, is common among all Jews and that of Maimon among those of the Maghrib (see Schiller-Szinessy's Cambridge *Catalogue of the Hebrew Manuscripts*, ii. p. 28, note 2), this little poem may, perhaps, belong to another (and inferior) rabbi of this name. If it really does belong to our Maimonides, we have a key to his contempt for the liturgical poets.[5] Being a poor poet himself, he judged them by his own merits, or rather demerits.

II. *Works composed by Maimonides in Arabic.*

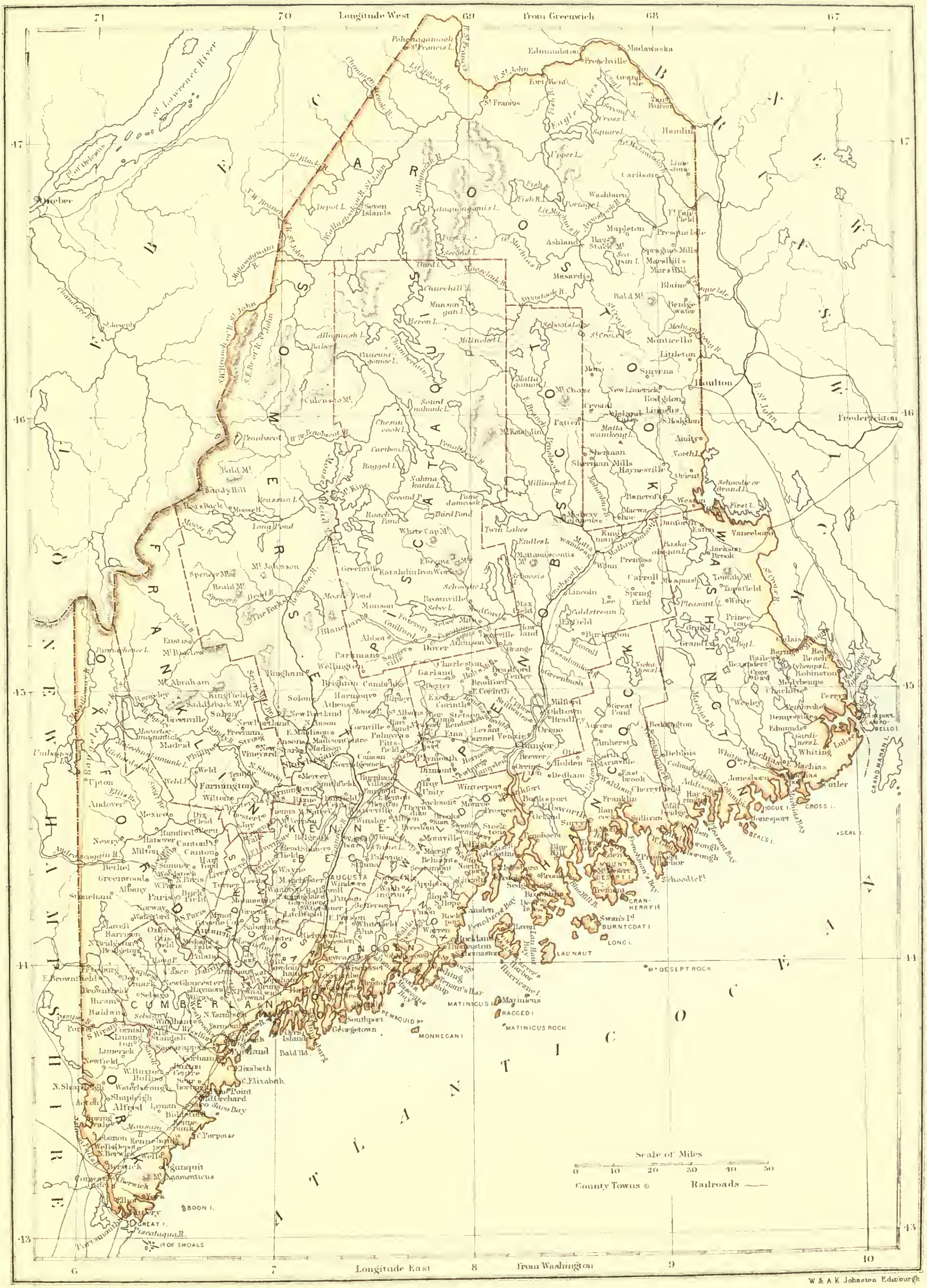
1. The commentary on the whole *Mishnah*. The author began this work whilst yet in Spain, continued it on his flight through Morocco, and finished it at his ease at Fostat (Cairo). The merit of this work is that the author explains therein the *Mishnah* in a very lucid and brief way; and, having privately digested the Talmudical controversies regarding each paragraph, he gives the result of it in the decision of the *Halakhah*. But this work has also its demerits. (1) It is occasionally incorrect in itself. (2) Being to most Talmudists accessible only in a translation, which they cannot gauge, the smallest clerical error produces confusion. (3) Nor were all the translators equally qualified for their task. Some were good Talmudists, but indifferent Arabic scholars; some were good Talmudists and good Arabic scholars, but not fine Hebraists. (For the translators see Schiller-Szinessy, *ut supra*, ii. pp. 16, 17.)

2. The *Sepher Hammisvoth* is a preliminary to the author's masterpiece, the *Mishneh Torah*. This small but important work has been twice translated,—first by R. Mosheh b. Shemuel b. Yehudah Ibn Tibbon (Tabbon?), and secondly by R. Shelomoh b. Yoseph Ibn Aiyúb. The former translation is known by printed editions[6] and the latter by MSS. Ibn Aiyúb's, though less known, is the more correct translation. There is a copy of it in the University Library of Cambridge (Add. 676, 2).

3. But the most important and most learned and to us the most interesting of Maimonides's Arabic works is the *Guide of the Perplexed* (Dalálatu 'l-Háirín in Arabic, and *Moreh Hannebokhim* in Hebrew). It is the result of deep research in Bible and Midrash on the one hand and in Greek philosophy, as interpreted by Aristotle and his followers, together with various religious systems, on the other. The purpose of its composition and publication was to reconcile Jewish theology with refined heathen philosophy. Maimonides deservedly held Aristotle in very high estimation; his traducers, however, said that he placed him in the *Guide* next to, if not above, Moses. No wonder, then, that religious Jews of a certain type in the author's lifetime took offence both at the book and the author. But serious warfare broke out only after Maimonides's death, which raged for more than a full century, and is not entirely extinguished even at this day. His followers, chiefly in Provence at the end of the 13th and the beginning of the 14th century, some of whom had only eyes for the master's negations and none for his affirmations, declared the whole history of the Bible to be mere symbolism. Abraham was, according to them, the Morphe, Sarah the Hyle, and so forth.[7] These absurdities were considered by the religious as highly irreligious, and provoked active opposition and even excommunication. These, in their turn, provoked again the strong remonstrance of the moderate middle party and the ultimate excommunication of the excommunicators by the excommunicated. But long before that time the *Guide* had been publicly burned,—an act quite un-Jewish, but in unison with an age which had more faith than knowledge, and which, dwelling in darkness, hated the light. People in our days cannot understand this; they cannot understand the fierce opposition to the *Guide*, and much less the attachment to it. They ask, Is this the great work of the great Maimonides? These explanations of the Scriptures we have long ago outgrown, and the philosophy it contains is not worth mention by the side of that of Schelling, Fichte, and Hegel! But the fact is that, if one wishes to form a proper estimate of this work, he must not merely read it, but earnestly study it. Then again, its contents must be viewed historically, *i.e.*, both in connexion with the theological and philosophical systems of past ages and with the influence it has exercised uninterruptedly from the time of its appearance down to almost our own days.[8] Isolated portions of it may have become antiquated. The symbolism of the Pentateuch and the meaning of the words of the prophetic books and Hagiographa may be clearer to us than they were in the author's time, by reason of our discoveries in science, our progress in philology, and our knowledge of history. Our knowledge of Greek philosophy may be much greater than Maimonides's was, owing partly to our acquaintance with the original writings of Aristotle and others, accessible to Maimonides only through a translation of a translation, and partly owing to our collation of numerous MSS., by which the errors are rectified of the copies from which the first translators made their version,—a rectification by which parts of the foundation and of the superstructure of the *Moreh* go down at one and the same time. But, when all this is considered, the *Guide* still remains a great work,—a product, indeed, of the Middle Ages, but truly immortal.[9]

[1] Luzzatto, *Kerem Ḥemed*, iii. 67.
[2] T. B., *Synhedrin*, 24a.
[3] So this work is commonly and especially called from the author's name.
[4] *R. Abraham Ben David* (*Rabad*) was the author's contemporary and the only literary man who ever conquered him, according to his own confession.
[5] See introduction to the *Sepher Hammisvoth*.
[6] The first edition appeared without place and date, but Constantinople about 1516, 4to.
[7] See Schiller-Szinessy, *Catalogue*, &c., i. p. 188, notes 1 and 2.
[8] Moses Mendelssohn, for example, became one of the greatest philosophers of his day through studying the *Moreh*.
[9] This book was till within the last few years known only through the translation of R. Shemuel b. Yehudah Ibn Tibbon, which has been printed numerous times, the *editio princeps* being without place or date, but somewhere in Italy (Bologna?) before 1480. There is, however, also another translation from olden times in existence. It is by the famous R. Yehudah Al-Harizi, and has been edited by Schlossberg (i., London, 1851; ii. and iii., Vienna, 1874 and 1879 respectively, all in 8vo). The late S. Munk has, however, surpassed in correctness both his predecessors in his *Guide des Égarés*, which contains the Arabic original with a French translation. It appeared at Paris, 1856–66, in 3 vols. 8vo.

MAINE.



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4. *Responsa* and other letters (*Teshuboth Sheeloth ve-Iggeroth*). These do not belong exclusively to Maimonides. The first edition came out without place or date, but at Constantinople about 1520, folio.

5. *Responsa* (printed under the title *Peer Haddor*) translated by R. Mordekhai Tammah, Amsterdam, 1765, 4to.

III. *Works composed by Maimonides in Arabic and translated into Hebrew by himself.*

1. The commentary on the *Mishnah* of the whole *Seder Tohoroth*. As is well known, the translation of this *Seder* has been hitherto regarded as anonymous. But the writer of this article has shown in the Cambridge *Catalogue, ut supra*, ii. p. 17, note 2, the high probability, amounting to a moral certainty, that nobody else could have been, and that Maimonides himself must have been, the translator of this *Seder*, which more than any other demanded the three necessary qualifications of a good translator.

2. The letter on the sanctification of the name of God (*Iggereth Hasshemad*, or *Maamar Kiddush Hasshem*[1]). Although the proofs which one can adduce for the translation by the author himself of this treatise are not so telling as those in the case just mentioned before, the moral certainty is not less. The treatise details (1) how much a Jew may yield, and how much he must resist, if forced to embrace another religion, and (2) that Mohammedanism is not a heathenish religion. It is generally held, though not quite conclusively proved, that Maimonides wrote this treatise *pro domo sua*, he and his family having been themselves forced to embrace Mohammedanism during the persecution by Ibn Tamurt. It ought to be borne in mind that the Jews generally look upon Christianity and Mohammedanism as having each taken a large share in their mother's (Judaism's) inheritance, and that, whilst the former looked more for her moral, the latter coveted her doctrinal possessions. Since morality, however, consists more in negatives than positives, and since doctrines are more openly challenged and openly avowed than morals, the Jews have always manifested less repugnance to profess, under pressure, Mohammedanism than Christianity.

There are other works both in Hebrew and in Arabic extant by our author. These relate mostly either to ritual affairs, and consist of letters to various rabbis, and colleges of rabbis, notably in the south of France, to congregations in Yemen and elsewhere, or to medical matters, and consist of short treatises, such as aphorisms, &c., but do not come up in interest to the great works already named. (S. M. S.-S.)

MAINE, a province of France, was bounded on the N. by Normandy, on the W. by Brittany, on the S. by Anjou and Touraine, and on the E. by Orléanais; along with the northern part of Anjou it is now represented by the departments of Sarthe and Mayenne. Together with a portion of Perche which was conterminous with it on the north-east, and the countship of Laval on the west, it constituted a great military government, of which Le Mans was the capital. Before the Roman conquest Maine was held by the Aulerci Cenomani, whence probably its name. Le Mans, a great city, was connected by the conquerors by good roads with Chartres, Orleans, Vendôme, Tours, Angers, Jublains (capital of the Aulerci Diablintes, inhabiting the western portion of Maine), and Sées. Under the later Cæsars the Cenomani became almost independent, and joined the Armorican republic. Christianity was first introduced in the 3d century by St Julian, first bishop of Le Mans. Down to the time of Hugh Capet the bishops were the real rulers of the country; but in consequence of the incursions of the Northmen, who came up the Sarthe and Mayenne, the erection of strongholds became necessary, and Hugh Capet made the countship of Maine hereditary in the person of Hugh I. One of the descendants of the latter, Count Herbert, having acknowledged the suzerainty of William, duke of Normandy, the people of Le Mans availed themselves of the absence of the Conqueror in England to rise against him, and were ultimately successful in gaining their freedom. Maine became united with Anjou by the marriage of its heiress with Fulk of Anjou, father of Geoffrey Plantagenet. Henry II. of England, the son of Geoffrey, was born at Le Mans. On the confiscation of the estates of King John, Maine passed to Philip Augustus of France; by Louis IX., the grandson of Philip, it was handed over in 1245 to Charles, count of Provence, afterwards king of Naples; and in 1328 it was reunited to the domains of the crown by Philip of Valois, who was count of Maine. It was again separated by his grandson Louis of Anjou, the brother of King Charles V. During the Hundred Years' War, Maine was a continual battlefield; the English were at last driven out by Dunois, who took possession of Le Mans in 1447. In 1481, on the death of Charles of Maine, the last scion of the house of Anjou, Maine was again united to the French crown by Louis XI. The province suffered much during the wars of religion; its strong places were dismantled by Henry IV. and Richelieu. At the Revolution the troops of La Vendée entered Maine, and took possession of Laval, Mayenne, and Le Mans at the end of 1793; after they had been defeated by the republican forces under Marceau and Westermann, their place was taken by the Chouans; and the pacification of the province, begun by General Hoche, was not completed until 1800. Towards the close of 1870 the second army of the Loire, retreating before the Prussians, was reformed in Maine, and in the neighbourhood of Le Mans one of the last great struggles in the Franco-German war took place in January 1871.

[1] See Geiger, *Moses b. Maimon*, Breslau, 1850, 8vo.

MAINE

MAINE, the most north-easterly of the United States, lies between 43° 4′ and 47° 27′ 33″ N. lat., and between 66° 56′ 48″ and 71° 6′ 41″ W. long. It is 302 miles in extreme length and 285 in width, with a total area of 33,040 square miles (of which 29,895 square miles are land), being nearly as large as all the other New England States combined. Its figure resembles that of a mountain peak, broken at the top. Its S.E. base rests on the Atlantic Ocean. On the E. and N. it has the province of New Brunswick, and on the N.W. the province of Quebec, while its southern half is bounded on the W. by the State of New Hampshire. Plate V.

Coast-line. The coast-line measured direct is about 225 miles in extent; but the numerous river mouths and indentations of the sea make an actual tide-water line of not less than 2500 miles. The headlands and far-stretching narrow points, together with innumerable outlying islands, give to the whole ocean front the appearance of a fringed and tasselled border. This striking feature, which gives peculiar interest in many ways to the coast of Maine, is chiefly the result of a southward glacial movement, which, coinciding with the trend of the rocks produced by a remote geologic upheaval, cut these fiord valleys far out into the sea, the prolongation of their edges being marked by islands, reefs, and scattered knobs of rock. In these deep bays and river mouths, and behind these outlying islands, are numerous harbours, convenient, safe, and capacious, and the poet is well within the truth who sings of "hundred-harboured Maine." There are no better harbours on the Atlantic coast than those of Portland and Wiscasset. The beaches and marshes and low grassy islands common in the west are scarcely found east of the Kennebec river, beyond which the shore becomes more and more bold, rising in the precipitous cliffs and rounded summits of Mount Desert and Quoddy Head to a height of from 1000 to 1500 feet. Drainage slopes. The general slope of the land surface falls from an extreme elevation of 2000 feet on the west, in the neighbourhood of the White Mountains, to 600 feet on the east. Two principal drainage slopes stretch respectively southward and northward from a watershed which crosses the State in a general easterly and westerly direction, at a distance of about 140 miles from the coast, while the northward slope has an extreme breadth of about 80 miles. The general direction of the rivers, as determined by these slopes, is about south-south-east for the southern slope and north-north-east for the northern. It is a noteworthy fact that the course of the principal rivers is at right angles to the general trend of the stratified rocks, throughout the large section where these are exhibited. The surface is hilly and rolling rather than mountainous. The Appalachian range, which becomes so prominent in the White Mountain group just westward of the State, seems to have broken its force there and to have strewn only a few scattered mountain masses across middle Maine and into New Brunswick. These all have a peculiar aspect, rising in conical peaks, heavily wooded at the base and bare at the summit. The most noteworthy is Mount Katahdin, with a height of 5385 feet (a little less than Mount Washington), and in its isolation and crater-like formation the most remarkable mountain in New England.

Mountains.

Lakes.

The lakes of Maine, situated for the most part among these mountain regions, are among its characteristic and most attractive features. They number more than 1570, with an aggregate area of 2300 square miles, about one-fifteenth part of the entire area of the State. The largest is Moosehead Lake, 35 miles long by 10 miles wide; but many others of less size are more picturesque. Their height above the sea-level is noticeable. Rangely Lake, at the head of the Androscoggin river, is 1511 feet high, this altitude being very nearly that of Lake Itasca at the head of the Mississippi; Moosehead, on the Kennebec waters, is 1023 feet in height, or nearly two-thirds as high again as Lake Superior at the source of the St Lawrence; Chamberlain Lake, on the headwaters of the St John, 926 feet, and Chesuncook, on the Penobscot, 900 feet high, are 400 or 500 feet above the level of Lake Winnepesaukee in New Hampshire. Most of the lakes of Maine lie within regions as yet unsettled, where nature's wild luxuriance and grandeur are still undisturbed by man. Few similarly habitable regions possess lakes in such numbers and of such size, variety of situation, and beauty of aspect and surroundings. They are, moreover, nearly all connected with the river systems of the State, and constitute vast reservoirs for evaporation, irrigation, and mechanical power.

Rivers.

All the principal rivers rise at great elevations—the Saco at an altitude of 1890 feet, the Androscoggin 3000, the Kennebec 2000, the Penobscot 2500, the St John 1980. The general drainage areas, however, fall off in height and increase in breadth in proportion as their location is easterly. The principal features of the water systems of Maine are the great amount of fall, the control of steady volume by the storage capacity of the lakes, and the situation of the best falls in the lower sections of the rivers where the volume is largest, and in many instances at the head of tide-waters where vessels may come to their very feet. The water-power of the State available for industrial purposes has been estimated by Walter Wells, in his valuable report on that subject, to amount to 1,229,200,000,000 cubic feet, with gross power of 4427 horse for each foot of fall, making a total of 2,656,200 horse-power.

Geology and minerals.

The important geological features are connected with the highly crystalline metamorphic condition of the strata, which rarely lie in horizontal position, but are upturned, bent, folded, and fractured. Fossiliferous rocks occur only in limited localities in the interior. In various places veins of silver-bearing galena and of copper are exposed. Granite of every variety and quality abounds in veins and in eruptive masses. The western portion of the State is largely granitic in its features, and a belt of the same rocks extends along the entire sea-coast. There are also beautiful varieties of syenite. In many places the granite is very coarse, so that the constituents can be separated, and each utilized for industrial purposes. The felspar, quartz, and mica often lie in large contiguous veins. Valuable beds of crystalline limestone are found in many places along the coast, and in the Aroostook region. Argillaceous slates as well as limestone occur in the interior and in the north. On the Piscataquis, a tributary of the Penobscot, the slate is suitable for writing-slates and pencils, blackboards, and tables, while large quantities of roofing slate are found throughout the whole region between the Kennebec and Penobscot. There are also some beds of marble well suited for building purposes. Some surface iron is found, especially in one locality in the interior known as the Katahdin iron-works, where the iron is remarkably pure owing to its freedom from sulphur and phosphorus. A bed of hæmatite is found in Aroostook county.

The soil is mostly of glacial origin, derived largely from boulders and a mixture of rocks transported from various and often distant localities. This drift is spread everywhere over the surface. Along the lake-beds and rivers are some alluvial soils and old flood-planes. Deposits of Quaternary marine clays occur along the south border, rising to the height of 200 feet above the sea. These clays were deposited during the Champlain epoch, at a time when the temperature of the water was much lower than at present, as is indicated by the fossil remains which abound in them. In the lower strata these remains of life are of the same species as are now found living in the Arctic seas. Skeletons of the walrus have been found in Portland and elsewhere. In the upper strata the remains of life indicate the same species as now exist on the coast. Isolated forms of life not elsewhere found north of Massachusetts occur in the north part of Quohaug Bay (north-east of Casco Bay), composed of various species which seem to be a remnant of former life on this coast. A family of living oysters is still found among the debris of giant progenitors in the Damariscotta river, east of the Kennebec; and remains of the oyster, quohaug, and scallop are abundant in the numerous and extensive shell-heaps found all along the coast.

Zoology.

In general it may be said that animal life in this State shows a mixture of northern and southern forms, and but little that is peculiar as compared with surrounding regions. The moose, caribou, and deer still roam in the vast forests in the north. The bear, wolf, catamount, wolverene, wild cat, fox, beaver, raccoon, marten, sable, woodchuck, rabbit, and squirrel keep at a due distance from man, and so still exist. Seals are found in many of the bays. Wild geese and ducks and other sea fowl frequent the lakes and bays in the migratory season, and eagles, ospreys, gulls, hawks, kingfishers, owls, plover, woodcock, partridges, pigeons, quails, blackbirds, robins, orioles, bobolinks, blue birds, swallows and sparrows in all variety, yellow birds, and humming birds are common. The inland waters teem with fish of various kinds—pickerel, togue, and bream, and, chief of all, the trout, whose beauty and size attract numbers of sportsmen; while in the rivers the sturgeon, bass, and salmon are still plentiful. Game laws protect several species of the fish, birds, and other animals. Along the coast the clam, mussel, and lobster are abundant, and in some places the horse-shoe crab is found. Of shore-fish the cunner, flounder, rock-cod, and sculpin are most common, while off shore cod, haddock, hake, herring, pollack, menhaden, porgy, and mackerel abound. The black fish and porpoise are not uncommon. Gigantic cuttle-fishes, measuring 40 feet and upwards in the long tentacles, and thus not inaptly termed sea-serpents, have sometimes been seen in these waters.

Forests.

The forests of Maine consist chiefly of pine, spruce, hemlock, and fir, although some oak is found along the coast, and other hard wood growth in the highlands of the Aroostook. The white cedar is common, especially in the low lands in the east and north-east. The hackmatack or black larch appears in the same localities. White and red oak, rock (or sugar) maple, white maple, white and yellow birch, white and brown ash, beech, cherry, basswood (linden), and poplar are the common deciduous trees. Chestnut and walnut are rare, and are found only near the south-west border. The majestic mast pine—the heraldic emblem of Maine, which has given it the sobriquet the "Pine Tree State"—is fast receding before the demands of commerce. Of fruit trees the chief is the apple. The plum, cherry, and pear are also natural. The peach thrives only in the south-west border. Species of grape, gooseberry, and currant are native, and others are cultivated with advantage. The blackberry, raspberry, and strawberry grow wild in profusion throughout the State.

ruits.

limate.

The climate of Maine, while on the whole cooler than might be expected from its mean latitude of 45° N., cannot be considered severe or unfavourable to health. The summer heats are tempered by the sea and the cool north winds. The winter cold has a constancy which makes it less severely felt than the changing temperature of more southern places. The air is also more dry and pure owing to the snow surface. The average winter temperature is about 20°, and remains pretty steadily below the freezing-point throughout the State for at least three months. By reason of the tides and the prevailing off-shore winds, which break up and drive off the ice, many of the harbours are unobstructed the winter through. The summers are short, giving something less than five months between frosts, even in the southern portion, but the heat sometimes rises for a few days to 100° Fahr. The average summer heat is 62°·5 Fahr. The lakes and forests of Maine attract great numbers of summer tourists, and the sea-coast is fast becoming lined with the cottages of summer residents from all parts of the country.

lealth.

The soil is well-drained, and the surface swept by sea breezes and winds from the forests and mountains of the north-west, which tend to banish malarious disease. The principal form of disease is phthisis or disease of the respiratory organs, the ratio of deaths therefrom being a little over 27 per cent. of the entire mortality. This has been called the "scourge of New England"; but in Old England the death-rate from this class of diseases is only a fraction less—26·6 per cent.

ldminis-
ration.

The old United States district court for Maine, constituted in 1779, remains; and Maine, New Hampshire, Massachusetts, and Rhode Island constitute the first district of the United States circuit court. The officers of these courts are a judge, district attorney, marshal, clerk, and reporter. Maine is also a district for the collection of United States internal revenue. There are seven United States forts in Maine, only one of which, Fort Preble, Portland, is fully garrisoned; and the United States navy yard, often called Portsmouth navy yard, is in Kittery, Maine.

Maine has two senators and four representatives in Congress, and six votes in the electoral college for choosing the president. The government of Maine rests on a constitution adopted in 1820, which closely resembles that of the other New England States. It is most liberal in respect to suffrage, every male citizen twenty-one years of age and upwards resident in the State for three months, except paupers, persons under guardianship, and Indians not taxed, being allowed to vote. The governor and legislature are chosen every two years, and the legislative sessions are also biennial. A council chosen by the legislature on joint ballot advises and assists the governor in the appointment of State officers, management of State institutions and lands, granting pardons, and other duties with which they may be charged by the legislature. The judiciary consists of a supreme court of eight members at a salary of $3000, with a reporter of decisions, appointed by the governor and council for seven years; the superior courts for Cumberland and Kennebec counties, whose judges are appointed in the same way; as also trial justices for the several counties with jurisdiction in minor cases; justices of the peace for the county, who are authorized to solemnize marriage, with other prescribed duties; and municipal and police judges. Each county elects judges of probate and insolvency, and registers of the same, a county attorney, clerk of court, sheriff, and county commissioners.

Militia.

The enrolled militia numbers 97,320. The present system keeps up an élite corps consisting of two regiments of volunteer infantry and one battery of light artillery, with two regiments of reserve infantry. Much pains is taken in the discipline and character of this small corps, and membership in it is regarded as honourable. The entire State militia is by existing orders constituted into one division under the command of a major-general, who is elected by concurrent ballot of the two houses of the legislature.

Reformatory and benevolent institutions.

Various reformatory, sanitary, and benevolent institutions are supported wholly or in part by the State. The State prison, with an average of one hundred and forty-six convicts, is managed on the "hard labour" and the "silent" system, at an annual expense of $30,000, which in some years is cancelled by the proceeds of the convicts' labour, chiefly employed in carriage and harness making. The hospital for the insane is an extensive establishment, with upwards of four hundred inmates and an increasing demand for more accommodation. The annual appropriation for State beneficiaries here is $40,000. An annual appropriation ($14,000) is made for the education of the deaf and dumb and the blind, and also ($1200) for the care of idiotic and feeble-minded persons in institutions out of the State.

Indians.

The remnants of two tribes of Indians still exist in Maine, with which the State is in public relations, the Penobscots, numbering about six hundred, and the Passamaquoddies, numbering five hundred. The former have their chief gathering place on the islands in the Penobscot river, and the latter on the shores of Passamaquoddy Bay and the St Croix river. Though classed usually as civilized, they are still virtually in tribal relations. Their status is determined by a series of treaties from early times, which are a curious mixture of notions of international rights and of wardship.

Maine liquor law.

The public policy which has culminated in the well-known prohibitory "Maine Law" began with the "Act to restrict the sale of intoxicating liquors," passed in August 1846. This was followed in 1851 by an "Act for the suppression of drinking houses and tippling shops," and by thirty-nine other statutes directed against liquor selling, drunkenness, and the habit of drinking in the community. The manufacture for sale of any intoxicating liquors, except cider, is forbidden. The sale of such liquor by the manufacturer is punished by imprisonment for two months and a fine of $100. Unadulterated cider in quantities of 5 gallons and upwards may lawfully be sold. No person is allowed to sell any intoxicating liquors, including wine, ale, porter, strong beer, lager beer, and all other malt liquors, also cider for tippling purposes, on a penalty for a first offence of $30 and costs, or imprisonment for thirty days; for a second offence $20 and costs and imprisonment for thirty days; third offence $20 and costs and imprisonment for ninety days. A common seller on conviction is punished for a first offence by fine of $100 and costs, or imprisonment for three months; for a second and subsequent offences $200 and costs, and four months' imprisonment. A person convicted of keeping a drinking house or tippling shop is punished by fine of $100 and costs, or imprisonment for three months, for a first offence, and the same with six months' additional imprisonment for every subsequent conviction. Any one injured in person, property, means of support, or otherwise by an intoxicated person may bring an action for damages against the person who sold the liquor; and the owner or lessee of the building where it was sold is jointly liable if cognizant of such use. Any person convicted of being intoxicated in the streets or in any house, or of disturbing the public peace or that of his own or any family, is punished by a fine of $10, or thirty days' imprisonment, and for the second offence $20 or ninety days. All intoxicating liquors kept for sale and the vessels containing them are contraband, and forfeited to the towns where seized, and are there to be destroyed. To provide for the necessary sale of such liquors a State commissioner is appointed by the governor and council to furnish to the municipal officers of towns pure, unadulterated intoxicating liquors to be sold for medicinal, mechanical, and manufacturing purposes. He is put under $10,000 bond, and is allowed 7 per cent. commission on his sales. Municipal officers may purchase what they deem necessary of such liquors, and appoint an agent to sell them for such purposes as have been named, and no other. This agent is forbidden to sell to any minor, soldier, Indian, or intoxicated person, or to any person of whose intemperate habits he has been notified by such person's relations or by the municipal officers. It is made the special duty of sheriffs and county attorneys to enforce the provisions of the laws relating to the sale of intoxicating liquors.

The history of this legislation is that of laws generally which are enacted rather from the high moral ends which they propose than from the sincere and settled judgment of the legislators, and which do not represent the average moral sentiment actually prevailing among the people in whose name they are enacted and are to be enforced. It was inevitable that towards an issue like this political parties should take an attitude not always sincere. The Maine law has not entirely suppressed drunkenness, or even liquor selling, but it has had a decided influence in that direction. It has also tended to make drinking disgraceful, and has removed much temptation from young men. The people would be reluctant to abolish it until they could see something better to put in its place.

Population.

The population of Maine has not increased at an equal ratio with the other States of the Union, as will be observed from the subjoined table. There is a constant emigration from the State of native-born people to other parts of the country, which is only about half made up for by immigration from the adjoining provinces and the Old World.

Census Years.	Total.	Males.	Females.	Density per sq. mile.
1790............	96,540	49,432	47,108	3·2
1800............	151,719	77,250	74,469	5·1
1810............	228,705	116,118	112,587	7·7
1820............	298,335	149,664	148,671	9·9
1830............	399,462	201,232	198,230	13·4
1840............	501,793	253,709	248,084	16·8
1850............	583,169	297,471	285,698	19·5
1860............	628,279	317,189	311,090	21·0
1870............	626,915	313,103	313,812	20·9
1880............	648,936	324,058	324,878	21·6

In 1880 the number of native-born was 590,053, and of foreign-born 58,883.

The following cities had in 1880 a population of 5000 and upwards :—Portland, Lewiston, Bangor, Biddeford, Auburn, Augusta, Bath, Rockland, Saco, Calais, Brunswick, Belfast, Ellsworth.

Divorces.

Divorces in Maine reach the highest ratio to the marriages, or to the population, of any State of which statistics are reported. The privilege of a jury trial favours the plaintiffs, and it is not easy to find a jury who will withhold a verdict for divorce.

Diminished birth-rate.

The birth-rate of the native or oldest and typical families of Maine has greatly fallen off, and the number of children of school age is diminishing, not only proportionately to the population but in positive numbers, the diminution for the last eleven years being 14,200.

Church statistics.

The latest reports as to the religious societies of Maine show that there are 242 Congregationalist churches, with a membership of 21,340 ; 261 Baptist churches, membership 20,954 ; Methodist 228, membership 20,774 ; Freewill Baptist 286, and membership 15,822 ; Christian 60, membership 6000 ; Universalist 41, membership 4500 ; Unitarian 21, membership (estimated) 2500 ; Episcopal 32, membership 2115 ; New Jerusalem 5, membership 341 ; others 9500 ;—total Protestant membership 103,846. There are 42 Roman Catholic churches, with a membership of 40,000. The tendency seems to be to a decrease of the Congregationalists, and a corresponding increase of the Free Baptists and Methodists.

Education.

Common school education in the State is widespread. In the number of citizens able to read and write it stands in the very front rank of States. Instruction in the public schools is not under ecclesiastical control, and is free to all between the ages of four and twenty-one, and compulsory upon all between the ages of nine and fifteen years for twelve weeks each year. Every city and town is required to raise and expend annually for schools not less than 80 cents for each inhabitant. The State meets this on its part by distributing, in proportion to the number of children of school age in each town, the income of a permanent school fund ($44,275,791), and by a State tax of 1 mill per dollar of valuation on the property in the State, and a tax of one per cent. on the average annual deposits in savings banks. The average cost of supporting the public schools is $1,240,000 a year. In the larger towns the schools are graded into primary, intermediate, and grammar schools. A system of free high schools was established in 1878, for which the State contributes a sum equal to that paid by the town, not exceeding $250. The whole sum appropriated in 1881 was $26,000. There are three normal schools, intended for the training of teachers in the common schools. For these tuition is free, and the annual appropriation required is $19,000. The State college of agriculture and mechanic arts may in some respects be considered the culmination of the public school system. A large farm and various workshops are here provided, and every facility afforded at the least possible expense for a good education, chiefly directed to the industrial arts, but still liberal in scope. There are three colleges, with the usual course of study leading to the degrees of bachelor and master of arts :—Bowdoin, founded by the old State of Massachusetts in 1794, and since liberally endowed by private benefactions, from which Hawthorne and Longfellow graduated ; Colby University, founded as Waterville College in 1820, and under the control of the Baptist denomination ; and Bates College, founded in 1863, in the interest of the Free Baptist denomination, with a fitting school and a theological seminary attached. The theological seminary at Bangor, under the care of the Congregationalists, is open to all denominations, and attracts many students from the adjacent provinces of Canada. The medical department of Bowdoin College is known as the medical school of Maine. It has an annual attendance of more than 100, and has graduated 1300. There are various societies which are of a nature to afford instruction. The Maine Historical Society is making interesting investigations, and preserving memorials and records of historical matters, and its publications are of much value.

Public debt.

The bonded debt of the State is $5,801,900, which matures on or before 1889. Deducting the sinking fund of $1,436,367, the actual balance of indebtedness is now (1882) $4,365,533. The local and municipal debt for all purposes, including aid to railroads, is $17,722,109.

Agriculture.

The total settled area of Maine is 17,900 square miles, of which 6000 have a population of 2 to 6 to the square mile, 3500 have 6 to 18, 5600 have 18 to 45, and 2800 have 43 to 90. Agriculture is still the most extensive occupation, engaging 83,000 of the people. There are 64,310 farms, with 1,864,136 acres of tillage. Of these 61,530 farms are occupied by their owners ; 24,640 contain over 100 acres each, and nearly as many have between 50 and 100 acres. The chief farm products are annually :—potatoes, 8,000,000 bushels ; hay, 1,200,000 tons ; butter, 14,103,960 lb ; cheese, 1,167,770 lb ; oats, 2,265,575 bushels ; maize, 960,633 bushels ; wheat, 665,714 bushels ; buckwheat, 382,701 bushels ; barley, 242,185 bushels ; rye, 26,398 bushels ; wool, 2,776,404 lb ; milk sold, 3,720,783 gallons.

Forest tracts.

The remaining unsettled area is mostly unbroken forest. At present this region only furnishes material for lumbering. The pine has been cut back to the headwaters of the rivers, and the chief material is spruce and hemlock, with some cedar. The principal shipping port is Bangor on the Penobscot, where the amount surveyed has been 200,000,000 feet a year.

Fisheries.

In fisheries the State stands second in the Union. There are 12,662 persons directly employed in fisheries, but it is estimated that 48,000 people are dependent chiefly on this business. The sea fish taken are cod, hake, haddock, pollack, herring, mackerel, and holibut. The amount taken is 206,778,693 lb annually. There are establishments for preparing oil from the menhaden, &c., where 168,732 gallons a year are produced. The canning of fish is a considerable industry ; and in the lobster canning business this State has a monopoly. The catch in 1879 was for Maine 14,234,182 lb, and that bought of British fishermen 10,588,578 lb. In the home establishments 1,830,200 cans were put up, and in those worked in the British Provinces on account of Maine owners 2,198,024 cans. A recent but rapidly growing interest is that of sardine canning, chiefly carried on at Eastport. In 1880 there were 1328 persons employed in this industry, with an annual product of 7,550,868 cans and 8365 barrels. The river fish chiefly taken are salmon, shad, alewives, and smelts. Much interest is taken in restocking the lower rivers, especially with salmon, shad, and bass. The Penobscot is the only river on the Atlantic coast of the United States from which a supply of sea salmon eggs can be obtained for propagation. An association of the United States with the States of Maine, New Hampshire, Massachusetts, and Connecticut appoints agents for procuring these eggs, which are distributed in proportion to the respective contribution of funds. The great hatchery is at Orland, where also there is one for the eggs of the land-locked salmon ; there is another at Grand Lake Stream, owned by the same association. The black bass and alewives have also been distributed in the lower ponds and streams.

Other industries.

The other native products are lime, quarried stone,—both for building and for monumental purposes—slate, iron, and copper. Ice is cut and shipped to various parts of the world, to the amount annually of 350,000 tons, and the value, when ready for transportation, of $600,000. Maine was long distinguished for her shipbuilding ; and, though of late years this industry has greatly fallen off, yet in the building of wooden ships the State probably holds her old rank. The shipping owned in Maine is mostly engaged in foreign commerce, or in coasting to and from distant States. There are 12,000 sailors in this service. There are 1022 miles of railroad in Maine. Of manufactories there are 24 cotton-mills, running 696,564 spindles, and employing 11,844 persons, of whom 7010 are women ; and 97 woollen-mills of all kinds, employing 3265 persons, of whom 1160 are women. The other chief industries are flouring mills, leather tanneries, boot and shoe making, paper making, and iron working of various kinds.

History.

The shores of what is now sometimes called the Gulf of Maine, whose waters stretch between Cape Sable and Cape Cod, attracted much attention from the early voyagers and explorers, as many glowing accounts remain to testify. The Cabots, under English auspices, visited this region in 1497 ; Verrazano, representing the French, in 1524 ; Gomez in the name of Spain in 1525, giving his name to Penobscot river and bay. In 1526 the Frenchman Thevet followed ; he states that before that time the French had a fort 30 miles up the river, named Norumbega. The enterprise of Sir Walter Raleigh and Sir Humphrey Gilbert first reveals a purpose on the part of Englishmen to colonize these shores. Gosnold (1602), Pring (1603), and Weymouth (1605) had made some explorations, but a century had passed and no European power had gained a foothold on the Atlantic coast north of Florida. But in 1603 Henry IV. of France granted a charter to De Monts, a Protestant gentleman of his household, of all North America between 40° and 46° N. lat. In 1604 De Monts established a settlement on what is now Neutral Island, in the St Croix river. In 1605 James I. of England granted to some English gentlemen all the territory between 34° and 45° N. lat. The portion between 40° and 45° was thus the subject of a double grant, to parties naturally antagonistic. The latter parallel, striking nearly at the mouth of the St Croix, includes almost all the southern half of Maine, and brought what was practically at that time the whole of Maine to be the theatre of the disputed jurisdiction. The French did not indeed claim further west than the Kennebec river, the limit of their actual occupation; but the English endeavoured by sporadic and violent sallies to hold, if not by occupation at least by desolation, to the St Croix river, the extreme north-east boundary of their claim. The Indians, already exasperated by the wrongs received from roving English shipmasters and traders, were easily persuaded to make alliance with the French, and this double frontier was a scene of strife for the space of one hundred years. The English with much earnestness of purpose proceeded to plant a colony in 1607, under the guidance of George Popham, brother of the chief-justice of England, and Captain Gilbert Raleigh, whose name indicates his lineage and spirit. This colony they planted with solemn ceremonies on a point at the mouth of the Kennebec. The little town rose rapidly, with its fort and its church in due order. They also built a vessel, the "Virginia of Sagadahock," the first vessel built by Europeans in America. The colony grew discouraged by their winter experiences, and the next year broke up, most of the colonists returning to England. It appears, however, that they did not utterly forsake their object, for scattered settlements still remained and increased about the Point and Bay of Pemaquid and the island of Monhegan, midway between the Kennebec and Penobscot. This region became a centre of trade and a base of operations, being the headquarters of the famous Captain John Smith, where he built a fleet of boats in 1614, and explored the adjacent coast, which he named New England. In 1620 a new impulse found expression in the great charter of New England, given to Sir Ferdinando Gorges and others, who proceeded to lay out their plans on a large scale. Two years afterwards a patent under this charter conveyed to Gorges and Captain John Mason the country between the Merrimac and Kennebec and 60 miles inland, which they proposed to call the province of Maine. In 1629 they divided their possession, Gorges taking the portion between the Piscataqua and the Kennebec.

The great council of New England surrendered their charter in 1635, and in the division of its territory Gorges retained his portion previously granted, while the region between the Kennebec and the St Croix and the St Lawrence rivers, though still claimed by the French as part of Acadia, was given to Sir William Alexander, earl of Stirling, and this was to be called the county of Canada. Gorges named his tract the county of New Somersetshire, and immediately commenced the administration of government, setting up a court at Saco (1636) under direction of his kinsman, William Gorges. In 1639 he obtained from Charles I. a new and extraordinary charter, confirming to him his province of Maine under that name, and under the feudal tenure of a county palatine, Gorges, as lord palatine, being invested with vice-regal powers. In 1641 he established a capital and court at Georgiana (now York), the first chartered city in America. But it was no easy task to administer government or hold a jurisdiction in his palatinate. The great council of New England, before breaking up, had granted not less than nine patents, conveying territory already included in Gorges's thrice-granted jurisdiction, to various parties, who had made vigorous beginnings to improve their holdings and confirm their claims. In like manner the council had made two important grants within the jurisdiction of Sir William Alexander, so that difficulties arose in that quarter also. In this confusion of jurisdiction Massachusetts, under a new construction of the extent of her chartered rights, laid claim to a line which included nearly all the settled portion of Gorges's territory, and by a farther extension she claimed the coast as far east as Penobscot Bay. This latter she named the county of Devonshire, and set up a court at Pemaquid (1674). This latter territory had been conveyed by the earl of Stirling to the duke of York, afterwards James II. of England. This was organized by James as the county of Cornwall, and was afterwards represented in the general assembly in New York (1683). In 1677, however, the claim of Massachusetts in Maine being contested and decided adversely to her, she took the occasion to buy of the heirs of Sir Ferdinand Gorges all his right, title, and interest in Maine for £1250. Matters were still more complicated by the persistent efforts of the Dutch to gain possession of the east coast, who had now (1676) effected a lodgment on the shores of Penobscot Bay; but they were finally driven off. The troubled state of things in England prevented Massachusetts from profiting very much by her purchase in Maine, and at last the new charter of William and Mary (1691) merged all the provinces of Plymouth, Massachusetts, Maine, Sagadahock, and Acadia under one title and jurisdiction, "the province of Massachusetts Bay."

That part of Acadia east of the St Croix was five years afterwards ceded back to the Crown. Thus Maine, with the St Croix for its eastern boundary, became an integral part of the Province, afterwards the State, of Massachusetts Bay. From that time for over one hundred years the history of Maine is merged in that of Massachusetts. Although its people were not of the religious or political faith of the Puritan colony, and for that reason had been shut out of the famous New England confederacy of 1643, yet they were true Englishmen, and stood manfully for the common cause. Not only was Maine an exposed frontier and battleground, during the long struggle of the English against the Indians and the French, but its citizens bore a conspicuous part in the expeditions beyond its borders. Two of these were commanded and largely manned by men of Maine. Port Royal was taken by Sir William Phipps and Louisburg by Sir William Pepperell. In fact these expeditions were such a drain on Maine population that Massachusetts was called upon to send men to garrison the little forts that protected the homes left defenceless by the men who had gone to the front. The great losses and destruction of these wars kept this portion of the province back from its natural increase.

In the stand made for the rights of Englishmen, which led to revolution and independence, Maine was behind none. Two years before the battles of Lexington and Concord its towns had offered themselves "as a sacrifice if need be to the glorious cause of liberty." Some, it is true, were deep-rooted in sympathy with the mother country, and these retired eastward, first beyond the Penobscot and afterwards beyond the St Croix. This war made Maine again an outpost and frontier. That same picturesque and commanding promontory of Castine in Penobscot Bay, which had been once the most eastern post held by the Pilgrims of Plymouth and afterwards the western advanced post of the French in Acadia, was now the stronghold of the English in this region, as against the Americans. Early in the war (1775) the chief town, Falmouth (now Portland), was bombarded and nearly destroyed. Some patriots the same year attacked a king's ship off Machias, and after a desperate struggle the British flag was struck to Americans for the first time on sea or land. Maine was fully and honourably represented in the war by a division of the Massachusetts line. It had also representatives in Congress, and some eminent officers and patriots of the Revolution resided within its borders. In fact, to all intents and purposes except in name, Maine was one of the original States of the Union.

At the close of the war, the old spirit of independent personality and self-government made a forcible expression. The people sought to be separated from Massachusetts, and to make their laws and their history in their own name. There were two parties, however, and the troubles which agitated the whole country at that time, postponed action on this issue, and Maine continued almost forty years longer an integral part of Massachusetts, but was at no time a dependent province of that State. At the conclusion of peace there was a large immigration into Maine, chiefly of soldiers of the Revolution, who strengthened the already vigorous character of the people. Everything prospered until the Embargo Act of 1808, cutting off commerce and the coast trade, struck Maine in a vital point. Its shipping at this time amounted to 150,000 tons, its exports to a million dollars a year. The war with England, which soon followed, almost destroyed these interests. Other industries, however, were stimulated. Manufactories of woollen, cotton, glass, of iron and other metals were set on foot, only to be ruined by the influx of British goods, which followed the new peace. It was a discouraging time, and one or two unusually severe winters threatened the only industries which the war and peace had spared, while in 1815–16 not less than 15,000 people emigrated to Ohio. In 1820 Maine was recognized as a separate State of the Union. Its population was then about 300,000, and its chief industries, agriculture, lumbering, and shipbuilding, were in prosperous course. Its encouragement of manufactures was slow. A prejudice against great corporations long kept Maine from entering largely at the auspicious time into those industrial enterprises which have built up neighbouring States. It is only within recent years that the State has begun to take proper advantage of its unsurpassed facilities for manufacturing. The difficulties about the north-eastern boundary had increased with each year since the treaty in 1783. Great Britain had gradually obtained possession of considerable territory within the line claimed by the States under the treaty, and after the war of 1812 laid claim to territory which had long been under the actual jurisdiction of Massachusetts. The question assumed national and international importance. The Government of the United States, apparently desirous of gratifying Great Britain, offered Maine 1,200,000 acres of land in Michigan to yield its claim, but the proposition only roused indignant protest in the State, which culminated in the sending of a military force to defend its territory. Finally, however, considerations of national policy urged at Washington induced Maine to acquiesce in a treaty, which took away a large area additional to that already silently yielded, amounting in all to 5500 square miles,—an area greater by 600 square miles than the State of Connecticut, and by

1680 square miles than the States of Rhode Island and Delaware combined.

In the war against secession the service of the State was prompt and efficient. Maine sent to the front 72,000 men, of whom not less than 20,000 gave their lives for the cause. These volunteers were distributed in thirty-two regiments of infantry, two regiments of cavalry, one regiment of artillery, one battalion of sharpshooters, and 6764 enlistments in the navy. The whole amount of State and municipal debt incurred in raising and equipping these troops was about $12,000,000. The United States afterwards reimbursed the State to the amount of $668,284, most of which was applied to form a sinking fund for extinguishing the war debt at maturity. The State also provided pensions for its disabled soldiers and their families. (J. L. C.)

MAINE DE BIRAN, FRANÇOIS-PIERRE-GONTHIER (1766–1824), a distinguished philosopher of France, the son of a physician, was born at Bergerac November 29, 1766. After studying with distinction under the *doctrinaires* of Perigueux, he entered the life-guards of Louis XVI., and was present at Versailles on the notable 5th and 6th of October 1789. On the breaking up of the *garde du corps*, Maine de Biran retired to his patrimonial inheritance of Grateloup, near Bergerac, where his sequestered residence and limited income preserved him from the horrors of the Revolution. It was at this period that, as he says himself, he "passed *per saltum* from frivolity to philosophy." The forced leisure of this fearful time decided the vocation of his life. He combined, in a more than ordinary degree, subtle sensitiveness to external influences with singular acuteness in surveying and analysing internal phenomena. The modes of the mind and their organic causes or conditions were alike submitted to his scrutiny. He began his philosophical studies with psychology, and he made psychology the study of his life. When the Reign of Terror was succeeded by calmer days, Maine de Biran was called to take part in the administrative and political affairs of his country. After his exclusion from the council of the Five Hundred on being suspected of royalism, he took part with his friend Lainé in the commission of 1813, which gave expression for the first time to direct opposition to the will of the emperor. After the Restoration he held the office of treasurer to the chamber of deputies, and habitually retired during the autumn recess to his native district to pursue his favourite study. He died 16th July 1824.

Maine de Biran's philosophical reputation has suffered from two causes—the obscure, laboured quality of his style, and the unfortunate mode of publication of his writings. In all his work there is evidence of thorough originality of thinking, but in the expression of his thoughts this very originality is so far a disadvantage in that it imposes on him a mode of exposition little calculated to attract and retain the attention of a reader. During his life, moreover, but few, and these the least characteristic of his works, were formally published. An essay on habit (*Sur l'Influence de l'Habitude*, 1803), a critical review of Laromiguière's lectures (1817), and the philosophical portion of the article Leibnitz in the *Biographie Universelle* (1819) appeared during his lifetime. A long memoir on the analysis of thought (*Sur la Décomposition de la Pensée*), crowned by the Institute in 1805, was sent to press, but, for some reason, was not finally printed. His manuscripts, very large in quantity, were not made accessible in their entirety to Cousin when that writer desired to prepare a collective edition of De Biran's works. In 1834 the writings above enumerated, together with the important essay entitled *Nouvelles considerations sur les rapports du physique et du moral de l'homme*, were published by Cousin, and in 1841 there were added three volumes by the same editor, under the title *Œuvres philosophiques de Maine de Biran*. The manuscripts from which Cousin had prepared this edition were, however, in a most imperfect condition, and it was known that some memoirs to which De Biran attached the greatest importance were still in obscurity. In 1845 a large mass of manuscript was placed by De Biran's son in the hands of F. M. E. Naville. The labour of preparing these for publication, interrupted by the death of Naville in 1846, was continued by his son, E. Naville, and completed, with the aid of M. Debrit, in 1859. The *Œuvres inédites de M. de Biran*, 3 vols., rendered it possible for the first time to obtain a connected view of a very remarkable monument of philosophical development. In these volumes the most important work is that entitled *Essai sur les fondements de la psychologie et sur ses rapports avec l'étude de la nature*, which represents the completest stage of De Biran's thinking. A later stage is represented by the fragments of a projected work entitled *Nouveaux Essais d'Anthropologie*, in which the psychology of the earlier treatise is developed in the direction of a somewhat mystical metaphysic.

De Biran's first essays in philosophy were written avowedly from the point of view of Locke and Condillac, but even in them he was brought to signalize the essential fact on which his later speculation turns. Dealing with the formation of habits, he is compelled to note that passive impressions, however transformed, do not furnish a complete or adequate explanation. With Laromiguière he distinguishes attention as an active effort, of no less importance than the passive receptivity of sense, and with Butler distinguishes passively formed customs from active habits. Prolonged meditation, evidenced in the occasional writings, prize essays, and the like of the subsequent years, brought him to the far-reaching conclusion that Condillac's notion of passive receptivity as the one source of conscious experience was not only an error in fact but an error of method,—in short, that the mechanical mode of viewing consciousness as formed by external influence was fallacious and deceptive. For it he proposed to substitute the genetic method, whereby human conscious experience might be exhibited as growing or developing from its essential basis in connexion with external conditions. The essential basis he finds in the real consciousness of self as an active striving power, and the stages of its development, corresponding to what one may call the relative importance of the external conditions and the reflective clearness of self-consciousness, he designates as the affective, the perceptive, and the reflective. These stages are characterized with much skill and psychological acuteness, and in connexion therewith De Biran treats most of the obscure problems which arise in dealing with conscious experience, such as the mode by which the organism is cognized, the mode by which the organism is distinguished from extra-organic things, and the nature of those general ideas by which the relations of things are known to us—cause, power, force, &c. His views are always suggestive, and the best recent psychology in France is but a reproduction of some of them.

In the latest stage of his speculation De Biran distinguishes the animal existence from the human, under which the three forms above noted are classed, and both from the life of the spirit, in which human thought is brought into relation with the supersensible, divine system of things. This stage, as above said, is left imperfect. Altogether De Biran's work presents a very remarkable specimen of deep metaphysical thinking directed by preference to the psychological aspect of experience. It is almost a solitary instance of an effort to treat psychology in a wide and philosophical manner.

The *Œuvres inédites* of De Biran by Naville contain an introductory study. Special monographs on him are—Merten, *Étude critique sur Maine de Biran*, 1865; E. Naville, *Maine de Biran, sa vie et ses pensées*, 2d ed., 1874; Gèrard, *Maine de Biran, essai sur sa philosophie*, 1876.

MAINE-ET-LOIRE, a western department of France, lying between 47° and 47° 50′ N. lat., and between 15′ E. and 1° 20′ W. long., consists of the southern portion of the former province of Anjou, and is bounded on the N. by the departments of Mayenne and Sarthe, on the E. by Indre-et-Loire, on the S. by Deux-Sèvres and Vendée, on the W. by Loire-inférieure, and on the N.W. by Ille-et-Vilaine. The extreme length from north-east to south-west is about 78 miles; the breadth from north to south ranges from 25 to 50 miles, and the area is 2750 square miles. The capital, Angers, lies 162 miles south-west from Paris. The department is made up of two distinct regions, the line of demarcation running from south-east to north-west, and passing through Angers; that to the south consists of granites, felspars, and a continuation of the geological formations of Brittany and Vendée; to the north, on the contrary, schists, limestone, and chalk prevail. The general elevation of the latter region is but small, and none of its eminences exceed 330 feet in height; the former, on the contrary, has a surface richly varied with deep winding valleys clothed with woods and thickets, though the highest points are under 700 feet. The department belongs entirely to the basin of the Loire, which traverses it from east to west by a valley varying in breadth from about 1 to 5 miles; the bed is wide but shallow, and full of islands, the depth of the water in summer being at some places little more than 2 feet. The floods which occur are sudden and destructive.

The chief affluent of the Loire within the department is the Maine, formed a little above Angers by the junction of the Mayenne and the Sarthe (the latter in turn having previously received the waters of the Loir). All three rivers are navigable. Other tributaries of the Loire are the Thouet (with its tributary the Dive), the Layon, the Èvre, the Divatte on the left, and the Authion on the right. The latter, which has a course parallel to that of the Loire, has been supposed, but erroneously, to occupy an ancient bed of that river. The Mayenne is joined on the right by the Oudon, which can be navigated below Segré. The Erdre, which joins the Loire at Nantes, and the Moine, a tributary of the Sèvre-Nantaise, both take their rise within this department. The climate, which is very mild, shares the characteristics both of the Sequanian and of the Armorican districts. The mean annual temperature of Angers is 3° Fahr. above that of Paris; the rainfall at the same place is only 18·64 inches, but rises to 23·6 inches farther down the river, and 27·75 as the sea is approached. Notwithstanding this deficiency of rain, the frequent fogs, combined with the peculiar nature of the soil in the south-east of the department, produce a degree of moisture which is highly favourable to meadow growths. The winter colds are never severe, and readily permit the cultivation of certain trees which cannot be reared in the adjoining departments.

Of the entire area more than one-half is arable; one-tenth is occupied by meadows; and considerably smaller areas are occupied by woods, vineyards, and heath respectively. Oxen number 225,000, pigs 100,000, and sheep 68,500; these figures represent a considerable commercial activity, as most of the animals are purchased out of neighbouring departments for the purpose of being fattened. Cholet alone exports annually 100,000 cattle, 150,000 or 200,000 sheep, and 25,000 or 30,000 pigs. The number of horses in the department is 55,000, chiefly of a race much used for light cavalry service. The cavalry school is at Saumur within this department. The production of cereals is in excess of the consumption; there are extensive areas in the valleys of the Loire and Sarthe under hemp, and linseed and colza oil are produced in quantity. The legumes of Saumur and Angers are specially prized. The wine of the department (14,000,000 gallons in 1880) is fairly good, and the white wine of Saumur is exported and sold as sparkling champagne (about 6,000,000 bottles yearly). Cider is produced, and large quantities of apples, pears, and plums are exported to the markets of Paris, England, and Russia. Floriculture is an important industry, and the forests of oak and beech abound in game (stag, roebuck, wildboar). Near Angers are slate quarries in which 3250 workmen are employed; and the "Layon-et-Loire" coal-bed produced in 1881 15,288 tons of coal and anthracite, which, however, did not supply the demand of the department. There are sandstone quarries in the arrondissements of Saumur and Baugé. Cholet, the chief manufacturing town, is famous for its pocket-handkerchiefs; it has also manufactures of linen cloths, flannels, and cotton stuffs, worsted and cotton thread factories, and bleaching works. Similar manufactures are carried on at Angers; the speciality of Saumur is the making of enamels and beads, in which it employs 600 workmen, producing goods to the annual value of 1,500,000 francs. The population of the department was 517,258 in 1876, being an increase of 141,714 since 1801. There are five arrondissements,—Angers, Baugé, Cholet, Saumur, and Segré. The capital is Angers.

MÁINPURÍ, or MYNPOOREE, a district in the lieutenant-governorship of the North-Western Provinces, India, between 26° 52′ 30″ and 27° 30′ N. lat., and 78° 27′ 45″ and 79° 28′ 30″ E. long., is bounded on the N. by Etah, on the E. by Farrukhábád, on the S. by Etawah, and on the W. by Muttra and Agra, and has an area of 1697 square miles, of which 949 are cultivated, and 190 cultivable. It consists of an almost unbroken level plain, intersected by small rivers, but unvaried by any greater elevations than a few undulating sand ridges. It is wooded throughout with mango groves, and isolated clumps of *bábul* trees occasionally relieve the bareness of its saline *usar* plains. On the south-western boundary the Jumna flows in a deep alluvial bed, sometimes sweeping close to the high banks which overhang its valley, and at others leaving room for a narrow strip of fertile soil between the river and the upland plain. From the low-lying lands thus formed a belt of ravines stretches inland for some 2 miles, often covered with jungle, but affording good pasturage for cattle. Moving north-eastward from this point, one reaches in succession the small rivers Aganga, Sengar, Rind, Isan, and Káli Nadi, most of which supply water to a small tract on either side, besides giving origin to rich deposits of cultivable silt. The Etawah and Cawnpur branches of the Ganges canal intersect the district for irrigation purposes, and the Lower Ganges canal, when completed, will furnish additional facilities in the same direction.

The census of 1872 returned the population of the district at 765,783 (males, 426,955; females, 338,828). The Hindus numbered 724,663, Mohammedans 40,965, Christians 85. Among high-caste Hindus, the Bráhmans number 67,072, and form a wealthy landholding class. Rájputs are returned at 60,155, amongst whom the Chauhans form the largest clan. They have long formed the aristocratic class of the district, and in 1872 owned 44 per cent. of the total area. Much of their hereditary property is, however, passing out of their hands into those of merchants and traders. Of the lower castes, the most important are the Ahírs, numbering 123,358, who own over 12 per cent. of the soil. For many centuries this tribe consisted of lawless robber hordes, who held the fastnesses of the Jumna ravines; and, though they have now been reduced to a comparatively industrial life, they still continue to afford the local authorities much trouble and anxiety. The Chamárs, 103,193 in number, are mere hewers of wood and drawers of water for the landholding classes, who held them in a condition of absolute serfdom under native rule. Other important Hindu tribes are Káchhis (72,898), Lodhás (53,658), Gadariyas (28,047), and Kahárs (25,273). The Moslems are for the most part poor and without social influence. Only four towns in the district contain a population exceeding 5000: Máinpurí, 21,117; Shikohábád, 10,069; Bhongáon, 6271; and Karhál, 5574.

Máinpurí is one of the districts where the question of female infanticide has long engaged the attention of Government, and even as late as 1872 this practice was so common as in a great measure to account for the large preponderance of males in the general population. In 1842 measures were first introduced for the supervision of the Chauhán Rájputs and Phátak Ahírs, among whom the practice was most common. Every female birth had to be duly reported and authenticated, together with a subsequent report on the child's health. Illness had to be immediately announced to the police, who held an investigation. These rules remained in force until supplemented by those of the Infanticide Act of 1870. In 1843 there was not a single female child among these tribes; in 1847 there were but two hundred and ninety-nine. In 1851 a convention of the heads of clans was held, when a body of rules was drawn up and subscribed to, but they were never observed. In 1865 a census of the Chauhán and Phátak villages was held, when six of the former were found without a single female infant. In some cases a daughter had never been known in the village. In 1870 it was found necessary to impose more stringent rules, and a special Infanticide Act was passed by the viceregal council. Inquiries instituted in connexion with the census of 1872 revealed the fact that many other tribes than the Chauháns and Pháţaks were implicated in the practice. In 1875, although a large proportion of the community had so far reformed in this respect as to be exempted from the special supervision provided by the Infanticide Act, there were still two hundred and seventy-six villages on the "proclaimed list" under the surveillance of a specially organized police, maintained by a tax levied on the guilty communities.

In Máinpurí almost every acre of available soil is under tillage. The total area under cultivation at the date of the last settlement was 607,991 acres. *Kharíf* or rain crops included cotton, 48,901 acres; *joar*, 120,497; *bájra*, 74,028; indigo, 5369; with a little maize, rice, hemp, &c., making up a total of 299,850 acres. *Rabí*, or spring crops were the following:—wheat, 105,488 acres; barley, 60,443; wheat and barley mixed together, 66,488; with gram, poppy, &c., making a total of 282,376 acres. There were also 17,523 acres under sugar-cane. Of the 607,360 acres cultivated in 1881, 337,726 were unirrigated, 180,415 were irrigated by private individuals, and 89,219 by Government. Two-thirds of the land is held by tenants with rights of occupancy, and one-third by tenants-at-will. Máinpurí suffers little from floods or blights, but in former years it used to be severely afflicted by drought. The means of communication, added to the large and increasing irrigation system, are now probably sufficient to protect the district from extreme distress in years of famine.

The district trade is almost entirely of a rural character. The chief exports are cotton, grain, indigo, *ghí*, and miscellaneous agricultural produce; while metals, English piece goods, sugar, pedlar's wares, tobacco, and rice are imported. Cotton thread is largely manufactured, and there is some trade in bangles, *hukás* or pipes, inlaid wood-work, and other fancy articles. Saltpetre is refined at several factories. The district is thoroughly supplied with land and water communications. Good metalled roads connect all the principal towns and villages; the East Indian Railway runs for 23 miles through the south-western angle; the navigable branch of the Ganges canal intersects the central plateau; and the natural highway of the Jumna skirts the district to the south.

The gross amount of assessment in 1880–81 was £115,132. Education was afforded in 1880–81 by 151 schools with 4146 pupils. The climate is hot but not excessively sultry during the summer months, and damp or foggy during the cold weather rains. The average annual rainfall for the five years ending 1870–71 was 32·20 inches. The chief endemic disease is malarial fever.

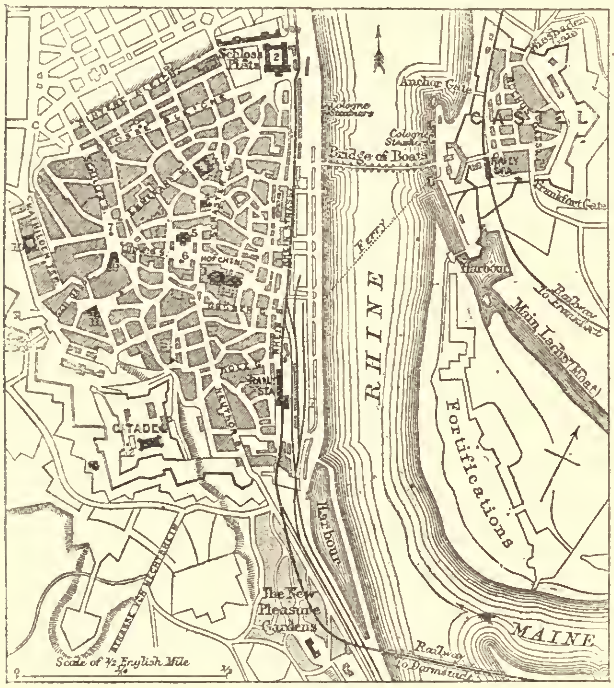
Máinpurí anciently formed part of the great kingdom of Kanauj, and after the fall of that famous state it was divided into a number of petty principalities, of which Rápri and Bhongáon were the chief. In 1194 Rápri was made the seat of a Moslem governor. Máinpurí fell to the Mughals on Bábar's invasion in 1526, and, although temporarily wrested from them by the short-lived Afghán dynasty of Sher Sháh, was again occupied by them on the reinstatement of Humáyún after the victory of Pánipat. Like the rest of the lower Doáb, Máinpurí passed, towards the end of the last century, into the power of the Mahrattas, and finally became a portion of the province of Oudh. When this part of the country was ceded to the British in 1801, Máinpurí town became the headquarters of the ex-extensive district of Etawah, which was in 1856 reduced by the formation of Etah and Máinpurí into separate collectorates. On the outbreak of the mutiny in 1857, the regiment stationed at Máinpurí revolted, and attacked the town, which was successfully defended by the few Europeans of the station for a week, until the arrival of the Jhánsí mutineers made it necessary to abandon the district.

MÁINPURÍ, the chief town and headquarters of the above district, is situated in 27° 14′ 15″ N. lat., 79° 3′ 5″ E. long., and had a population in 1872 of 21,117, viz., Hindus, 17,596; Mohammedans, 3435; Christians and "others," 146. The town consists of two separate portions, Máinpurí proper and Mukhamganj; the former traditionally dates from the prehistoric period of the *Mahábhárata*, while the latter was founded by Rájá Jaswant Sinh in 1803. Holkar plundered and burned part of the town in 1804, but was repulsed by the local militia. Since the British occupation the population has rapidly increased, and many improvements have been carried out. The Agra branch of the Grand Trunk Road runs through the centre, and forms a wide street lined on both sides by shops, which constitute the principal bazaar. Besides the usual Government offices, &c., in the civil station, the chief buildings are the police station, opium warehouses, jail, post-office, dispensary, two large schools, American Presbyterian mission, church, reading-rooms; there are two public gardens. The town carries on a considerable trade in cotton, indigo seed, country produce, and iron; and there is a manufacture of wooden articles inlaid with wire.

MAINTENON, FRANÇOISE D'AUBIGNÉ, MARQUISE DE (1635-1719), the second wife of Louis XIV., and unacknowledged queen of France for the last thirty years of his reign, was born in a prison at Niort on November 27, 1635. Her father Constant d'Aubigné, was the son of Agrippa d'Aubigné, the famous friend and general of Henry IV., and had been imprisoned as a Huguenot malcontent, but her mother, a fervent Catholic, had the child baptized in her religion, her sponsors being the Duc de la Rochefoucauld, father of the author of the *Maxims*, and the Comtesse de Neuillant. In 1639 Constant d'Aubigné was released from prison and took all his family with him to Martinique, where he died in 1645, after having lost what fortune remained to him at cards. Madame d'Aubigné returned to France, and from sheer poverty unwillingly yielded her daughter to her sister-in-law, Madame de Villette, who made the child very happy, but, unfortunately for her, converted or pretended to convert her to Protestantism. When this was known, an order of state was issued that she should be entrusted to Madame de Neuillant, her godmother. Every means, every indignity even, was now used to convert her back to Catholicism, but at the last she only yielded on the condition that she need not believe that the soul of Madame de Villette was lost. Once reconverted, she was neglected, and sent home to live with her mother, who had only a small pension of 200 livres a year, which ceased on her death in 1650. The Chevalier de Meré, a man of some literary distinction, who had made her acquaintance at Madame de Neuillant's, discovered her penniless condition, and introduced his "young Indian," as he called her, to Scarron, the famous wit and comic writer, at whose house all the literary society of the day assembled. The wit, who was of good legal family, and had a kind heart, took a fancy to the friendless girl, and offered either to pay for her admission to a convent, or, though he was deformed and an invalid, to marry her himself. She accepted his offer of marriage, and became Madame Scarron in 1651. For nine years she was not only his most faithful nurse, but an attraction to his house, where she tried to bridle the licence of the conversation of the time. On the death of Scarron in 1660, Anne of Austria continued his pension to his widow, and even increased it to 2000 livres a year, which enabled her to entertain and frequent the literary society her husband had made her acquainted with; but on the queen-mother's death in 1666 the king, in spite of all the efforts of her friends, refused to continue her pension, and she prepared to leave Paris for Lisbon as lady attendant to the queen of Portugal. But before she started, she met Madame de Montespan, who was already, though not avowedly, the king's mistress, at the Hôtel d'Albret, and the lady in question took such a fancy to her that she obtained the continuance of her pension, which put off for ever the question of going to Portugal. Madame de Montespan did yet more for her, for when, in 1669, her first child by the king was born Madame Scarron was established with a large income and a large staff of servants at Vaugirard to bring up the king's children in secrecy as they were born. In 1674 the king determined to have his children at court, and their governess, who had now made sufficient fortune to buy the estate of Maintenon, accompanied them. The king had now many opportunities of seeing Madame Scarron, and, though at first he was prejudiced against her, her even temper showed so advantageously against the storms of passion and jealousy exhibited by Madame de Montespan that she grew steadily in his favour, and had in 1678 the gratification of having her estate at Maintenon raised to a marquisate, and herself entitled Madame de Maintenon by the king himself. Such favours brought down the fury of Madame de Montespan's jealousy, and Madame de Maintenon's position was almost unendurable, until, in 1680, the king severed their connexion by making the latter second lady in waiting to the dauphiness, and soon after Madame de Montespan left the court. The new "amie" used her influence on the side of decency, and the queen openly declared she had never been so well treated as at this time, and eventually died in Madame de Maintenon's arms in 1683. The queen's death opened the way to yet greater advancement; in 1684 she was made first lady in waiting to the dauphiness, and in the winter of 1685, or, Voltaire says, in January 1686, she was privately married to the king by Harlay, archbishop of Paris, in the presence, it is believed, of Père la Chaise, the king's confessor, the Marquis de Montchevreuil, the Chevalier de Forbin, and Bontemps. No written proof of the marriage is extant, but that it took place is nevertheless certain. Her life during the thirty years of her second married life must be studied from more than one side, and can be so fully from her letters, which are masterpieces even of an age when Madame de Sevigné wrote, and of which many authentic examples are extant. As a wife she is wholly admirable; she had to entertain a man who would not be amused, and had to submit to that terribly strict court etiquette of absolute obedience to the king's inclinations which Saint-Simon so vividly describes, and yet be always cheerful, and never complain of weariness or ill-health. Her political influence has probably been overstated, but it was supreme in matters of detail. The ministers of the day used to discuss and arrange all the business to be done with the king beforehand with her, and it was all done in her cabinet and in her presence, but the king in more important matters often chose not to consult her. Such mistakes as, for instance, the replacing of Catinat by Villeroi may be attributed to her, but not whole policies,—notably, according to Saint-Simon, not the policy with regard to the Spanish succession. Even the revocation of the edict of Nantes and the Dragonnades have been laid to her charge, but there can be no doubt that, in spite of ardent Catholicism, she retained a liking for her father's religion, and opposed, if not very vigorously, the cruelties of the Dragonnades. She was probably afraid to say much, or peril her great reputation for devotion, which had in 1692 obtained for her from Innocent XII. the right of visitation over all the convents in France. Where she deserves blame is in her use of her power for personal patronage, as in compassing the promotions of Chamillart and Villeroi, and the frequent assistance given to her brother Comte Charles d'Aubigné. Her influence was on the whole a moderating and prudent force, and the king, when he wanted her advice, used to say, "Qu'en pensez votre Solidité?" or "Consultons la Raison." Her social influence was not as great as it might have been owing to her holding no recognized position at court, but it was always exercised on the side of decency and morality, and it must not be forgotten that from her former life she was intimate with the literary people of the day, and never deserted her old friends. Side by side with this public life, which wearied her with its shadowy power, occasionally crossed by a desire to be recognized as queen, she passed a nobler and sweeter private existence as the foundress of St Cyr. Madame de Maintenon was a born teacher; she had so won the hearts of her first pupils that they preferred her to their own mother, and was similarly successful later with the young and impetuous Duchesse de Bourgogne, and she had always wished to establish a home for poor girls of good family placed in such straits as she herself had experienced. As soon as her fortunes began to mend she started a small home for poor girls at Ruel, which she afterwards moved to Noisy, and which was the nucleus of the splendid institution of St Cyr, which the king had endowed in 1686 at her request out of the funds of the Abbey of St Denis. She was in her element there. She herself drew up the rules of the institution; she examined every minute detail; she befriended her pupils in every way; and her heart often turned from the weariness of Versailles or of Marly to her "little girls" at St Cyr. It was for the girls at St Cyr that Racine wrote his *Esther* and his *Athalie*, and it was because he managed the affairs of St Cyr well that Chamillart became controller-general of the finances. The later years of her power were marked by the promotion of her old pupils, the children of the king and Madame de Montespan, to high dignity between the blood royal and the peers of the realm, and it was doubtless under the influence of her dislike for the Duc d'Orleans that the king drew up his will, leaving the personal care of his successor to the Duc de Maine, and hampering the Duc d'Orleans by a council of regency. On or even before her husband's death she retired to St Cyr, and had the chagrin of seeing all her plans for the advancement of the Duc de Maine overthrown by means of the parlement of Paris. However, the regent Orleans in no way molested her, but on the contrary visited her at St Cyr, and continued her pension of 48,000 livres. She spent her last years at St Cyr in perfect seclusion, but an object of great interest to all visitors to France, who, however, with the exception of Peter the Great, found it impossible to get an audience with her. On April 15, 1719, she died, and was buried in the choir at St Cyr, bequeathing her estate at Maintenon to her niece, the only daughter of her brother Charles, and wife of the Maréchal de Noailles, to whose family it still belongs. Such was the life of the extraordinary woman who kept till the last the heart of Louis XIV., marked by a virtue almost amounting to prudery, in strong contrast to the generations which preceded and followed her, by a love of power, and a use of it which can indeed be excused by her early life, but which was not exercised for the good of France, and by a religious devotion which was narrow, if not violently fanatical, but sweetened throughout by her ardent love for her "little girls," whom she had saved from the difficulties of life, and whom she loved with all a mother's love.

La Beaumelle published the *Lettres de Madame de Maintenon*, but much garbled, in 2 vols. in 1752, and on a larger scale in 9 vols. in 1756. He also in 1755 published *Mémoires de Madame de Maintenon*, in 6 vols., which caused him to be imprisoned in the Bastille. Next must be noted *Madame de Maintenon peinte par elle même*, by Madame Suard, 1810; *Histoire de Madame de Maintenon*, by Lafont d'Aussonne, 1814; *Lettres inédites de Madame de Maintenon et la princesse des Ursins*, 1826, reviewed by Sainte-Beuve, *Causeries du Lundi*, vol. v.; and *Histoire de Madame de Maintenon*, by the Duc de Noailles, 1848-58. All materials for her life have, however, been superseded by Théophile Lavallée's *Histoire de St Cyr*, reviewed in *Causeries du Lundi*, vol. viii., and by his edition of her *Lettres historiques et édifiantes*, &c., in 7 vols., and of her *Correspondance Générale*, in 4 vols., which latter must, however, be read with the knowledge of many forged letters, noticed in P. Grimblot's *Faux Autographes de Madame de Maintenon*. Saint-Simon's fine account of the court in her day and of her career is contained in the twelfth volume of Chéruel and Regnier's edition of his *Mémoires*. (H. M. S.)

MAINZ, or MENTZ (in French, MAYENCE), the largest town in the grand-duchy of Hesse-Darmstadt, one of the strongest fortresses in Germany, and formerly the seat of an archbishop and elector, is situated on a rising ground on the left bank of the Rhine, nearly opposite the influx of the Main. The fortifications, which consist of three *enceintes* with a series of outlying forts, embrace the small town of Castel on the opposite bank, and have recently been widened so as to admit of a large extension of the town. Mainz is connected with Castel by a bridge of boats, and the Rhine is also spanned there by a railway bridge. The interior of the town consists chiefly of narrow and irregular streets, but the oldest part of all, to the west, was almost entirely destroyed by the explosion of a powder-magazine in 1857, and has been rebuilt in a much improved style. There are also several handsome modern streets on the side next the Rhine, which is bordered by a fine quay, upwards of 300 feet in breadth. To the south lies the Neue Anlage, a park laid out on the site of the chateau of Favorite, where the duke of Brunswick signed his famous manifesto to the French people in 1792. The principal object of historical and architectural interest in Mainz is the grand old cathedral, an imposing Romanesque edifice with numerous Gothic additions and details. It was originally erected between 975 and 1009, but has since been repeatedly burned down and rebuilt, and in its present form dates chiefly from the 12th, 13th, and 14th centuries. The largest of its six towers is 300 feet in height. The whole building was restored by order of Napoleon in 1814, and another thorough renovation has been recently in progress. The interior contains the tombs of Boniface, the first archbishop of Mainz, of Frauenlob the minnesinger, and of most of the archiepiscopal electors. Mainz possesses other eight Roman Catholic churches, the most noteworthy of which are those of St Ignatius, with a finely painted ceiling, and St Stephen, built in 1318, and restored after the explosion of 1857. The old electoral palace, erected in 1627–78, now contains valuable collections of Roman and Germanic antiquities, a picture gallery, and a library of 130,000 volumes, including several productions of Gutenberg, Fust, and Schöffer. Among the other principal buildings are the palace of the grand-duke, built in 1731–39 as a lodge of the Teutonic Order, the theatre, the arsenal, the Government house, the commandant's residence, and several fine private houses. A handsome statue of Gutenberg, by Thorwaldsen, was erected at Mainz in 1837,



Plan of Mainz.

1. Cathedral.	5. Theatre.	9. Government House.
2. Palace.	6. Gutenberg's Monument.	10. St Stephen's Church.
3. Courts of Justice.	7. Schiller's Monument.	11. Action Beerhouse.
4. Town-House.	8. Neubrunnen.	12. Eichelstein.

and the town is also embellished with a statue of Schiller and two architectural fountains. Mainz still retains many relics of the Roman period, the most important of which is the Eigelstein, a monument believed to have been erected by the Roman legions in honour of Drusus. It stands within the citadel, which occupies the site of the Roman castrum. A little to the south-west of the town are the remains of a large Roman aqueduct, of which upwards of sixty pillars are still standing. The educational and scientific institutions of Mainz include an episcopal seminary, a gymnasium, a society for literature and art, a musical society, and an antiquarian society, the fine collection of which has been mentioned above. The university, founded in 1477, was suppressed in 1791.

The site of Mainz would seem to mark it out naturally as a great centre of trade, but the illiberal rule of the archbishops and its military importance seriously hampered its commercial and industrial development, and prevented it from rivalling its neighbour Frankfort. It is now, however, the chief emporium of the Rhenish wine traffic, and also carries on an extensive transit trade in grain, timber, flour, and oil. The natural facilities for carriage by water are supplemented by seven railways. The principal manufactures of Mainz are leather goods, furniture, carriages, chemicals, musical instruments, and carpets, for the first two of which it has attained a wide reputation. Mainz is the seat of the administrative and judicial authorities of the province of Rheinhessen, and also of a Roman Catholic bishop. The population in 1880 amounted to 61,322, including a garrison of about 8000 men. Fully two-thirds are Roman Catholics. Castel has about 5000 inhabitants.

Mainz, one of the oldest cities in Germany, was originally a Celtic settlement. Its strategic importance was early recognized by the Romans, and in 13 B.C. Drusus, the son-in-law of Augustus, erected a fortified camp (*castrum*) there, to which a smaller *castellum* (the modern Castel) on the opposite bank was afterwards added. The Celtic name became Latinized as *Maguntiacum* or *Moguntiacum*, and a town, *Maguntia*, gradually arose, which became the capital of Germania Superior. In the "Völkerwanderungen," or migrations of peoples during the gradual dissolution of the Roman empire, Mainz was destroyed on different occasions by the Alemanni, the Vandals, and the Huns (451 A.D.). Christianity seems to have been introduced at an early period, and soon after its recovery from the last of these calamities we find it the seat of a bishop. In the middle of the 8th century, under Boniface, the see became an archbishopric, to which the primacy of Germany was annexed. Charlemagne built a bridge here and granted the town important privileges, and in the following centuries it was the seat of several diets and ecclesiastical councils. In 1254 Mainz was the head and mainspring of the league of Rhenish towns, and had attained to such a pitch of commercial prosperity that it was known as the "Goldene Mainz." Soon after this time it is believed that the population was as numerous as at the present day. In 1462, during the strife between the rival archbishops Diether von Isenburg and Adolph von Nassau, Mainz espoused the cause of the former, but was taken by the latter, who had the support of the emperor, lost its imperial privileges, and was henceforth subject to the archbishops. Many of its citizens were driven into exile, and carried into other lands a knowledge of the art of printing, which had been invented at Mainz by Gutenberg in 1440. In the Thirty Years' War Mainz was occupied by the Swedes and the French. In 1792 it enthusiastically welcomed the principles of the French Revolution, and opened its gates to the Republican troops under General Custine. It was recaptured in the following year, but was ceded to France by the peace of Campo Formio in 1797. In 1814 it was restored to Germany and handed over to the grand-duchy of Hesse, remaining, however, a fortress of the German Confederation, garrisoned in common by Prussian, Austrian, and Hessian troops. Since 1871 it has been a fortress of the German empire.

For further information consult Schaab, *Geschichte der Stadt Mainz*, 1841–44; K. Klein, *Mainz und seine Umgebungen*, 1868; Bockenheimer, *Beiträge zur Geschichte der Stadt Mainz*, 1874, and *Mainz und Umgebungen*, 1880; Werner, *Der Dom von Mainz und seine Denkmäler*, 1827–36. (J. F. M.)

MAISTRE, JOSEPH DE, diplomatist and polemical, writer was born at Chambéry on the 1st April 1754, and died at Turin on the 26th February 1821. The family was an ancient and noble one, enjoying the title of count, and is said to have been of Languedocian extraction. The father of Joseph was president of the senate of Savoy, and held other important offices. Joseph himself, after studying at Turin, received various appointments in the civil service of Savoy, finally becoming a member of the senate. In 1786 he married Françoise de Morand. The invasion and annexation of Savoy by the French Republicans made him an exile. He did not take refuge in that part of the king of Sardinia's domains which was for the time spared; but betook himself to the as yet neutral territory of Lausanne. There, in 1796, he published his first important work (he had previously written certain discourses, pamphlets, letters, &c.), *Considérations sur la France*. In this he developed his views, which were those of a Legitimist, but a Legitimist entirely from the religious and Roman Catholic point of view. The philosophism of the 18th century, as shown in its political views, or rather the second as a consequence of the first, was Joseph de Maistre's life-long object of assault.

After the still further losses which, in the year of the publication of this book, the French Revolution inflicted on Sardinia, Charles Emmanuel summoned Joseph de Maistre to Turin, and he remained there for the brief space during which the king retained a remnant of territory on the mainland. Then he went to the island of Sardinia itself, and held office at Cagliari. In 1802 he was appointed envoy extraordinary and minister plenipotentiary at St Petersburg, and journeyed thither the next year. Although his post was no sinecure, its duties were naturally less engrossing than the official life, with intervals of uneasy exile and travelling, which he had hitherto known, and his literary activity was great. He only published a single treatise, on the *Principe générateur des Constitutions;* but he wrote his best and most famous works, *Du Pape*, *De l'Église Gallicane*, and the *Soirées de St Pétersbourg*, the last of which was never finished. *Du Pape*, which the second-named book completes, is a treatise in regular form, dealing with the relations of the sovereign pontiff to the church, to temporal sovereigns, to civilization generally, and to schismatics, especially Anglicans and the Greek Church. It is written from the highest possible standpoint of papal absolutism. The *Soirées de St Pétersbourg*, so far as it is anything (for the arrangement is somewhat desultory), is a kind of *théodicée*, dealing with the fortunes of virtue and vice in this world. It contains two of De Maistre's most famous pieces, his panegyric on the executioner as the foundation of social order, and his acrimonious, and in part unfair, but also in part very damaging, attack on Locke. The *Du Pape* is dated May 1817; on the *Soirées* the author was still engaged at his death. Besides these works he wrote an examination of the philosophy of Bacon, some letters on the Inquisition (an institution which, as may be guessed from the remarks just noticed about the executioner, was no stumbling-block to him), and, earlier than any of these, a translation of Plutarch's "Essay on the Delay of Divine Justice," with somewhat copious notes. After 1815 he returned to Savoy, and was appointed to high office, while his *Du Pape* made a great sensation. But the world to which he had returned was not altogether in accordance with his desires. He had domestic troubles; and chagrin of one sort and another is said to have had not a little to do with his death by paralysis at no very advanced age. Most of the works mentioned were not published till after his death, and it was not till 1851 that a collection of *Lettres et Opuscules* appeared, while even since that time fresh matter has been published.

Joseph de Maistre was one of the most powerful, and by far the ablest, of the leaders of the Neo-Catholic and anti-revolutionary movement. The most remarkable thing about his standpoint is that, layman as he was, it was entirely ecclesiastical. Unlike his contemporary Bonald, Joseph de Maistre regarded the temporal monarchy as an institution of altogether inferior importance to the spiritual primacy of the pope. He was by no means a political absolutist, except in so far as he regarded obedience as the first of political virtues, and he seldom loses an opportunity of stipulating for a tempered monarchy. But the pope's power is not to be tempered at all, either by councils or by the temporal power or by national churches, least of all by private judgment. The peculiarity of Joseph de Maistre is that he supports his conclusions, or if it be preferred his paradoxes, by the hardest and heaviest argument. Although a great master of rhetoric, he never makes rhetoric do duty for logic. Every now and then it is possible to detect fallacies in him, but for the most part he has succeeded in carrying matters back to those fundamental differences of opinion which hardly admit of argument, and on which men take sides in consequence chiefly of natural bent, and of predilection for one state of things rather than for another. The absolute necessity of order may be said to have been the first principle of this thinker. He could not conceive such order without a single visible authority, reference to which should settle all dispute. He saw that there could be no such temporal head, and in the pope he thought that he saw a spiritual substitute. The anarchic tendencies of the revolution in politics and religion were what offended him. It ought to be added that he was profoundly and accurately learned in history and philosophy, and that the superficial blunders of the 18th century *philosophes* irritated him as much as their doctrines. To Voltaire in particular he shows no mercy.

A good and complete edition of De Maistre has yet to appear. Of the two works named as his masterpieces, *Du Pape* is to be found in the *Bibliothèque Charpentier*, and the *Soirées de St Pétersbourg* is printed in two volumes, the fifteenth edition, so-called, bearing date Lyons, 1878. (G. SA.)

MAISTRE, Xavier de, the younger brother of Joseph, was born at Chambéry in October 1763, and died at St Petersburg on the 12th June 1852. He served when young in the Piedmontese army, and wrote his *Voyage autour de ma Chambre* when he was in garrison at Turin. This, a delightful fantasy piece which may have owed something to the example of Sterne in its conception, but which is quite original in execution, he showed to his brother Joseph, and on his approval it was published at Turin in 1794. Xavier, however, shared the politics and the loyalty of his brother, and the annexation of Savoy, followed as it was at no long date by the extinction of Piedmontese independence, made him quit his country. He served in the victorious Austro-Russian campaign in which Suwaroff performed such wonders, and accompanied the marshal to Russia. For a time he was in very reduced circumstances, and is said to have supported himself by painting. But on his brother's arrival in St Petersburg he was introduced to the minister of marine. He was appointed to several posts in the capital, but also saw active service, was wounded in the Caucasus, and attained the rank of major-general. He married a Russian lady and established himself in his adopted country, even after the overthrow of Napoleon, and the consequent restoration of the Piedmontese dynasty. For a time, however, he lived at Naples, but he returned to St Petersburg and died there. He was only once at Paris (in 1839), when Sainte-Beuve, who has left some pleasant reminiscences of him, met him. Besides the *Voyage* already mentioned, Xavier de Maistre's works (all of which are of very modest dimensions) are *Le Lépreux de la Cité d'Aoste*, a touching little story of human misfortune, *Les Prisonniers du Caucase*, a powerful sketch of Russian character, *La Jeune Sibérienne*, and the *Expédition Nocturne*, a sequel to the *Voyage autour de ma Chambre.* But his *Voyage* is, with the *Lépreux*, his title to fame. Both have a certain resemblance to Sterne, the first in its quaintness and desultory arrangement, the second in its sentiment. Xavier de Maistre is, however, much less artificial than his forerunner, especially in his pathos, and he is also much better bred. His style is of remarkable ease and purity. The works of Xavier de Maistre, with the exception of some brief chemical tractates, are usually printed in a single volume, which figures in the collections of Charpentier, Garnier, &c.

MAITLAND, a town of Australia, in New South Wales, 93 miles north of Sydney, in the valley of Hunter river, and communicating with Newcastle and Port Hunter both by steamboat and railway. It consists of two distinct municipalities—East Maitland, incorporated in 1862, and West Maitland, in 1863. The former, which is the seat of a Roman Catholic bishop, contains a court-house, a large prison, and a mechanics' institute; the latter a court-house, an excellent hospital (Campbell's Hill), a school of arts with a considerable library, a benevolent asylum, a theatre, and a Dominican nunnery. The district is a rich agricultural country, growing maize, barley, oats, wheat, tobacco, grapes, and oranges; coal and shale are regularly worked near the town; and a good trade is carried on with the interior townships. The inhabitants number 7881, East Maitland having 2500 and West Maitland 5381.

MAITLAND, John (1614–1682), earl and afterwards duke of Lauderdale in the peerage of Scotland, was a great-grandson of Sir Richard Maitland (*q.v.*). In early life a Presbyterian, he attended the Westminster Assembly in 1643 as an elder of the Church of Scotland; and he was a party to the surrender of Charles I. to the English army in 1645. Soon afterwards, changing his politics, he became a zealous supporter of the royal cause, and promoter of the Engagement for raising forces for the king's rescue. He was taken prisoner at the battle of Worcester; and, on being set at liberty in 1660, he repaired to the Hague and accompanied Charles II. to Scotland. From 1663 he was virtually ruler of Scotland,—at first moderate in his counsels, but afterwards severe in his measures against the Covenanters. In 1672 he was made duke of Lauderdale and a Knight of the Garter; and he had also an English peerage conferred on him (with the title of earl of Guildford) in 1674. One of the administrative council known as the "Cabal," he eventually fell into disgrace, and died in 1682. His dukedom and English honours expired with him; the earldom of Lauderdale passed to his brother Charles, and is still in possession of his descendants. The voluminous correspondence of Lauderdale, which is still extant, shows that, in addition to a remarkable power over men of all classes, great watchfulness and resolution, and very clear ideas of what was needed to keep Scotland peaceful and in a state of usefulness for further ends, he was possessed of no slight learning.

MAITLAND, Sir Richard (1496–1586), an early Scottish lawyer and poet, was born in 1496. His father, William Maitland of Lethington and Thirlstane, fell at Flodden; his mother was a daughter of George, Lord Seton. He studied law at the university of St Andrews, and afterwards in France. He was in 1552 one of the commissioners to settle matters with the English about the debatable lands on the borders, and about that time had the honour of knighthood conferred upon him. In 1554 he was made an extraordinary lord of session. About 1561 he seems to have lost his sight, but this did not render him incapable of attending to public business, as he was the same year admitted an ordinary lord of session by the title of Lethington, and in 1562 was nominated lord privy seal. He resigned this latter office in 1567, in favour of John, prior of Coldingham, his second son, but he sat on the bench till he attained his eighty-eighth year. He was an amiable and accomplished man, and died in 1586, aged ninety, after having been employed in public offices for upwards of seventy years. His eldest son, William, forms the subject of next article. His second son, John, was a lord of session, and was made a lord of parliament in 1590, by the title of Lord Maitland of Thirlstane, in which he was succeeded by his son John, also for some time a lord of session, who was created earl of Lauderdale in 1624. The latter was the father of John Maitland, duke of Lauderdale, noticed above. One of Sir Richard's daughters, Mary, assisted her father in his studies, and also wrote verses.

The poems of Sir Richard Maitland, none of them lengthy, are somewhat satirical, and are principally directed against the abuses of his time. He must, however, be regarded as the industrious collector and preserver of many pieces of ancient Scottish poetry. These were copied into two large volumes, one in folio and another in quarto, the former written by himself, and the latter by his daughter. After being in the possession of his descendant the duke of Lauderdale, these volumes were purchased at the sale of the duke's library by the celebrated Samuel Pepys, who was one of the first collectors of rare books in England. They have since been preserved in the Pepysian Library, Magdalene College, Cambridge. They lay there unnoticed for many years till Bishop Percy published one of the poems in his *Reliques of English Poetry*. Several of the pieces were then transcribed by John Pinkerton, who afterwards published them under the title of *Ancient Scottish Poems, comprising Pieces written from about* 1420 *till* 1586, *with Notes and a Glossary*, 2 vols. 8vo, London, 1786. Sir Richard left in manuscript a history of the family of Seton, and a volume of legal decisions collected by him between the years 1550 and 1565. Both are preserved in the Advocates' Library, Edinburgh, and the latter work is still unpublished. The *Poems* of Sir Richard Maitland were printed in 1830 by the Maitland Club, a literary society, founded in Glasgow in 1828, which took its name from him. The MS. used for the purpose was one preserved in the Drummond collection in the library of the university of Edinburgh. It seems to have been written shortly before the year 1627, when it was presented by Drummond to the library. In 1829 there was also printed for the club *The History of the House of Seytoun* to the year 1559, with a continuation to 1687 by Alexander, Viscount Kingston.

MAITLAND, William (*c.* 1525–1573), best known in Scottish history by the name of his father's estate of Lethington, near Haddington, where he resided, was the eldest son of Sir Richard Maitland, noticed above. Born about 1525, and partly educated in France, he was at an early age initiated into public life. He was made secretary of state by Mary of Guise in 1558; but the favour with which he regarded the views of the reforming party soon exposed him to the queen mother's resentment. He became one of the "lords of the congregation," and was also one of the Scottish commissioners who negotiated with Queen Elizabeth regarding the terms on which she would agree to aid the Reformers. Soon after Mary's arrival in Scotland, he was employed in two embassies to England, and was made first an extraordinary and then an ordinary lord of session. He had a controversy with Knox, whom he accused in the General Assembly of 1564 of teaching seditious doctrine. He went again to England as ambassador to notify the queen's marriage to Darnley, and was implicated both in the conspiracy against Rizzio and in the Kirk of Field tragedy, though he was also a member of the secret council at which the depositions of Darnley's murderers were taken, and signed the act of council accusing Mary of being the author of the crime. He fought against the queen at Langside, but at the conference at York identified himself in a measure with her interests. At the instance of the regent Murray he was in 1569 arrested as a participant in the king's murder, and would have been brought to trial but for a ruse of Kirkcaldy of Grange, who, as commander of Edinburgh Castle, conveyed him thither as a prisoner. The two principal representatives of Mary's cause, Lethington and Grange, who may be described as the forlorn hope of the captive queen, held the castle of Edinburgh for some time against the regent Morton and an English force; and, when surrender became a matter of necessity, they made their submission, not to the regent, but to the English queen. Kirkcaldy was executed; but Maitland died in prison, it was generally believed of poison administered by his own hand, on 9th June 1573. "Secretary Maitland" was a man of great learning and power of repartee, wanting in integrity, but skilled in intrigue, and reputed the most accomplished and most versatile statesmen that his country has produced; in the opinion of his contemporaries his capacities were too great for the narrow sphere of Scottish politics.

MAITTAIRE, Michel (1668–1747), bibliographer and editor, was a native of France, and was born in 1668. On the revocation of the edict of Nantes his parents, who were Protestants, removed to England, where he was educated at Westminster and at Christ Church, Oxford, graduating in 1696. From 1695 to 1699 he taught in Westminster School, but afterwards devoted himself exclusively to private teaching and editorial work. He died on August 4, 1747.

Maittaire was a great lover of books, but no critic; and his numerous editions take rank only as compilations. His works include *De Græcæ Linguæ Dialectis*, 1706; *Stephanorum Historia, vitas ipsorum et libros complectens*, 1713; *Historia Typographorum* *aliquot Parisiensium, vitas et libros complectens*, 1717; *Annales Typographici*, 9 vols. 4to, The Hague, Amsterdam, and London, 1719-41; *Marmora Oxoniensia*, 1732; editions of a large number of Latin authors (Lucretius, Phædrus, Sallust, Terence, &c.), as well as an edition of Anacreon (1725), and *Miscellanea Græcorum aliquot scriptorum Carmina*, 1722.

MAIZE, or INDIAN CORN, *Zea Mays*, L., from ζεά or ζειά, which appears to have been "spelt" (*Triticum spelta*, L.), according to the description of Theophrastus, is of the tribe *Phalarideæ* of the order *Gramineæ* or grasses. It is unknown in the native state, but is most probably indigenous to tropical America (Endlicher, *Gen. Pl.*, No. 742). Small grains of an unknown variety have been found in the ancient tombs of Peru. Bonafous, however (*Histoire naturelle du Maïs*), quotes authorities (Bock, 1532, Ruel and Fuchs) as believing that it came from Asia, and maize was said by Santa Rosa de Viterbo to have been brought by the Arabs into Spain in the 13th century. A drawing of maize is also given by Bonafous from a Chinese work on natural history, *Li-chi-tchin*, dated 1562, a little over sixty years after the discovery of the New World. It is not figured on Egyptian monuments, nor was any mention made of it by Eastern travellers in Africa or Asia prior to the 16th century. On the authority, however, of Mr J. Crawford, who resided for nine years in Java, Bonafous says it had been cultivated from a very ancient period in the Asiatic islands under the equator, and that it was received thence into China, and so passed westwards into India and Turkey, hence its name of "Turkey corn," under which title Gerard in 1597 figured and described seven kinds, as well as one called "Corne of Asia." Both Gerard and Bonafons think that it first came from the East, but that on the discovery of America it was reintroduced into Europe from that country. The former observes:—"These kinds of graine were first brought into Spaine, and then into other provinces of Europe out of Asia, which is in the Turkes Dominions; as also out of America and the Ilands adioyning from the East and West Indies and Virginia, &c." Humboldt and others, however, do not hesitate to say that it originated solely in America. It had been long and extensively cultivated there at the period of the discovery of the New World. The plant is monœcious, producing the staminate (male) flowers in a large feathery panicle at

FIG. 1.—Male.

FIG. 2.—Male.

the summit, and the (female) dense spikes of flowers, or "cobs," in the axils of the leaves below, the long pink styles hanging out like a silken tassel. They are invested by the sheaths of leaves, much used in packing oranges in South Europe, and the more delicate ones for cigarettes in South America. The accompanying figures are after Nees von Esenbeck, *Gen. Pl. Fl. Germ.* Fig. 1 shows a branch of the terminal male inflorescence. Fig. 2 is a single spikelet of the same, containing two florets, with the three stamens of one only protruded. Fig. 3 is a

FIG. 3.—Female.

spike of the female inflorescence, protected by the sheaths of leaves,—the blades being also present. Usually the sheaths terminate in a point, the blades being arrested. Fig. 4 is a spikelet of the female inflorescence, consisting of two outer glumes, the lower one ciliated, which enclose two florets,—one barren (sometimes fertile), consisting of a flowering glume and pale only, and the other fertile, containing the pistil with elongated style. The mass of styles from the whole spike is pendulous from the summit of the sheaths, as in fig. 3. Fig. 5 shows the fruit or grain.

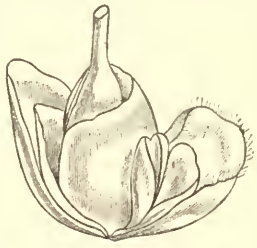


FIG. 4.—Female.

More than three hundred varieties are known, which differ more among themselves than those of any other cereal. Some come to maturity in two months, others require seven months; some are as many feet high as others are inches; some have kernels eleven times larger than others. They vary similarly in shape and size of ears, colour of the grain, which may be white,

FIG. 5.—Grain.

yellow, purple, striped, &c., and also in physical characters and chemical composition,—in short, in all those characters in which the different species of a genus differ among themselves. The varieties grown most abundantly in the United States may be roughly grouped into four great classes. The "Flint" varieties are most common east of Lake Erie and north of Maryland, and the "Dent" varieties are the common ones west and south of these points. The "Horsetooth" varieties are grown extensively only in the south, and there they are grown along with the dent. These three classes pass into each other by every gradation, and the grain from all is similar in chemical composition. The "Sweet" varieties are not grown for the ripe grain, but for boiling corn, and that the stalks may serve as "corn fodder." "Green corn" was an important food with the native Indians. Many of the tribes celebrated its season with religious ceremonies and festivals. In the large cities of America "green corn" is a table luxury, but in the smaller towns and country districts it is an important article of food. Chemical analysis, as well as common experience, shows that this is a very nutritious article of food, being richer in albuminoids than any other cereals when ripe (calculated in the dry weight). It is capable of being grown in the tropics from the level of the sea to a height equal that of the Pyrenees, and in the south and middle of Europe, but it cannot be grown in England with any chance of profit, except perhaps as fodder. Frost kills the plant in all its stages and all its varieties; and the crop does not flourish well if the nights are cool, no matter how favourable the other conditions. Consequently it is the first crop to disappear as one ascends into the mountain regions, and comparatively little is grown west of the great plains of North America. In Brittany, where it scarcely ripens the grain, it furnishes a strong crop in the autumn upon sandy soil where clover and lucern will yield but a poor produce. It prefers a deep, rich, warm, dry, and mellow soil, and hence the rich bottoms and fertile prairies of the Mississippi basin constitute the region of its greatest production. Illinois leads in total amount, producing in 1879 nearly 326 millions of bushels, or 105 bushels per head of population. The region of chief production in the United States may be described as a rude ellipse 900 miles long from east to west by 600 miles wide, with Springfield (the capital of Illinois) as its centre. This region produces annually from 1000 to 1400 millions of bushels, or nearly three-fourths of the total crop of the country.

As an article of food, maize is one of the most extensively used grains in the world. Although rich in nitrogenous matter and fat, it does not make good bread. A mixture of rye and corn meal, however, makes an excellent coarse bread, formerly much used in the Atlantic States, and a similar bread is now the chief coarse bread of Portugal and some parts of Spain. When the harder "flint" varieties are roasted, the grains "pop," the skin bursts, and the white interior swells up, emitting a pleasant odour. It is either baked into cakes called *tortilla* by the Indians of Yucatan, or made into a kind of porridge, as in Ireland. When deprived of the gluten it constitutes oswego, maizena, or corn flour (see Letheby's *Lectures on Food*, p. 19; and *Foods*, by E. Smith, 156). Maize contains more oil than any other cereal, ranging from 3·5 to 9·5 per cent. in the commercial grain. This is one of the factors in its value for fattening purposes. In distilling and some other processes this oil is separated and forms an article of commerce. When maize is sown broadcast or closely planted in drills, the ears may not develop at all, but the stalk is richer in sugar and sweeter, and this is the basis of growing "corn-fodder." The amount of forage that may be produced in this way is enormous; 50,000 to 80,000 ℔ of green fodder are grown per acre, which makes 8000 to 12,000 ℔ as field-cured. Sugar and molasses have from time to time been manufactured from the corn stalks, but at present this manufacture is not commercially successful.

In the treeless western prairies maize is often grown for fuel, as in many places fuel can be procured so cheaply in no other way. A hundred bushels of ears is equal in heating power to a cord of the best hard wood, and may be grown for a price less than a cord of hard wood brings in the large cities. The use of corn in the industries, as the raw material for the manufacture of alcohol, whisky, starch, glucose, oil, and various food products, increases year by year, with the increase of facilities for production and the increasing applications of chemistry to the arts.

For fuller details see a paper by Professor W. H. Brewer, Yale Col., Conn., from which some of the above details are taken, as well as the *Special Report on Cereal Products*, Washington, 1882, and the 38th *Annual Report* of the New York State Agricultural Society, 1878. (G. H.)

MAJLÁTH, JÁNOS or JOHN, COUNT (1786-1855), Hungarian historian and poet, was born at Pest on the 5th of October 1786. First educated at home, he subsequently studied philosophy at Eger (Erlau) and law at Györ (Raab), his father, Count Joseph Majláth, an Austrian minister of state, eventually obtaining for him an appointment in the public service. The weakness of his eyesight having rendered it necessary for him a few years later to resign the Government secretaryship to which he had been promoted, Majláth turned his attention to literature, especially devoting himself to historical research, and the translation into German of Magyar folk-tales, and of selections from the works of the best of his country's native poets. Moreover, as an original lyrical writer, and as an editor and adapter of old German poems, Majláth showed considerable talent; and, in general, his activity as an author was remarkable, his various literary productions in German and Hungarian amounting together to more than sixty volumes. During the greater part of his life he resided either at Pest or Vienna, but a few years before his death he removed to Munich, where he fell into a state of destitution and extreme despondency. Seized at last by a terrible infatuation, he and his daughter Henriette, who had long been his constant companion and amanuensis, determined to put an end to their dependent position by drowning themselves in the Lake of Starnberg, a few miles south-west of Munich. This fatal resolution was carried into effect on the 3d of January 1855.

It is generally admitted that in his great historical treatises Count Majláth has failed in a critical discrimination between the merely mythical or poetical and the true historical element,—the former not unfrequently being allowed to unduly influence and obscure the latter. The political tendency of his writings, moreover, has been objected to, especially by his own countrymen, as being too conservative and over-favourable to Austria. Of his historical works the most important are the *Geschichte der Magyaren* (Vienna, 1828-31, 5 vols.; 2d ed., Ratisbon, 1852-53), and his *Geschichte des österreichischen Kaiserstaats* (Hamburg, 1834-50, 5 vols.). Specially noteworthy among his metrical translations from the Hungarian are the *Magyarische Gedichte* (Stuttgart and Tübingen, 1825); and *Himfy's auserlesene Liebeslieder* (Pest, 1829; 2d. ed., 1831; see KISFALUDY, SÁNDOR). A valuable contribution to folk-lore appeared in the *Magyarische Sagen, Märchen, und Erzählungen* (Brünn, 1825; 2d ed., Stuttgart and Tübingen, 1837, 2 vols.).

MAJOLICA. See POTTERY.

MAJOR, or MAIR, JOHN (*c.* 1470-1550), a theological and historical writer, was born at the village of Cleghorn, near North Berwick, Scotland, about the year 1470. After a short period spent at Cambridge, he entered the university of Paris in 1493, studying successively at the colleges of St Barbe and Montaigu, and graduating as master of arts in 1496. Promoted to the doctorate in 1505, he lectured in philosophy at Montaigu College for some time, and had several distinguished auditors. From 1518 to 1522 he held the office of principal in the university of Glasgow, John Knox being among the number of those who attended his lectures there; he was afterwards removed to St Andrews, where George Buchanan was one of his pupils in 1525. He appears again to have returned to France for some time, but we find him once more at St Andrews in 1530, where he was head of St Salvator's College from 1533 until his death, which took place about 1550.

He wrote *In Libros Sententiarum commentarius*, Paris, 1509-19; *De Historia Gentis Scotorum libri sex*, Paris, 1521; *Commentarius in Physica Aristotelis*, Paris, 1526; and *In Quatuor Evangelia Expositiones Luculentæ*, Paris, 1529. By Knox he is spoken of as having been in his day an oracle in religious matters; and it has been conjectured that both the great Reformer and Buchanan were largely indebted to him for their advanced opinions on political and ecclesiastical questions. His writings do not now, however, possess any interest or importance apart from this circumstance; and even Buchanan has allowed himself to speak of his old preceptor as "Joannes solo cognomine major."

MAJORCA. See BALEARIC ISLANDS.

MAJORIANUS, JULIUS VALERIUS, emperor of the West from 457 to 461, was the successor of Avitus. He had been a distinguished soldier under Aetius, and also after the death of that general; for his election to the purple he was indebted to the powerful Count Ricimer, patrician of Rome. To put a stop to the harassing incursions of the Vandals he, in 458, resolved to lead an expedition against Genseric himself; for this purpose he got together a large army, composed chiefly of barbarians, and, passing the Alps in November 458, made Lyons, and afterwards Arles, his headquarters until the preparations for the invasion of Africa had been completed. Having during his stay in Gaul succeeded in pacifying Theodoric, he, in the beginning of 460, crossed the Pyrenees for the purpose of joining his armament at Carthagena. Genseric, however, after all overtures for peace had been rejected, succeeded through the treachery of certain officers in surprising the Roman fleet, most of the ships being either taken or destroyed. Majorianus returned at once to Gaul, where he made peace with Genseric in the following year. Soon afterwards, while at Tortona in Lombardy, he was surrounded by partisans of Ricimer, and compelled to abdicate (August 2, 461). He died, most probably by violence, five days afterwards, and was succeeded on the throne by Severus. He was the author of several laws, which, "remarkable for an original cast of thought and expression, faithfully represent the character of a sovereign who loved his people, who sympathized in their distress, who had studied the causes of the decline of the empire, and who was capable of applying (as far as such reformation was practicable) judicious and effectual remedies to the public disorders" (Gibbon, *Decline and Fall*, chap. 39).

MAKALLÁ, or MACULLA, a port on the south coast of Arabia, in 14° 31′ N. lat. and 49° 13′ E. long. The town, which appears to be of no great antiquity, is described by Wellsted as built on a low projecting point, with many lofty and substantial houses, and a suburb of huts, chiefly inhabited by slaves, Somalis, and Arab sailors, on the slopes leading up to a lofty chalk-hill (Jebel el-Kára) which overhangs the town. The Arab inhabitants are of the Beni 'Isá tribe. The Somali traders do not settle permanently in Makallâ, but they form an important element in the population. There are also Indian residents (Banians). The harbour is good, and the town, which may be regarded as the port of Hadramaut, rose during the decline of Aden to the rank of the chief emporium between India and the Somali coast. It still exports, among other productions of Hadramaut, tobacco, mother-of-pearl, and incense to Jeddah and shark fins to India, but has lately declined in the general transformation of the character of the Eastern trade. According to the latest Arabic accounts (see Badger in the *Academy*, March 4, 1882), the town contains about a thousand houses. Makallâ is governed by a prince or nakîb who is esteemed one of the chief minor potentates of that coast. The present prince Salah el-Kesádí has made himself quite independent of the surrounding Bedouins, and is even reported to have made conquests in the interior.

MAKKARÍ. Abu'l-'Abbâs Ahmed ibn Mohammed el-Makkarí, Arabic historian, was born at Tilimsán (Tlemcen) in Algeria, towards the close of the 16th century, and studied at Fez, where he remained occupied with literary pursuits till, for some unknown cause, he was driven into exile and, after visiting Mecca, settled in Cairo. In 1628 he came to Damascus after a pilgrimage to Jerusalem. Warmly received by the scholars there, he delivered lectures on the traditions of the Prophet, and in the evenings entertained his friends with stories of the glories of Moslem Spain, a subject of interest to all Arabs, and especially to those of Syria. His friends made him promise to reduce his narrative to writing, and on returning to Cairo he devoted three years to this task. He had divorced his wife and made other preparations to settle definitively in Damascus when death overtook him in 1631.

Makkary's great work, *The Breath of Perfume from the Branch of Green Andalusia, and Memorials of its Vizier Lisán el-Dín ibn el Khatíb*, consists, as the name indicates, of two parts. The first is a general history and description of Mohammedan Spain, mainly in the form of analecta from a number of authors, with many verses interspersed. This part, which is of great historical value, was published in an (incomplete) English version by P. de Gayangos (London, 1840-43) and in Arabic by Wright, Krehl, Dozy, and Dugat (*Analectes sur l'histoire et la littérature des Arabes d'Espagne*, Leyden, 1855, 1856, 1858, 1861). An edition in four volumes, published at Cairo (1863), contains also (in vols. iii. and iv.) the life of the famous statesman and author Lisán el-Dín, vizier of Granada (*ob.* 1374). Further references to literature are given by Pertsch, *Arab. Hdschr. zu Gotha*, No. 1697. Among other works of Makkarí a commentary on the *prolegomena* of Ibn Khaldún is mentioned (H. Kh., 8043).

MAKÓ, a corporate town of Hungary, and capital of the trans-Tisian county of Csanád, is situated near the right bank of the Maros, about 15 miles east-south-east of Szeged, in 46° 13′ N. lat., 20° 28′ E. long. The town consists of the three wards of Buják, Szent-Lörincz (Saint-Lawrence), and Ujváros (New Town), and has, besides the usual official buildings connected with the administration of a county, Roman and Greek Catholic, Lutheran, and Calvinist churches, and a synagogue; also an elegant (Calvinist) gymnasium, the bishop of Csanád's palace and gardens, royal and circuit courts of law, barracks, tax and salt offices, a timber trading agency, a manufactory of agricultural implements, and numerous mills. The surrounding country is fertile. The communal lands are extensive, and afford excellent pasturage for horses and sheep, as also for large herds of horned cattle, for the size and quality of which Makó has obtained a high repute. An abundance of fish and aquatic fowl is supplied by the Maros, the water of which river is used also for drinking purposes, that from the wells being unpalatable. The town is protected from inundations of the Maros by a powerful dike, but the commune nevertheless sometimes suffers during the spring floods (see HUNGARY, vol. xii. p. 363). The population, which is chiefly agricultural, amounted in 1880 to 30,077,[1] mostly Magyars by nationality. A great part of the business of the town is in the hands of Jews.

MAKRÍZÍ. Takí el-Dín Ahmed ibn 'Alí el Makrízí (1364[2]-1441), one of the most meritorious of Arabic historians and archæologists, was descended on both sides from families of scholarly distinction. His hereditary surname of Makrízí, by which he is usually known, was derived from Makríz, a suburb of Ba'lbek, with which town his paternal ancestors had been connected. Takí el-Dín himself was born in Cairo, and spent his life mainly in Egypt, where he was brought up as clerk in a Government office, and at a later date he became *Mohtesib* (a sort of police officer in charge of the markets) for Cairo and northern Egypt, and afterwards inspector of the Kalánesí foundation at Damascus. He declined the post of cadi in the latter town. He was, however, mainly engrossed in scholarly pursuits as a traditionist and a jurisconsult, but especially as an indefatigable student of history. He is reproached by his contemporaries for a somewhat inordinate zeal in theological controversy, but otherwise passed a quiet and uneventful life. Makrízí's literary activity was very great; he was not a man of original power, and his books are largely compilations, in which he is not always scrupulous in naming the sources to which he is indebted, but his learning was vast, his observation accurate, and his

[1] Roman Catholics, 11,178; Greek Catholics, 1456; Greek Eastern Church, 50; Calvinists, 15,492; Lutherans, 445; Jews, 1452; Unitarians, 4.

[2] The year of his birth is variously given as 760, 766, 769 A.H.; but 766 A.H. (1364 A.D.) is the date best authenticated.

judgment sagacious. His most important work is the historical and topographical description of Egypt (*El-Mawá'iẓ wa'l-I'tibár fí dhikr el-Ḥiṭaṭ wa'l-Áthár*), of which an edition in 2 vols. folio has appeared at Búlák (1270 A.H., 1854 A.D.). This is in many respects a monumental work; the elaborate description of mediæval Cairo is of unique interest.[1] It has enjoyed a great reputation, having even been translated into Turkish.

Besides this work Makrízí wrote a variety of other books bearing on Egypt. The unfinished *Mukaffá* is a vast alphabetical cyclopædia of Egyptian biography; three volumes of the author's autograph are at Leyden (DCCCXX of the printed catalogue), and one is at Paris. He also wrote three works on the history of Egypt under the Moslems. An imperfect copy of the second in the author's autograph, containing the history of the Fatimites, is at Gotha (Pertsch, No. 1652; Kosegarten, *Chrest.*, p. xvii.), while the third (history of the Ayyúbite and Mameluke sovereigns) has been in great part translated by Quatremère (*Histoire des Sultans Mamlouks de l'Egypte*, 2 vols., 1837–45). Of a biographical dictionary of Makrízí's contemporaries one autograph volume is preserved at Gotha (No. 1771). A number of minor works of our author are known in Europe in MS., and several have been published, viz., on the *Moslems in Abyssinia*, by Rink, 1797; on *Mohammedan Coinage*, by Tychsen, 1797, and French translation by De Sacy, 1797; on *Arab Weights and Measures*, by Tychsen, 1800; on the *Arabic Tribes that Migrated to Egypt*, by Wuestenfeld, 1847; *History of Hadramaut*, by Noskowy, 1866. Of a great work on the earliest history of the Arabs part at least is still known in Egypt.

For further details as to Makrízí and his writings see the contemporary biographies published by De Sacy (*Chrest. Arabe*) and Hamaker (*Spec. Cat. Cod. Lugd. Bat.*), and the introduction to Quatremère's work already named.

MALABAR, a district in the Madras presidency, India, between 10° 15′ and 12° 18′ N. lat., and 75° 14′ and 76° 52′ E. long., is bounded on the N. by South Kánara, on the E. by Coorg, the Nílgiri hills, and Coimbatore district, on the S. by Cochin and Travancore states, and on the W. by the Arabian Sea. The extreme length is 145 miles, while the breadth varies from 25 miles in the north to 70 miles in the south; the area is 5763 square miles. Malabar is singularly diversified in its configuration; from the eastward, the great range of the Western Gháts, only interrupted by the Palghát gap, looks down on a country broken by long spurs, extensive ravines, dense forests, and tangled jungle. To the westward, gentler slopes and downs, and gradually widening valleys closely cultivated, succeed the forest uplands, till, nearer the seaboard, the low laterite table-lands shelve into rice plains and backwaters fringed with cocoa-nut palms. The coast runs in a south-easterly direction, and forms a few headlands and small bays, with a natural harbour in the south at Cochin. In the south there is considerable extent of table-land. The mountains of the Western Gháts run almost parallel to the coast, and vary from 3000 to 7000 feet in height. One of the most striking features in the country is the Palghát gap, a complete opening in the Western Gháts some 25 miles across. The chief rivers are the Beliapatam, Kota, Mahe, Beypur, Kadelundi, and Ponáni. One of the most characteristic features of Malabar is an all but continuous chain of lagoons or backwaters lying parallel to the coast, which have been formed by the action of the waves and shore currents in obstructing the waters of the rivers. Of these backwaters the most important are the Kavái and Beliapatam in the north, the Payangadi, Quilandi, and Elatur in the middle, and the Chetwái and Kodungalúr in the south. Connected as they are by artificial canals, they form a cheap and abundant means of transit; and a large local trade is carried on by inland navigation. Fishing and fishcuring is an important industry, the value of the exports of salt fish to Ceylon being about £20,000 per annum. The forests are extensive and of great value, but they are almost entirely private property. The few tracts which are conserved have come into Government hands by escheat or by contract. Wild animals include the elephant, tiger, panther, bison, *sambhar*, spotted deer, hog, Nílgiri ibex, hyæna, and bear. Small game is very abundant.

The census of 1872 returned the population of the district at 2,261,250, namely, Hindus, 1,637,914; Mohammedans, 581,609; Europeans, 2579; Eurasians, 5409; native Christians, 32,280; Jains, 31; and "others," 1428. The Moplás or Mapilas, who form a leading section of the Mohammedans, are the descendants of Malayalam converts to Islám, mainly confined to the coast tract. They are fanatical and bigoted, and their outrages, partly fanatical and partly agrarian, have for long been a distinct feature in Malabar history. Many of these outbreaks have necessitated the use of European troops for their suppression. A few Syrian Christians are found in the south of the district, where they have one church. The Roman Catholics have several churches and villages, the chief occupation of the people being fishing and cultivating vegetables. The existing Roman Catholic mission dates from 1656, having been founded by the Carmelites. The Protestant Basel mission, established in 1839, has founded churches and schools at Calicut, Cannanore, Tellicherri, and Palghát, with branch establishments at Chombla and Todakel. The native Christian population is steadily increasing, mainly through the conversion of low-caste Hindus, who gain in social position by the change. The five largest towns, which are all municipalities, are Calicut, the capital, population 48,338; Palghát, 31,115; Tellicherri, 20,479; Cochin, 13,588; and Cannanore (Kananúr) town and cantonment, 10,265.

In 1880-81 926,359 acres were under cultivation, and 2,869,965 were returned as cultivable. Rice, which occupied 580,281 acres in 1881, forms the principal food crop, but it is also largely imported from neighbouring districts. Other crops are *cholam*, *ragi*, *chama*, gingelly seed, castor-oil seed, gram, coffee, pepper, ginger, arrowroot, cardamoms, chillies, onions, cocoa-nut, areca nut, cinnamon, &c. Cocoa-nut gardens form one of the greatest sources of commercial wealth; the value of the exported produce from Madras in 1880-81 was £141,800, chiefly from Malabar, this being a decrease of 18 per cent. on the year preceding. Pepper and spices yield over a quarter of a million. As a rule, the peasantry are well off and free from debt. The district is not liable to blight, flood, or drought. When, however, the neighbouring districts to the east suffer from scarcity, Malabar, which ordinarily imports grain, is affected by the prevalence of high prices.

The district is fairly supplied with means of communication, and possesses 400 miles of good metalled roads, besides minor cart tracks. The water communication provided by the backwaters and their canals has already been referred to. The Madras railway traverses the southern part of the district for a total distance of 89 miles from Walliar to Beypur. Except cloth weaving, and the making of tiles, bricks, &c., at the mission stations at Calicut and Cannanore, and the weaving of coarse cotton cloths and mats at Palghát, there are no local manufactures worthy of mention. The weaving of calico, which derived its name from Calicut, seems to have altogether died out; while unsuccessful attempts have been made to manufacture canvas at Beypur and silk at Palghát. The principal seats of commerce are Calicut, Cannanore, Tellicherri, Cochin, Palghát, and Badagara. In 1876–77 the value of the imports (which were abnormally increased by the famine demand for rice) amounted to £1,765,200, of which £1,118,000 was for rice; exports £2,466,000, of which £960,000 represented coffee. European banks are represented at Calicut, Cochin, and Tellicherri.

The revenue has largely increased of late years. In 1880–81 the land revenue amounted to £176,062, and the gross revenue to £332,628. The number of pupils connected with the various schools at the same date was 20,971. The principal educational institutions are the provincial school at Calicut, the mission school at Tellicherri, the Palghát high school, and the "Kerala Vidya Sala," recently established by the zamorin, for the instruction of the young noblemen of his family and of other influential persons in the district. Nearly one hundred schools are exclusively confined to Moplás. There are several printing presses at Calicut and Cochin, and at the latter port are published two English and two Malayalam newspapers. The climate of the district is, on the whole, healthy; the rainfall is heavy, averaging 120 inches a year, of which about 80 inches fall in June, July, and August. The temperature varies from 60° in December to about 92° in the hot weather in May. The principal diseases are small-pox, dysentery, and fever.

MALACCA. The town of Malacca lies on the south-west coast of the Malay Peninsula, in 2° 14′ N. lat. and

[1] Various extracts have been published in Europe, *e.g.*, the *History of the Copts*, in Arabic and German, by Wuestenfeld (Gött., 1845). For other extracts, list of MSS., &c., see Pertsch, *Arab. Handschriften zu Gotha*, No. 1675; and *Cat. Codd. MSS. Or. Mus. Brit.*, p. 156.

102° 12′ E. long. It is situated on a small river bearing its name, which separates it into two parts. That on the right bank is occupied by the old Dutch town, and that on the left by the business quarter, which is connected with the former by a small bridge, and is chiefly inhabited by Chinese and native traders. The view of Malacca from the harbour is picturesque and pleasing to the eye. From Flagstaff Hill on the left—whose slopes are always of a bright emerald green—to St John's Hill on the right, on which stand the ruins of the old "Dutch redoubt,"—hidden in a mass of wild vegetation,—stretches for a distance of about half a mile a row of spacious dwelling houses belonging to European and wealthy Chinese and Arab residents. These houses are roofed with neat red tiles, and have windows opening to a stone verandah facing the sea. Each house is surrounded by a large "compound," laid out with a flower garden in front and a "plantation" or orchard at the back. Adjoining this European quarter lies a large suburb of native and other dwellings almost concealed in a dense forest of beautiful fruit trees. Behind this we see a prominent green hill, formerly used as a fort, and now as a Chinese burial-ground, and beyond this the horizon is hemmed in by a long chain of the Bruong and Rumbow Hills, while far in the extreme east rises the jagged cone of Mount Ophir, blue as sapphire in the distance.

Since the destruction (in 1807) of the old Portuguese fort erected by Albuquerque, the "antiquities" of Malacca are reduced to a mere name. At the foot of Flagstaff Hill, however, are the remains of the massive wall which surrounded the hill, with an arched and carved gateway. On the summit of the hill, where a fine view is had of the harbour and the Water Islands, are the ruins of the first Christian church planted in Malayan territory, and also a portion of the old convent. At the back of this hill to the right may be noted the barracks, hospital, and convict lines, and passing under some fine "ansana" trees—the shady elms of the East—we reach the garden of the old Dutch stadthouse, and then a green square, facing which are the court-house and other Government buildings, and the old Dutch church. All these buildings have sloping roofs covered with small square tiles after the Dutch style of architecture of the 16th century. This is quite a unique example of Dutch domestic architecture in the East, and several of the adjoining streets still bear their Dutch designation, as "Heren Straat," "Jonker Straat," &c. The stadthouse is approached by a fine flight of stone steps, forming a covered way to the upper rooms. These are occupied by the governor of the Straits Settlements and the judge during their annual or biennial visits, and those in the lower story are used as Government offices. From the interesting ruins of the Dutch redoubt on St John's Hill an extensive view may be had of the country running around and to the north and south of Malacca. Its general aspect in the immediate vicinity is that of a flat country covered with luxuriant "dusoons" or plantations of fruit trees, and extensive forests of tall timber; beyond this is an open country, interspersed with extensive plantations of tapioca, which at a distance resemble fields of clover; then follow rice-fields, and marshes or fens, and at the foot of the hills patches of virgin forest, the whole being walled in by a range of blue hills. The climate of Malacca is very healthy, and the thermometer in the shade ranges from 72° to 84° or even 90° Fahr. The population, which is not very large, consists of Malays of the surrounding countries, of Malacca Portuguese (the mixed descendants of early Portuguese settlers), of Chinese proper and a large number born of Malay mothers. There is also a sprinkling of natives of India and of Arabs. The Malacca Portuguese employ themselves as fishermen, servants, and clerks; the rest are chiefly engaged in agricultural and commercial pursuits.

In consequence of its shallow harbour, Malacca has been completely outstripped as a seaport by Singapore and Penang, though it still carries on a brisk trade with the surrounding countries in Malacca canes, stuffed birds of beautiful plumage, poultry, and large quantities of the most luscious fruits. The import and export returns show a large apparent increase in the trade,—the imports in 1880 amounting to $3,817,848 (£812,308), and the exports to $3,634,640, as against an average of $2,505,175 and $2,577,020 respectively for 1869–72; and, though Malacca has been a drag on the revenue of the colony generally, a marked increase is shown in the principal items of revenue, viz., in land rents, tenths in paddy, tapioca, and fruits, royalty on timber, and survey fees. In 1880 the revenue was $182,323, and the expenditure $174,333, while the income and expenditure of the municipality in the same year were $22,428 and $18,899 respectively. The Government is improving the drainage of the country by clearing its natural water course. The municipality has no debts, and the general progress of the settlement during the year ending 1880 must be regarded as satisfactory, with an increase under almost every heading of revenue that bids fair to continue.

See C. A. Cameron, *Our Tropical Possessions in Malayan India*, and *Papers Relating to H. M. Colonial Possessions*, 1879–1881.

MALACHI. According to the title (Mal. i. 1) the last book of the minor prophets contains the word of Jehovah to Israel by the hand of Malachi. The word מַלְאָכִי may either be an adjective, "angelic," or may signify "the angel (messenger) of Jehovah." In either case it seems a strange (though hardly an impossible) name for a man to bear, and from the time of the Septuagint, which translates "by the hand of His messenger," it has often been doubted whether Malachi is the real name of the author, or only an epithet assumed by himself, or attached by the collector to a work which he found anonymous (so Ewald), with reference to iii. 1.[1] A Hebrew tradition given in the Targum of Jonathan, and approved by Jerome, identifies Malachi with Ezra the priest and scribe; but, though this opinion is ingeniously supported by reference to ii. 7, where the priest and custodian of the law is called the messenger of Jehovah of hosts, it is unlikely that Ezra's name would have been lost had he been the real author.[2]

The tradition, however, may at least be taken as implying the perception of a real affinity between the prophet and the great restorer of the law. The religious spirit of Malachi's prophecy is that of the prayers of Ezra and Nehemiah. A strong sense of the unique privileges of the children of Jacob, the objects of electing love (i. 2), the children of the Divine Father (ii. 10), is combined with an equally strong assurance of Jehovah's righteousness amidst the many miseries that pressed on the unhappy inhabitants of Judæa. At an earlier date the prophet Haggai had taught that the people could not expect Jehovah's blessing while the temple lay in ruins. In Malachi's time the temple was built (i. 10) and the priests waited in their office, but still a curse seemed to rest on the nation's labours (iii. 9). To Malachi the reason of this is plain. The "law of Moses" was forgotten (iv. 4 [iii. 22]); let the people return to Jehovah, and He will return to them. It was vain to complain, saying, "Every one that doeth evil is good in the eyes of Jehovah," or "Where is the God of judgment?"—vain to ask "Wherein shall we return?" Obedience to the law is the sure path to blessing (ii 17–iii. 12).

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[1] Stade (*Z. f. ATliche Wiss.*, 1882, p. 308; comp. 1881, p. 14) thinks that the title in Mal. i. 1 is by the same hand as that in Zech. xii. 1, and that both are copied from Zech. ix. 1, under the misconception that משׂא was to be construed with the following words.

[2] The LXX. rendering of i. 1 gave rise to strange fancies. Jerome and Cyril mention that some supposed the prophet to have been an angel in bodily form; and the *Vitæ Prophetarum* of Pseudo-Epiphanius have a "word-myth" to the effect that his prophecies were regularly confirmed by an angelic apparition. The same book will have it that Malachi was of the tribe of Zebulon, born in a town Sopha or Sophera, had his name from his great beauty, and died young.

It is not easy to say whether the law to which Malachi recalls the people is that which was established by the covenant taken under Ezra, or whether the prophet wrote before that event. It is at least the Deuteronomic law that is most familiar to him, as appears from his use of the name Horeb for the mountain of the law, and the Deuteronomic phrase "statutes and judgments"[1] (iv. 4), from his language as to tithes and offerings (iii. 8, 10, comp. Deut. xii. 11, xxvi. 12),[2] and especially from his conception of the priesthood as resting on a covenant with Levi (ii. 4 *sq.*). The abuses of which he particularly complains are such as were found rampant by Ezra and Nehemiah,—marriage with foreign women (ii. 11, comp. Ezra ix., Neh. xiii. 23 *sq.*, Deut. vii. 3) and failure in payment of sacred dues (iii. 8 *sq.*, comp. Neh. x. 34 *sq.*, xiii. 10 *sq.*, Deut. xxvi. 12 *sq.*). Add to this that the position of the priests had fallen into contempt (ii. 9), and that the oral law is still one of their chief trusts (ii. 6 *sq.*), and we shall be disposed to conclude that, if Malachi's work did not precede the reformation of Ezra, it must have fallen very little later, and before the new order was thoroughly established.[3] The prophecy of Joel shows the new theocracy in much fuller development.

The object of Ezra and Nehemiah was to establish the law by means of the organs of government under warrant from the Great King. Malachi looks for reformation in another direction. He calls the people to repentance, and he enforces the call by proclaiming the approach of Jehovah in judgment against the sorcerers, the adulterers, the false swearers, the oppressors of the poor, the orphan, and the stranger. Then it shall be seen that He is indeed a God of righteous judgment, distinguishing between those that serve Him and those that serve Him not. The Sun of Righteousness shall shine forth on those that fear Jehovah's name; they shall go forth with joy, and tread the wicked under foot. The conception of the day of final decision, when Jehovah shall come suddenly to His temple (iii. 1) and confound those who think the presumptuous godless happy (iii. 15), is taken from earlier prophets, but it receives a special character from an application of a thought based on Isa. xl. 3. The day of Jehovah would be a curse not a blessing if it found the nation in its present state, the priests listlessly performing a fraudulent service (i. 7–ii. 9), the people bound by marriage to heathen women, while the tears of the daughters of Israel, thrust aside to make way for strangers, cover the altar (ii. 11–16), all faith in divine justice gone (ii. 17, iii. 14 *sq.*), sorcery, uncleanness, falsehood, and oppression rampant (iii. 5), the house of God deprived of its dues (iii. 8), and the true fearers of God a little flock gathered together in private exercises of religion (perhaps the germ of the later synagogue) in the midst of a godless nation (iii. 16). That the day of Jehovah is delayed in such a state of things is but a new proof of His unchanging love (iii. 6), which refuses to consume the sons of Jacob. Meantime He is about to send His messenger to prepare His way before Him. The prophet Elijah must reappear to bring back the hearts of fathers and children before the great and terrible day of Jehovah come. Elijah was the advocate of national decision in the great concerns of Israel's religion; and it is such decision, a clear recognition of what the service of Jehovah means, a purging of His professed worshippers from hypocritical and half-hearted service (iii. 3) that Malachi with his intense religious earnestness sees to be the only salvation of the nation. In thus looking to the return of an ancient prophet to do the work for which later prophecy is too weak, Malachi unconsciously signalizes the decay of the order of which he was one of the last representatives; and the somewhat mechanical measure which he applies to the people's sins, as for example when he teaches that if the sacred dues were rightly paid prosperous seasons would at once return (iii. 10), heralds the advent of that system of formal legalism which thought that all religious duty could be reduced to a system of set rules. It was left to a greater Teacher to show that hypocrisy and vain religion might coexist with Pharisaic exactness in the observance of the whole letter of the law. Yet Malachi himself is no mere formalist. To him, as to the Deuteronomic legislation, the forms of legal observance are of value only as the fitting expression of Israel's peculiar sonship and service, and he shows himself a true prophet when he contrasts the worthless ministry of unwilling priests with the pure offering of prayer and praise that rises from all corners of the Hebrew dispersion (i. 11), or when he asserts the brotherhood of all Israelites under their one Father (ii. 10), not merely as a ground of separation from the heathen, but as inconsistent with the selfish and cruel freedom of divorce current in his time. It is characteristic of later Judaism that an arbitrary exegesis transformed this anticipation of the doctrine of marriage laid down in the gospel into an express sanction of the right of the husband to put away his wife at will.[4]

The style of Malachi, like his argument, corresponds in its generally prosaic character to that transformation or decay of prophecy which began with Ezekiel; and Ewald has rightly called attention to the fact that the conduct of the argument already shows traces of the dialectic manner of the schools. Yet there is a simple dignity in the manner not unworthy of a prophet, and rising from time to time to poetical rhythm.

The exegetical helps to the study of Malachi are mainly the same as have been already cited in the article HAGGAI. Reference may also be made to the lengthy commentary of Reinke (Roman Catholic), 1856; to M. Sänger, *Maleachi, eine exegetische Studie*, 1867; and among older commentaries to that of Pococke (2d ed., 1692). (W. R. S.)

MALACHITE, an ore of copper, presenting in its finer varieties a beautiful green colour which has led to its use as an ornamental stone. It is chemically a hydrated basic carbonate of copper, and appears to have been formed in most cases by the action of meteoric agencies on native copper, red oxide of copper, copper pyrites, and other ores. Upon these minerals the malachite frequently forms an incrustation. Although occasionally found in crystals belonging to the monoclinic system, its usual mode of occurrence is in stalactitic and stalagmitic forms,—frequently with a globular, botryoidal, or mammillated surface; while in other cases it forms compact and even earthy masses. The stalagmitic varieties display, when fractured, a beautiful internal structure, being made up of concentric zones of light and dark tints; and it is upon this structure that much of the beauty of polished malachite depends. The colours include various shades of apple-green, emerald-

[1] Malachi had the law of Deuteronomy in its present historical frame-work (the opening chapters), according to which all "the laws and statutes" apart from the Decalogue were given to Moses for Israel upon Horeb. This description would not hold good of the priestly legislation, which accordingly is hardly contemplated in Mal. iv. 4.

[2] Malachi indeed assumes that the "whole tithe"—the Deuteronomic phrase for the tithe in which the Levites shared—is not stored in each township, but brought into the treasury at the temple. But this was a modification of the Deuteronomic law naturally called for under the circumstances of the return from Babylon, and Neh. x. and xiii. produce the impression that it was not introduced for the first time by Ezra and Nehemiah, though the collection of the tithe was enforced by them.

[3] As the "governor" in i. 8 is hardly Nehemiah, Köhler and other recent writers think of the period between Nehemiah's first and second visit to Jerusalem, when the evils complained of by the prophet broke out afresh.

[4] In ii. 16 the Targum renders "If thou hatest her put her away," and this translation seems to be intended by the Massoretic punctuation. We should probably point שָׂנֵא in the sense of Arabic *makrûh*, used of actions not illegal but offensive to right feeling.

green, and verdigris-green. Certain varieties of the mineral exhibit, when fractured, a finely fibrous texture and soft silky lustre. The name *malachite* is derived from μαλαχή (the mallow), in allusion to the resemblance of the colour of the mineral to that of mallow leaves. Malachite was probably one of the green minerals described by Theophrastus under the general name of σμάραγδος, or emerald. It is believed to have been the *smaragdus medicus* of Pliny, while the *molochitis* of that author does not appear to have represented our modern malachite. Malachite is a mineral of very wide geographical distribution, being found more or less abundantly in the upper part of most deposits of copper ore. The finer varieties, such as lend themselves to purposes of ornament, are, however, found only in Siberia, in Australia, and at Bembe on the west coast of Africa. Probably the finest deposits in the world were those discovered some years ago in Prince Demidoff's mines at Nijni Tagilsk, in the government of Ekaterinburg, on the Siberian side of the Ural mountains. The mineral is highly prized in Russia for use in mosaic work, and for the manufacture of vases, snuff-boxes, and other small ornaments. Magnificent examples of malachite work, in the shape of mantelpieces, folding doors, tables, chairs, and other articles of furniture, have occasionally been executed. Such objects are veneered with thin slabs of malachite ingeniously fitted together so as to preserve the pattern, and having the interspaces between the component pieces filled up with a cement formed of small fragments of the malachite itself. The mineral is sawn into slabs, ground smooth with emery, and finally polished with tripoli. Although its degree of hardness is only from 3·5 to 4, it takes an excellent polish. It is rather denser than marble, its specific gravity being 3·7 to 4; but it is much more difficult to work, in consequence of its tendency to break along the planes of deposition. Malachite is occasionally used for cameo-work, but not with great success; some fine antique cameos in malachite are, however, known. The mineral has also been ground to powder, and used as a pigment under the name of mountain-green. The coarser masses are extensively used as ores of copper, malachite containing about 57 per cent. of metal. The mineral called azurite or chessylite, a hydrated basic carbonate of copper closely resembling malachite, save in colour, is occasionally known as blue malachite.

MALACHY, ST (*c.* 1094–1148), otherwise known as Maelmaedog Ua Morgair, for some time archbishop of Armagh, and afterwards papal legate in Ireland, was born of noble parentage at Armagh about the year 1094, early gained a high reputation for sanctity, and was ordained to the priesthood at the age of twenty-five (thirty being at that time, according to his biographer St Bernard, the canonical age). For some time he was employed as vicar by Archbishop Celsus or Ceallach of Armagh, and in this capacity was successful in effecting throughout the diocese many important reforms in the direction of increased conformity with the usage of the Church of Rome; afterwards he undertook the government of the decayed monastery of Bangor or Benchor, in what is now known as county Down, and made it a flourishing seminary of learning and piety. When thirty years of age he was chosen and consecrated bishop of Connor; after the sack of that place by the king of Ulster he withdrew into Munster and built the monastery of Ibrac. Meanwhile he had been designated by Celsus (in whose family the see of Armagh had been hereditary for many years) to succeed him in the archbishopric; reluctantly but dutifully in the interests of reform he accepted the dignity, and thus became involved for some years in a struggle with the so-called heirs. Having finally settled the diocese he, as had been previously stipulated by himself, was permitted to return to his former diocese, or rather, it having in the meanwhile been divided, to the smaller and poorer portion of it, the bishopric of Down, where he reorganized a house of regular clergy. In 1139 he set out from Ireland with the purpose of soliciting from the pope the pallium for the archbishop of Armagh; on his way to Rome he visited Clairvaux, and thus began a life-long friendship with St Bernard, who survived to write his biography. Malachy was received by Innocent II. with great honour, and made legate in Ireland, though he did not at once obtain the pallium; on his way homeward he revisited Clairvaux, and took with him from thence four members of the Cistercian order, by whom the abbey of Mellifont was afterwards founded in 1141. For the next eight years after his return from Rome Malachy was active in the discharge of his legatine duties, and in 1148 he received from the bishops of Ireland a commission to return to Rome and make fresh application for the pallium; he did not, however, get beyond Clairvaux, where he died on November 2, 1148. The object of his life was realized four years afterwards, in 1152, during the legateship of his successor (see IRELAND, vol. xiii. p. 255). Malachy was canonized by Clement IV.

MALAGA, a maritime province of Spain, one of the eight modern subdivisions of Andalucia, is bounded on the W. by Cadiz, on the N. by Seville and Cordova, on the E. by Granada, and on the S. by the Mediterranean, having an area of 2823 square miles, and a population (1877) of 500,231. The rise from the sea is rapid, and the average elevation of the province is considerable. Of the numerous sierras may be mentioned that of Alhama, separating the province from Granada, and at one point rising above 7000 feet; its westward continuation in the Sierra de Abdalajis and the Axarquia between Antequera and Malaga; and not far from the Cadiz boundary the Sierras de Ronda, de Mijas, de Tolox, and Bermeja, converging and culminating in a summit of nearly 6500 feet. The principal river is the Guadalhorce, which rises in the Sierra de Alhama, and after a westerly course past the vicinity of Antequera, bends southward through the wild defile of Peñarrubia and the beautiful vega or vale of Malaga, falling into the sea near that city. The only other considerable stream is the Guadiaro, which has the greater part of its course within the province, and flows past Ronda. The mountains are rich in minerals,—lead, nickel, and (in the neighbourhood of Marbella) iron being obtained or obtainable in large quantities. There are much frequented warm springs of sulphuretted hydrogen at the baths of Carratraca. Though the methods of agriculture are for the most part rude, the yield of wheat in good seasons is considerably in excess of the local demand; and large quantities of grapes and raisins, oranges and lemons, figs and almonds, are annually exported. The oil and wines of Malaga are also highly esteemed; and in recent years, especially since the phylloxera invasion, the growth of the sugar-cane has developed into a considerable industry. In 1880 the total production of wine within the province was estimated at about 5,250,000 gallons; of this amount about 1,575,000 gallons were exported (1,000,000 gallons to Great Britain and the continent of Europe, and the remainder chiefly to South America and the Spanish colonies). In 1879 about 1,400,000 gallons of olive oil were exported, chiefly to the Baltic. The sugar produced in 1880 was calculated to amount to about 5650 tons. The internal communications of the province are in many parts, owing to the broken nature of the surface, very defective; it is traversed, however, from north to south by the Cordova-Malaga Railway, which sends off a branch, recently made continuous, from Bobadilla to Granada. The only towns with a population exceeding 10,000 are Malaga (the capital), Antequera, Ronda, and Velez Malaga.

Malaga, the capital of the above province, and, next to Barcelona, the most important seaport of Spain, is finely situated on the Mediterranean coast, at the southern base of the group of hills known to history as the Axarquia, and at the eastern extremity of the fertile vega of Malaga (36° 43′ N. lat., 4° 25′ W. long.). The population in 1877 was 115,882. In the clearness of its sky, which a cloud rarely obscures, and the beautiful sweep of its bay, Malaga has sometimes been compared to Naples. The climate is one of the mildest and most equable in Europe, the mean annual temperature being 66°·7 Fahr. (55°·6 in winter, 80°·4 in summer); the yearly average of rainy days is thirty-nine, and the rainfall is slightly under 16 inches. The town lies principally on the left bank of a mountain torrent, the Guadalmedina ("river of the city"); the streets near the sea are spacious and comparatively modern, but those in the older part of the town, where the buildings are huddled around the ancient citadel, are narrow, winding, and often dilapidated. There are various squares or plazas and public promenades: of the former the most important are the Plaza de Riego

Plan of Malaga.

1. Cathedral. | 2. Custom House. | 3. Prison. | 4. Hospital.

(containing the monument to General Torrijos, who, along with forty-eight others, was executed in Malaga in 1831) and the Plaza de la Constitucion; adjoining the quay is the fine Paseo de la Alameda. The town has no public buildings of commanding importance architecturally or historically. The cathedral, on the site of the ancient mosque, was begun about 1528, in the Græco-Roman style; after the works had been once and again interrupted and resumed, it was completed to its present state in the 18th century, and is in consequence an obtrusive record of the degeneration of Spanish architecture. The woodwork of the choir, however, is worthy of attention. The church of El Cristo de la Victoria contains some relics of the siege by the "Catholic kings." Of the old Moorish "Atarazanas" or arsenal only a single horse-shoe gateway now remains, the rest of the site being chiefly occupied by an iron structure used as a meat and provision market; the "Alcazaba" or citadel has entirely disappeared. The castle of Gibralfaro, on a bold eminence to the north-east, dating from the 13th century, is still in fairly good preservation. The harbour, which in the beginning of the present century was deep enough to float a line-of-battle ship, has in recent years been permitted to silt up, so that it is not now safe for vessels drawing more than 18 feet to enter. These are consequently obliged to lie in the roads outside, and receive and discharge cargo by means of lighters. New harbour works were begun in 1880, but from time to time have been suspended, and only some 280 yards of the new eastern mole (about one-fourth of the intended length) have been constructed in October 1882. The trade of the port is chiefly in the products of the province,—lead, wine, raisins, oranges, lemons, figs, and esparto being the staples. The most active period is from the middle of August to the end of October. In 1880 the total quantity of muscatel raisins exported was estimated at 1,864,000 boxes (of 25 ℔ each), 35,500 frails (of 25 ℔), and 15,000 barrels (of 50 ℔); of this amount more than half was sent to the United States of America, and the remainder to other countries (chiefly Great Britain, France, and Germany). In the same year 50,000 boxes of lemons and 21,500 boxes of oranges were shipped, besides 20,000 barrels of muscatel grapes. The wine exported in 1879 was only 1,400,000 gallons as against 3,108,000 in 1878; the lead 310,251 cwts. as against 481,021 cwts. in 1878. The olive oil is sent chiefly to the Baltic. The principal imports are coal (41,822 tons in 1878), codfish, timber, pig-iron, hardware, machinery, and rails.

Malaga is the Μάλακα of Strabo (iii. 156) and Ptolemy (ii. 4, 7), and the *Malaca fœderatorum* of Pliny (iii. 3). The place seems to have been of some importance even during the Carthaginian period; under the Romans it became a municipium, and under the Visigoths an episcopal see. After the battle of Guadalete it passed into the possession of the Arabs, and soon came to be regarded as one of the most important cities of Andalucia. It was attached to the caliphate of Cordoba, but on the fall of the Omayyad dynasty it became for a short time the capital of an independent kingdom; afterwards it was dependent on Granada. In 1487 it was taken and treated with great harshness by Ferdinand and Isabella after a protracted siege. In 1810 it suffered much from the French general Sebastiani.

MALARIA, an Italian colloquial word (from *mala*, bad, and *aria*, air), introduced into English medical literature by Macculloch (1827) as a substitute for the more restricted terms marsh miasm or paludal poison. By very general consent the word is understood to mean an actual poisonous substance existing as a separate entity, and giving rise to the definite unhealthy condition of body known by a variety of names, such as ague, intermittent (and remittent) fever, marsh fever, jungle fever, hill fever, "fever of the country," and "fever and ague." By a figure of speech, the name of malaria is often applied to the disease itself; strictly speaking, the effects on the human body are "malarial fever," or manifestations of the "malarial process." The existence of a specific malaria-poison is a pure hypothesis; and it has been attempted by a respectable minority to dispense with the hypothesis of an actual poisonous agent, and to find the cause of intermittents and remittents in the excessive and sudden abstraction of heat through damp and cold after sunset from the bodies of individuals who had previously endured great solar heat. In either view, the unknown cause of ague is denoted with sufficient etymological accuracy by the word malaria.

A single paroxysm of simple ague is much the same in all countries, temperate, subtropical, or tropical. It may come upon the patient in the midst of good health, or it may be preceded by some *malaise.* The ague-fit begins with chills proceeding as if from the lower part of the back, and gradually extending until the coldness overtakes the whole body. Tremors of the muscles, more or less violent, accompany the cold sensations, beginning with the muscles of the lower jaw (chattering of the teeth), and extending to the extremities and trunk. The expression has meanwhile changed: the face is pale or livid; there are dark rings under the eyes; the features are pinched and sharp, and the whole skin shrunken; the fingers are dead white, and the nails blue. All those symptoms are referable to spasmodic constriction of the small surface arteries, the pulse at the wrist being itself small, hard, and quick. In the interior organs there are indications of a compensating accumulation of blood, such as swelling of the spleen, engorgement (very rarely rupture) of the heart, with a feeling of oppression in the chest, and a copious flow of clear and watery urine from the congested kidneys. The body temperature will have risen suddenly from the normal to 103° or higher. This first or cold stage of the paroxysm varies much in length; in temperate climates it lasts from one to two hours, while in tropical and subtropical countries it may be shortened. It is followed by the stage of dry heat, which will be prolonged in proportion as the previous stage is curtailed. The feeling of heat is at first an internal one, but it spreads outwards to the surface and to the extremities; the skin becomes warm and red, but remains dry; the pulse becomes softer and more full, but still quick; and throbbings occur in exposed arteries, such as the temporal. The spleen continues to enlarge; the urine is now scanty and high-coloured; the body temperature still rises (up to 104° or 105° or even higher); there is considerable thirst; and there is the usual intellectual unfitness, and it may be confusion, of the feverish state. This period of dry heat, having lasted three or four hours or longer, comes to an end in perspiration, at first a mere moistness of the skin, passing into sweating that may be profuse and even drenching. Sleep may overtake the patient in the midst of the sweating stage, and he awakes, not without some feeling of what he has passed through, but on the whole well, with the temperature fallen almost or altogether to the normal, or it may be even below the normal, the pulse moderate and full, the spleen again of its ordinary size; the urine that is passed after the paroxysm deposits a thick brick-red sediment of urates. The three stages together will probably have lasted six to twelve hours. The paroxysm is followed by a definite interval in which there is not only no fever, but even a fair degree of bodily comfort and fitness; this is the intermission of the fever. Another paroxysm begins at or near the same hour next day (quotidian ague), or the interval may be forty-eight hours (tertian ague), or seventy-two hours (quartan ague). It is the general rule, with frequent exceptions, that the quotidian paroxysm comes on in the morning, the tertian about noon, and the quartan in the afternoon. Another rule is that the quartan has the longest cold stage, while its paroxysm is shortest as a whole; the quotidian has the shortest cold stage and a long hot stage, while its paroxysm is longest as a whole. The point common to the various forms of ague is that the paroxysm ceases about midnight or early morning. Quotidian intermittent is on the whole more common than tertian in hot countries; elsewhere the tertian is the usual type, and quartan is only occasional.

If the first paroxysm should not cease within the twenty-four hours, the fever is not reckoned as an intermittent, but as a remittent.

Remittent is a not unusual form of the malarial process in tropical and subtropical countries, and in some localities or in some seasons it is more common than intermittent. It may be said to arise out of that type of intermittent in which the cold stage is shortened while the hot stage tends to be prolonged. A certain abatement or remission of the fever takes place, with or without sweating, but there is no true intermission or interval of absolute apyrexia. The periodicity shows itself in the form of an exacerbation of the still continuing fever, and that exacerbation may take place twenty-four hours after the first onset, or the interval may be only half that period, or it may be double. A fever that is to be remittent will usually declare itself from the outset: it begins with chills, but without the shivering and shaking fit of the intermittent; the hot stage soon follows, presenting the same characters as the prolonged hot stage of a quotidian, with the frequent addition of bilious symptoms, and it may be even of jaundice and of tenderness over the stomach and liver. Towards morning the fever abates; the pulse falls in frequency, but does not come down to the normal; headache and aching in the loins and limbs become less, but do not cease altogether; the body temperature falls, but does not touch the level of apyrexia. The remission or abatement lasts generally throughout the morning; and about noon there is an exacerbation, seldom ushered in by chills, which continues till the early morning following, when it remits or abates as before. A patient with remittent may get well in a week, under treatment, but the fever may go on for several weeks; the return to health is often announced by the fever assuming the intermittent type, or in other words, by the remissions touching the level of absolute apyrexia. Remittent fevers (as well as intermittents) vary considerably in intensity; some cases are intense from the outset, or pernicious, with aggravation of all the symptoms—leading to stupor, delirium, collapse, intense jaundice, blood in the stools, blood and albumen in the urine, and, it may be, suppression of urine followed by convulsions. The severe forms of intermittent are most apt to occur in the very young, or in the aged, or in debilitated persons generally. Milder cases of malarial fever are apt to become dangerous from the complications of dysentery, bronchitis, or pneumonia. Severe remittents (pernicious or bilious remittents) approximate to the type of yellow fever, which is conventionally limited to epidemic outbreaks in western longitudes and on the west coast of Africa. Blood in the urine has been described by several recent writers as distinctive of a form of bilious remittent occurring at a number of malarious localities in the tropical zone of both hemispheres. The remittent type occurs wherever and whenever the malarial conditions are severe; when it has appeared in colder climates, it has usually been at the height of an epidemic of intermittent. With all the foregoing statements, it should be borne in mind that anomalies are frequent.

Of the mortality due to malarial disease a small part only is referable to the direct attack of intermittent, and chiefly to the fever in its pernicious form. Remittent fever is much more fatal in its direct attack; it often kills in the first few days, according to its initial intensity or the severity of the complications. But probably the greater part of the enormous total of deaths set down to malaria is due to the *malarial cachexia*. The malarial cachexia may be either the sequel of one or more actual attacks of fever, or it may arise insidiously in those who inhabit a malarious district and have never experienced the sharp paroxysms of fever. In the latter case, malaria is almost as much an ethnological as a pathological factor. The dwellers in a malarious region like the Terai (at the foot of the Himalayas) are miserable, listless, and ugly, with large heads and particularly prominent ears, flat noses, tumid bellies, slender limbs, and sallow complexions; the children are impregnated with malaria from their birth, and their growth is attended with aberrations from the normal which practically amount to the disease of rickets. The malarial cachexia that follows definite attacks of ague consists in a state of ill-defined suffering, associated with a sallow skin, enlarged spleen and liver, and sometimes with dropsy.

Nearly allied to the malarial cachexia is the so-called state of *masked ague*. Many common ailments have been set down to malaria, without sufficient reason; but there is hardly any doubt that intermittent paroxysms of *neuralgia*, especially of the supra-orbital nerve (*brow-ague*) and of the infra-orbital (*tic douloureux*), are often malarial in origin. These non-febrile effects are apt to follow exposure to malaria; they occur (not exclusively) in those who have had fever and ague; they are sometimes accompanied by suggestions of the cold, and hot, and sweating stages of the true paroxysm; and they often yield to the great anti-malarial remedy, quinine. Such patients have the general ill-health and suffering, as well as the pallor, of the malarial cachexia.

The morbid anatomy of malarial fevers is chiefly confined to congestions and enlargements (with textural changes) of the spleen and liver. One of the most salient pathological facts is the occurrence of black pigment in the blood, and deposits of it in the spleen, liver, and other parts. The malarial process sometimes leads to ulcerations and sloughing of the mucous membrane of the great intestine, not distinguishable from those of dysentery. The malarial fever of Rome is often associated with more or less of swelling and, it may be, even ulceration of the lymphatic follicles of the small intestine, as in typhoid fever; the same anatomical condition was associated with much of the malarial fever of the American Civil War (typho-malaria).

Geographical Distribution and Prevalence.—Malaria has been estimated to produce one-half of the entire mortality of the human race; and, inasmuch as it is the most frequent cause of sickness and death in those parts of the globe that are most densely populated, the estimate may be taken as at least rhetorically correct.

In the British Islands, sporadic cases of ague may occur anywhere; but malaria is not now endemic except in a few localities, among which may be mentioned certain parishes on the Essex side of the Thames estuary. In France there are several districts that are still notoriously malarious. In the interior these are chiefly found in the valley of the Loire (Sologne) and of its tributary the Indre (Brenne), and also in the valley of the Rhone, more particularly near the confluence of the Saône (Dombes, Bresse). France has two great coast regions of malaria,—the one on the Atlantic seaboard, from the estuary of the Loire to the Pyrenees, with especial intensity in the Charente, and the other on the Mediterranean coast, from the Pyrenees to the Rhone delta. The most considerable malarious district of Switzerland is in the Rhone valley from Sion to the Lake of Geneva. In Germany, the upper valley of the Rhine and the sources of the Danube have a certain character for malaria; but it is chiefly on the western seaboard of Schleswig-Holstein and in the moors and marshes of Oldenburg, Hanover, and Westphalia that the disease is endemic. Scarcely any province of Holland can be said to be quite free from it, while Gröningen, Friesland, and Zealand (with brackish marshes) are the most unhealthy. The parts of Belgium that are almost or altogether exempt are the high-lying districts of Brabant, Namur, and Liége. In Sweden, malaria is endemic in the central depression of the country (especially on the shores of Lake Wener), and it has of late years spread northwards in epidemic outbreaks. For the countries of southern and eastern Europe (Spain and Portugal, Italy, Hungary and other Danubian states, Turkey, Greece, southern Russia), the language used to describe the prevalence of malaria has to be pitched in a somewhat higher key. There are certain pestilential districts of those countries where almost the half of the population suffers from ague, and there are even limited areas which are too malarious to be inhabited. The lower basin of the Danube (from above Vienna to the Black Sea), and the basin of its tributary the Theiss, are in the first rank. Both sides of the Adriatic have malarious localities, the chief being the delta of the Po and the Gulf of Comaccio; among other unhealthy parts of Italy are the strip of coast from Pisa to Civita Vecchia (Maremma), the Roman Campagna, the Pontine Marshes, the neighbourhood of Capua, and the Neapolitan and Calabrian coasts. Sicily is highly malarious, both in the plains and in the higher districts; and that is equally the character of Sardinia, Corsica, and the Balearic Isles. Greece, the Ionian Islands, and Crete take a high place among European malarious countries; there are also numerous unhealthy localities on the shores of the Caspian and Black Seas and in Asia Minor. For countries in both hemispheres situated between 35° N. and 20° S., to describe the prevalence of malaria in detail would be practically to give the whole geography within those latitudes. The regions of special intensity are the west coast of Africa, the American seaboard (with the West Indies) from the Gulf of Mexico to Pernambuco, parts of India (the Terai, the Doab, the Sunderbunds), parts of Sumatra, of Java, and of Borneo. Gibraltar, Malta, Aden, Singapore, and Manila enjoy a comparative immunity from fever; the healthiest islands of the West Indies are Barbados, St Vincent, and Antigua.

In England, the fen district of the eastern counties, Romney Marsh in Kent, and the marsh district of Somerset have in great part ceased to be malarious within recent memory; and there has been a proportionate improvement, through drainage, in most parts of Holland, in some of the malarious districts of France and Italy, and in Algiers. Portsmouth in England and Rochefort in France are examples of towns that have entirely lost their evil repute for malaria; and there are many towns in the United States, as well as in the East, which are much less malarious than they used to be. Wherever malarial fevers have become less frequent, they have also become milder in type. On the other hand, malaria has become intense where it was formerly unimportant or altogether unknown. It is incredible that the Roman Campagna could have been so malarious at the time of the empire as it is now; places on the coast, such as Ostia and Palo (Alsium), which are now almost uninhabitable in summer, were then the favourite summer resorts of the rich; while the Campagna, which is now almost entirely given up to pasturage, was not only densely populated, but was even specially commended as salubrious. In North Africa, Asia Minor, and the East, malaria has taken possession of the ruined sites of ancient cities, and of large tracts of land that must have been at one time highly cultivated, but are now treeless, barren, and sometimes marshy. Of recent years malaria has appeared in Réunion and Mauritius, and it has reappeared in Connecticut; in the two islands the associated circumstances are somewhat complicated, but they relate to changes in the cultivated area. The reappearance of ague in New England and the recent appearance of a form of masked ague in New York and elsewhere are at present unaccounted for. Earthquakes were said by older writers to have brought malaria to a locality; a recent and well-authenticated instance is that of Amboyna in the Moluccas, which has become strikingly unhealthy since the earthquakes that occurred in it in 1835.

Among the numerous military enterprises into whose records malaria enters largely, may be mentioned the expedition against Carthagena (1741), the Walcheren expedition (1810), and the capture of Rangoon (1824). Recent enterprises in which malarial fever has been a great factor are the expedition against Achin by the Dutch (1873), the occupation of Cyprus by the English (1878), and the subjugation of Tunis by the French (1881). Schemes of colonization, such as the Darien scheme (1701), have sometimes been frustrated by malaria. Of historical personages, James I. and Cromwell died in London of malarial fever, the latter of a pernicious tertian.

There have been numerous historical epidemics of intermittent and remittent fever, from that of 1557-58 (which spread over all Europe) down to that of 1872, which prevailed simultaneously in Europe, North America, and southern India. The epidemic or pandemic prevalence of intermittent and remittent fever in certain years probably finds its explanation in the meteorology of those years, but no uniform law has been discovered. Whenever malaria has settled endemically in a new locality, there had been epidemics coming and going for some time previously.

Malarious Localities.—The most malarious localities are the deltas and estuaries of rivers (Ganges, Euphrates, Po, Mississippi, Orinoco), low-lying country that is apt to be inundated (Danubian states), tropical or subtropical forests in which there is a moist atmosphere, with stagnation of the air and rank vegetation (jungles), tracts of land that have been cleared of trees and have gone out of cultivation, being in more cases dry than wet (Roman Campagna, Tuscan Maremma, many parts of Persia, Asia Minor, and North Africa, including the sites of ruined cities), inland swamps and marshes (Pontine Marshes), and situations on the coast where the tidal and fresh water join to form brackish marshes (mangrove swamps of the West Indian, Central American, Brazilian, and West African coasts). The mangrove is associated with the most pestilential localities; it springs "like a miniature forest out of the greasy mud-banks, the bright green colour of the bushes reminding one of the rank grass in a churchyard" (C. Darwin). In all those localities there is a soil, usually wet but sometimes dry, rich in the products of vegetable decay; the soil has been either deposited by rivers and tides, or it has formed on the spot out of the undisturbed accumulation of decaying vegetation season after season over a long period. There is, however, a second great class of malarious localities, distinguished by characters that are to some extent the opposite of the foregoing. These are barren rocks (Ionian Islands, Hong Kong, parts of Baluchistan, De Los Islands near Sierra Leone); high table-lands more or less barren (Deccan, Mysore, Persia, New Castile); mountainous regions (Andes, Rocky Mountains); prairies of North America and savannas of Venezuela and Brazil; sandy plains (North Africa, Rajputana, Sindh). A somewhat exceptional locality for malaria is on board ship at sea; there are several well-authenticated instances of epidemic outbreaks at sea, in most cases referred to the putrid bilge-water, and in one case to a cargo of wet deals from the Baltic.

There are several localities whose exemption from malaria has been thought remarkable. Among these, Singapore has long been noted; other instances are the Amazon (as compared with its tributaries and with the Orinoco), the pampas of the La Plata and the Parana, marshy parts of Australia, New Zealand, and New Caledonia, and the marshy Bermudas. The explanation given of the exemption of Singapore, where many of the supposed malarial conditions are present, is that the range of temperature (diurnal and annual) is small; the explanation for the Amazon is that a wind constantly blows up the river from the sea (not reaching the side streams), which serves to equalize the day and night temperature and to obviate the nocturnal radiation of heat.

Malarious Seasons.—In temperate climates autumn is the season when malaria prevails most. "In the autumn, and after the harvest has been gathered, when the ground is covered with its debris, when the rain falls in torrents and when the solar heat has acquired its greatest intensity, all the conditions of greatest quantity of vegetable matter, of moisture, and of highest temperature are united, so that the season which realizes the hopes of the husbandman is the period of pestilence and of his greatest danger" (R. Williams). In the equatorial regions of the East Indies, Africa, and America, the rainy season (May to July or August) is most unhealthy, and especially the time of commencement of the rains and the time of cessation; on the west coast of Africa the months of February, March, and April, which are the hottest months of the year, are at the same time the most healthy. But while autumn and the time of the rains are the malarious season for those localities that are distinguished by wet soil, rank vegetation, &c., it is summer, or the time of extreme heat and drought, that is the unhealthy season for the localities distinguished by dryness of the soil and often by barrenness. The hill fever of the Deccan and Mysore is often most prevalent and most severe in the hottest and driest seasons; in Algeria there is most fever when the country is parched to a desert. The malarial season in the Tuscan Maremma is from June to the middle of September. In military experience it has frequently happened that malaria has attacked the troops in the hottest weather after camping in the dried-up water-courses of uplands, or in parched meadows and sandy levels that are apt to be flooded only in winter.

Conditions of Origin.—In all localities and at all seasons, it is at or after sunset that the malarial influence prevails, and it tells most when a cold night follows a hot day. Perhaps the most constant fact relating to malaria is that it goes with watery exhalations and with the fall of dew. On wet soils, and over marshes, swamps, and jungles, the aqueous vapour condenses as the air cools; while on dry surfaces the rapid radiation of heat causes a heavy dew-fall. The occurrence of malaria on bare rocks, parched uplands, and treeless tracts of dry fallow land may have several associated circumstances; but that which has been most uniformly observed in such localities is great diurnal range of temperature, with rapid radiation of heat after sunset, and copious fall of dew. The "hill fever" of Mysore occurs among bare rocks and stones and brown earth; at the hottest season (March to June) the diurnal range of the shade temperature may be 20° to 30°, while the rocks in the sun may show a surface temperature up to 220°, and undergo a rapid cooling after sunset. The most malarious locality at all times of the year on the Orinoco is around the great cataract, where the banks of the river for some distance are covered with bare black rocks piled to a considerable height; the rocky substance and the black surface combine to produce the greatest absorption of heat and the most rapid radiation, and the rocks there, as well as in other parts of South America and in India, are credited by the natives with giving off poisonous exhalations which cause the fever. Among the conditions of origin the predisposition of the human subject takes a prominent place. Those who have been habituated to extreme heat, and are on occasion exposed to cold and damp, are likely to acquire intermittent or remittent fever; and those who are poorly clad, housed, and fed are most likely. Fires at night in a malarious locality are a well-known protection from fever; the cover of trees (preventing the radiation of heat) is also a protection. Those who have had ague before are liable to have it again on exposure in a malarious locality, or to chill anywhere.

Diffusion of Malaria.—On the hypothesis that malaria is a poisonous substance, it is permissible to speak of its diffusion. It acts for the most part only within a few feet of the ground; in the East Indies the raising of dwellings on piles serves to keep off, or at least lessen, the liability to fever, and the Indians in South America escape it by sleeping in the branches of trees. Although it is not known to act beyond a few feet from the earth's surface, it may produce fever in localities situated at a height of 7000 to 9000 feet above the sea-level. It sometimes acts at a distance from its supposed place of origin. Thus, it it is said to have caused fever on board ships lying 2 or 3 miles off a malarious shore, although it is more usual for ships at even a short distance from the shore to escape. In West Indian experience it has been known to render the high limestone ridge more unhealthy than the swamp at its foot, and a similar experience has occurred on the Kentish shore of the Thames estuary, and at other parts of the English (Channel) coast. There are instances where it has, so to speak, travelled along a narrow valley from an unhealthy marsh to a salubrious situation. Although a still night is most favourable to its production, there is a popular opinion that it is carried by the wind. In many malarious localities there is a definite "ague line," beyond which the noxious influence is not felt. A belt of trees, or even a wall, will "keep it off." It clings to those surfaces that are most easily bedewed. Situations to windward of a malarious swamp are usually reckoned safe.

Hypothesis of Malaria.—Malaria is known only by its effects on the animal body; the effects, although they vary much in intensity, are uniform, definite, or specific, and are characterized by a truly remarkable periodicity. The oldest and most prevalent hypothesis of malaria is that it is a specific poison generated in the soil. Perhaps not every soil is capable under circumstances of causing malaria, but it is difficult to assign limits to its potential presence. There are seemingly well-authenticated cases of malarial disease appearing during the making of railway cuttings, canals, and other excavations in places where malaria had not previously been known; and there is sufficient evidence that malaria has appeared in the track of cultivation in the western States of America, and that it follows on the upturning of virgin soil, and even of soil that has been long fallow. Attempts have been made, without success, to separate a malarious poison from the gases generated by swamps, or from the air of malarious localities. Still more frequent and elaborate attempts have been made to discover the hypothetical poison among the numerous minute vegetable organisms that occur in the soil of malarious (and non-malarious) places; and these also have hitherto yielded no solid result. Another hypothesis is that malaria is a "telluric intoxication," generated by the vegetative power of the soil when that power is not duly exhausted by plant growth. Lastly, there is an hypothesis that malarial fevers are caused by the excessive and sudden abstraction of heat from the body under the influence of cold and damp, and that the specific effects of the nocturnal chill, amounting to intermittent and remittent fever, are most usual and most marked in hot climates because of the antecedent exposure of the body to great solar heat.

Remedies.—Cinchona or Peruvian bark (with its alkaloid quinine) is a remedy universally applied with good effect in the treatment of malarial fevers. The treatment is usually commenced during the first intermission or remission. There is no good evidence that the taking of quinine wards off the attack of malaria. The extent of cinchona planting in southern India, Ceylon, Jamaica, and elsewhere is the best measure of the value of quinine as a remedy, and more particularly as a remedy for ague. Arsenic has proved one of the most efficient substitutes for quinine. The dwellers in malarious localities have found in opium a palliative of the misery induced by the malarial cachexia.

Literature.—Hirsch, *Geographisch-historische Pathologie*, 2d ed., Stuttgart, 1881, pt. i. sec. 7 (the bibliographical references appended to Hirsch's chapter on malaria include upwards of eight hundred names); W. Ferguson, "On the Nature and History of the Marsh Poison," *Trans. Roy. Soc. Edin.*, ix., 1823 (omitted by Hirsch; was the first to dwell upon the fact that malaria is often associated with heat and drought, and elevated rocky localities); Macculloch, *Malaria, an Essay*, &c., London, 1827; Robert Williams, *Morbid Poisons*, London, 1836-41, vol. ii., chapter on "Paludal Diseases"; Colin, *Traité des fièvres intermittentes*, Paris, 1870 (expounds the theory of "intoxication tellurique"); C. F. Oldham, *What is Malaria? and Why is it most Intense in Hot Climates?* London, 1871 (a comprehensive review and acute criticism of established facts and current theories, with the motive of showing that there is no specific malarial poison); Morehead, *Clinical Researches on Disease in India*, London, 1856, vol. i. (for symptoms, diagnosis, and treatment of intermittent and remittent fevers); Fayrer, *Climate and Fevers of India*, London, 1882 (both general and clinical). (C. C.)

MALAṬIA, less correctly MALAṬÍYAH, the ancient Melitene of Cappadocia, a town of Kurdish Armenia in the vilayet of Diarbekir, about 8 miles to the south-west of the Euphrates below the confluence of the Tokhma-su, and about half way between Baghdad and Constantinople, on a route which for ages has been one of the most important in that part of Asia. Asbuzi or Aspuzi, a place about 5 miles distant, which was formerly inhabited by the people of Malatia during the summer only, has become the permanent residence of a large part of the population (about 20,000, including both), but Malatia proper remains the administrative centre of the sanjak. The remains of the ancient town are much dilapidated.

In the time of Strabo (xii. 537) there was no town in the district of Melitene. Under Titus the place became the permanent station of the 12th legion; Trajan raised it to a city. Lying in a very fertile country at the crossing-point of important routes, it grew in size and importance, and was the capital of Armenia Minor or Secunda. Justinian, who completed the walls commenced by Anastasius, made it the capital of Armenia Tertia; it was then a very great place (Procop., *De Æd.*, iii. 4). The town was burnt by Chosroes on his retreat after his great defeat there in 577. Taken by the Saracens, retaken and destroyed by Constantine Copronymus, it was presently recovered to Islam, and rebuilt under Mansúr (757-58 A.D.). It again changed hands more than once, being reckoned among the frontier towns of Syria (Istakhry, p. 55, 62). At length the Greeks recovered it in 934, and Nicephorus II., finding the district much wasted, encouraged the Jacobites to settle in it, which they did in great numbers. A convent of the Virgin, and the great church which bears his name, were erected by the bishop Ignatius (Isaac the Runner). From this time Malatia continued to be a great seat of the Jacobites, and it was the birthplace of their famous maphrian Barhebræus (or Abulfaragius). At the commencement of the 11th century the town was said to number 60,000 fighting men (Assem., *Bib. Or.*, ii. 149; comp. Barheb., *Chr. Eccl.*, i. 411, 423). At the time of the first crusade, the city, being hard pressed by the Turks under Ibn Danishmend, was relieved by Baldwin, after Bohemund had failed and lost his liberty in the attempt. But the Jacobites had no cause to love Byzantium, and the Greek governor Gabriel was so cruel and faithless that the townsmen were soon glad to open their gates to Ibn Danishmend (1102), and the city subsequently became part of the realm of Kilij Arslan, sultan of Iconium.

MALAY PENINSULA, MALACCA, or TÁNAH MALÁYU Plate V. ("Malay Land"), the southernmost region in Asia, attached to Further India by the isthmus of Krá, in 10° N. lat., whence it projects for about 600 miles, first south, then south-east parallel with Sumatra, to Cape Ramúnia (Romania) in 1° 23′ N., within 95 miles of the equator; it varies in width from 45 miles at the isthmus of Krá, and again at Talung in 7° 30′ N., to 210 at Perak in 5° N., and 150 at Selángor, 3° 20′ N. The area is about 70,000 square miles, with a population of at least 650,000.[1] The peninsula, which is washed on the west by the Bay of Bengal and Malacca Strait, on the east by the Gulf of Siam and China Sea, belongs geographically and ethnically rather to the eastern archipelago than to the Asiatic continent. Hence, whenever the proposed canalization[2] of the isthmus of Krá is carried

[1] A careful calculation made by T. J. Newbold in 1838 gave a total population of 375,000, since which date the British possessions have increased about fourfold, from 90,000 to 330,000. Hence, allowing for a slight increase elsewhere, the present population must be at least 650,000 (*Political and Statistical Account of the British Settlements in the Straits of Malacca*, London, 1839, vol. i. p. 418).

[2] The several projects of canalization are fully discussed by M. Léon Dru in *L'Exploration* for March 9 and 16, 1882. The most feasible, but not the shortest, follows the line of railway already projected in

MALAY PENINSULA.

out, this region will fall into its natural position as one of the great islands of Malaysia. In a wider sense the peninsular formation begins properly at the head of the Gulf of Siam, about the parallel of Bangkok. But this northern section between 10° and 13° 30′ N. being comprised within the limits of Siam proper and British Burmah, is not usually included in Malacca, whose political frontier towards the north-west is thus traced by the lower course of the river Pakshan, which there separates it from Tenasserim, the southernmost division of British Burmah. But east of that river there is no natural or political frontier towards Lower Siam, which embraces all the land as far south as the river Muda on the west coast in 5° 33′ N., and on the east side as far as the state of Pahang in 4° N. The seaboard, which is generally flat and overgrown with mangroves for 5 or 6 miles inland, is fringed with numerous islands and insular groups, of which the chief are Salanga (Junk Ceylon), Langkawi, and Pulo Penang on the west side; Singapore, Batang, and Bintang at the southern extremity; Tantalem and Bardia on the east coast. All these islands, which may have a total area of some 5000 square miles, seem to have originally formed part of the mainland, of which they may be regarded as scattered geological fragments.

Although known to Europeans since the beginning of the 16th century, and nowhere more than 100 miles from the sea, the interior still remains one of the least known lands in Asia. D'Souza's large map, prepared in 1879 for the British Government, is still in many places almost a complete blank; the mountain ranges are traced only for short distances, chiefly on the west side below Kedah; the river courses and political boundaries are often merely conjectured, while the elevation of some of the highest peaks is absolutely unknown. Accurate surveys, however, have since then been made, especially by H. S. Deane in the Perak and Selángor states, by D. D. Daly in most of the British native states,[1] by Dru in the extreme north, and by others in the extreme south about the Endau river basin and at several other points, from which a rough idea may be formed of the general orographic and geological features and hydrographic systems. The surface seems to be everywhere essentially mountainous, and considerably more elevated than had till recently been supposed. The land is traversed in its entire length by a somewhat irregular and ill-defined backbone, forming a southern continuation of the Arakan and Tenasserim ranges, but here falling to a mean elevation of perhaps 3000 feet, and constituting a distinct water-parting between the streams flowing east and west to the surrounding seas. The surface is further varied by numerous spurs and detached ridges running mainly north and south, besides isolated masses often vying in elevation with the central ranges. Little space is thus left for upland plateaus, broad valleys, or lowland alluvial plains of any extent, except about Tringgánu and Pahang on the east, and Selángor on the west side. The highest ascertained altitudes are the Titi Bangsa range (7000 feet), between Kedah and Perak; the Gunong Inas (5000) ascended in 1881 by Deane; the Gunong Bubu (5650), and Gunong Ulu Tumulang (6435), near the right and left banks of the Perak river; the Slim range (6000 to 7000) in south-east Perak; the Gunong Rajah (6500), in the main range; a peak (7000) in the Endau river basin, nearly double the height of Gunong Ledang, or Mount Ophir (3849), hitherto supposed to be the highest point in the extreme south. But an unexplored ridge towards the west frontier of Kelantan, with a probable elevation of 8500 or 9000 feet, is taken by Miklucho Maclay as the culminating land of the whole peninsula. These mountains are scarcely anywhere traversed by recognized beaten tracks, the natural passes between the eastern and western watersheds being still mostly overgrown by dense jungle. Deane, however, came upon a forest path across the main water-parting from Kedah to Patáni, and a route is said to lead from the Bernam river basin across the main axis to Pahang on the east side.

Owing to the formation of the land, the rivers, although numerous, are necessarily of short length, and, as their mouths are generally obstructed by bars and coral reefs, they are on the whole more useful for irrigation than as water highways. Nevertheless some are navigable by light craft for considerable distances, and in 1881 Deane steamed up the Bernam between Perak and Selángor to Kampong Chankat Bertiham, 76 miles from the coast. He proceeded by boat thence for 9 miles to Simpang, where the stream divides and shallows. For about 80 miles it is 10 to 17 feet deep, while the Perak, with its chief tributaries, the Plus, Kinta, and Batang Padang, presents a total navigable waterway of perhaps 200 miles. The Perak on the west and the Pahang on the east slope are by far the largest river basins in the peninsula, each draining an area of 5000 to 6000 square miles. The other chief streams are the Selángor and Klang on the south-west coast, the Johór facing Singapore, and on the east side the Endau, Kelantan, and Patáni.

As far as has been ascertained, the main geological formations would appear to be Lower Devonian sandstones and unfossilized clay slates, with a basis of grey stanniferous granite everywhere cropping out. Although no trace has been found of recent volcanic action, there are several isolated and unstratified limestone masses from 500 to 2000 feet high, of a highly crystallized character, with no fossils of any kind. Earthquakes also are frequent, while numerous hot springs attest the presence of still active igneous forces beneath the surface. In the south porphyry occurs, associated with granite and clay ironstone; and laterite, resembling that of the Malabar coast, abounds, especially along the west slope. The rich stanniferous granites forming the backbone of the peninsula render this region the most extensive storehouse of tin in the world. Vast deposits of tin ores, sometimes associated with gold and silver,[2] occur almost everywhere, and are continued in the neighbouring islands as far south as Banca on the Sumatra coast.[3] Gold, whence the land was known to the ancients as the *Aurea Chersonesus*, is also found in considerable quantities, either disseminated in quartz or in alluvial deposits, especially about Mount Ophir, in Pahang, Gomichi, Tringgánu, and Kemáman. The total yield has amounted in some years to 25,000 and 30,000 ounces. Iron ores abound especially in the south, and coal has recently been found in the isthmus of Krá conveniently situated for the future ship canal across the peninsula.

The climate, everywhere moist and hot, becomes

1861 by Fraser and Forlong across the neck of the isthmus in 10° 30′ between the estuaries of the rivers Pekshan and Champon. This scheme, which might be carried out for about £5,000,000, would shorten the sea route from India to China by four days, besides avoiding the dangerous navigation of the Straits.

[1] A detailed account of Mr Daly's surveys, which extended over the years 1875–82, appeared in the *Proceedings of the Royal Geographical Society* for July 1882. It is accompanied by a large map which fills up several gaps left in that of D'Souza. Yet the surveyor remarks that "there is a vast extent—more than half—of the Malayan Peninsula still unexplored," p. 409.

[2] Although the Perak river is named from the Malay word *perak*, "silver," the presence of this metal has been doubted. M. Alfred Marche, however, who recently visited the west coast, found it in Laroot, associated with the rich tin ores of that district (*Comptes Rendus* of the French Geol. Soc. for April 14, 1882, p. 165).

[3] "The alluvial tin deposits permeate the whole length of the Malayan Peninsula on the western side of the dividing range" (Daly).

oppressive and even malarious along the low muddy banks of the coast streams. Higher up, although cooler, it is not always more healthy, and the uplands, especially about Mount Ophir, have the reputation of being extremely dangerous to Europeans (Wallace). Yet the mean temperature, thanks to the general elevation of the land and the prevailing sea-breezes, is much lower than that of many Asiatic lands lying much farther from the equator. While the glass rises normally on the Makrán coast and in the Persian Gulf to 110°, 120°, and even 125° Fahr., the mean summer range in the peninsula scarcely exceeds 90°, while at an altitude of 2500 feet it is under 70° for the whole year. There is strictly speaking no winter, nor a distinctly marked rainy season, the alternate north-east and south-west monsoons distributing the moisture over the east and west slopes throughout most of the year. The average number of rainy days is about one hundred and ninety, and the mean rainfall from 100 to 130 inches. The west coast is exposed to sudden squalls of short duration, known as "Sumatras" from the direction whence they blow, while the opposite side is often visited by tornadoes during the monsoons.

Except in some limestone tracts, especially in Perak and Kedah, the soil is generally poor, and the country, which may be described as of comparatively recent formation slowly undergoing decomposition, is incapable of growing sufficient rice even for the local demand (D. D. Daly). The land, however, is almost everywhere clothed with a magnificent tropical vegetation, in which the most conspicuous and useful plants are the gutta-percha (here first discovered), the camphor tree, ebony, sapan, ratan, eagle wood, bamboo, nibung, and nipa palm. Unfortunately the work of reckless destruction has already commenced, and the Chinese miners have in many places cleared extensive tracts, cutting down the finest trees to serve as fuel for smelting the tin ores. Of fruits the most characteristic are the durian and mangosteen; and of cultivated plants the most common are rice, the sugar-cane, cotton, tobacco, yams, batata, cocoa and areca palms. Tea and coffee might be successfully cultivated along the slopes of the Perak and Selángor rivers (Deane). A species of climbing indigo and the wild nutmeg are indigenous, and the true nutmeg, cinnamon, and cloves have long been introduced, and thrive well (Newbold).

The fauna of the peninsula, which is unusually rich, is allied, like the flora and the inhabitants, rather to that of the Eastern Archipelago than the mainland. Here are the one-horned rhinoceros, Malay tapir (tánau), elephant, and hog, all of the same species as those of Sumatra. Here is also a small bear (bruangh), found elsewhere only in Borneo, as well as the Sunda ox of Java, besides two kinds of bison said to be peculiar to the peninsula (Crawfurd). On the other hand, the Asiatic tiger has extended his range throughout the whole region, even crossing over to Singapore and other adjacent islands. Of quadrumanes there are no less than nine species, including the chimpanzee (*Simia troglodytes*), the kukang (*Lemur tardigradus*), the black and white unka, but apparently not the orang-outan, although the word is in common use among the Malays, who often apply it in its natural sense to the Sakai and other wild tribes of the interior. Of birds perhaps the most characteristic are the rhinoceros hornbill (*Buceros*), the banga or Javanese stork, the argus and pencilled pheasants, birds of paradise (*Paradisea regia* and *P. gularis*), myna or grackle (*Gracula religiosa*), murei or dial bird (*Gracula saularis*), the humming bird, besides kingfishers, flycatchers, doves, and pigeons in endless variety. The islands are frequented by the *Hirundo esculenta*, or swallow that builds edible nests. The forests swarm with coleoptera, lepidoptrea, and other insects, including the magnificent butterfly *Ornithoptera Brookeana*, till recently supposed to be peculiar to Borneo (Deane). The surrounding waters are inhabited by the halicore, or "mermaid," a sirenian whose Malay name *duyong* has been corrupted to dugong in our natural history books.

Politically the peninsula is partly held directly by Siam and Great Britain, and partly divided among a number of petty Malay states, either tributary to or in treaty with those paramount powers. The Siamese territory and states embrace the whole of the northern section southwards to 5° 35′ N., and thence on the east side as far as the southern frontier of Tringgánu in 4° 35′ N. A line drawn from this parallel on the east coast across the peninsula north-westwards to Kedah on the west coast will thus mark the southern limits of all the land directly or indirectly subject to Siam. The rest of the peninsula is occupied by the British possessions grouped under the collective name of the STRAITS SETTLEMENTS (*q.v.*), and by the more or less independent Malay states proper, which may be regarded as forming part of the British system. Subjoined is a table of all the political divisions of the peninsula :—

Siamese Political System.

Ligor, Sengora. These two provinces of Lower Siam proper comprise the isthmus of Krá between 7° and 10° N., with a coast-line of 240 miles on the east and 260 on the west side; area perhaps 17,000 square miles; population, 50,000 (?).

Kedah, between Ligor and Perak, 7° to 5° 35′ N., with 120 miles on west coast; area, 3600 square miles; population, 30,000.

Patáni or Raman, between Sengora and Kelantan, 7° to 5° 30′ N., with coast-line on east side 50 miles; area, 5000 square miles; population, 30,000.

Kelantan, between Patáni and Tringgánu, 6° to 4° N., 60 miles coast on east side; area, 7000 square miles; population, 20,000.

Tringgánu with Kemáman, between Kelantan and Pahang, 5° 30′ to 4° N., with 80 miles coast-line on the east side; area, 6000 square miles; population 50,000 (?).

British Political System.

Perak, between Kedah and Selángor, 5° 30′ to 4° N., with 80 miles coast-line on west side; area, 6500 square miles; population, 30,000.

Selángor with Kalang, between Perak and Malacca territory, 4° to 3° N., with 120 miles coast-line on west side; population, 15,000.

Johór, southern extremity of the peninsula from 2° 40′ N. to Cape Romania; area, 10,000 square miles; population, 20,000.

Pahang, between Johór and Tringgánu, 3° to 5° N., 90 miles coast on east side; area, 3500 square miles; population, 20,000.

Jelébu, Sungei Ujong, Sri Menanti, Jumpól, Johól, Rambau, Jelai, Segámat or Moar. These inland states, lying between 2° and 4° N., formerly constituted with Naning (Malacca territory) the so-called Negri Sambilan, or "Nine Lands," governed by panghúlus or chiefs, feudatory first to the sultans of Malacca and then to those of Johór. It is now proposed again to consolidate them in one state under the suzerainty of or in alliance with Great Britain. They lie surrounding Malacca territory, between Johór on the east, Pahang on the north, and Selángor on the west and north-west. Total area probably not more than 5000 square miles; population, 50,000 (?). The more important are Rambau (Linggi river basin), Segámat (Moar river basin), Johól (north from Mount Ophir), and Sungei Ujong (Lángat river basin).

Straits Settlements: parts of Perak, Malacca, Pulo Penang, and Singapore; total area, 1445 square miles; population (1881), 314,000.

Excluding the Chinese, Klings, Bugis, and other more recent arrivals, the inhabitants of all these states belong to three distinct stocks—the Tai (Siamese), Malay, and Negrito. The Siamese of pure blood occupy the extreme north with scattered communities as far south as the town of Sengora (7° 10′ N.). A mixed Malayo-Siamese people, commonly known as Samsams, form the bulk of the population in the lower parts of Ligor and Sengora, and in the north of Kedah. Although entirely assimilated to the Siamese in speech, customs, and religion, these Samsams appear to be allied physically much more to the Malay than to the Tai stock. Yet their national sympathies seem to be altogether with the dominant race, and the people, especially of Ligor, have during the present century zealously co-operated with the Siamese in their persistent efforts to subdue the Malays of the neighbouring states.[1]

All the rest of the peninsula, from about 7° N. to Cape Romania, may be regarded as essentially "Malay land," as it is in fact called by the people themselves. But whether the Malays are here indigenous, or intruders from Sumatra, is a question still warmly discussed by ethnologists. Those, however, who support the latter view by appealing to the undoubted historic migrations of civilized Malays from Menangkabo or Palembang in the 12th century, or even to still earlier arrivals from Java, do not understand the point at issue. For the peninsula is occupied, not only by these civilized Orang Maláyu of cultured speech, Mohammedans and mostly no doubt originally from Sumatra, but also by the Orang Benua, that is, "men of the soil," or aborigines, of Malay stock and of rude Malay speech, nature worshippers, and settled here from prehistoric times. Similar uncultured Malay tribes, such as the Orang Kubu of Palembang, are no doubt also found in Sumatra. But it is unlikely that any of these people ever crossed the shallow intervening Straits of Malacca, which were probably dry land when the race was gradually diffused over the common area. Whether the migration proceeded eastwards or westwards is therefore a point which cannot be determined pending the settlement of the further and broader question of the origin and dispersion of the Malay race itself. If the Malays are a branch of the Mongol stock, as many hold, then the Orang Benua must have passed through the peninsula southwards to the archipelago at a time when most of it still formed part of the Asiatic mainland. But if they originated in the archipelago itself, as others maintain, then the stream of migration must have been reversed.

In any case the Orang Benua are not the only aborigines in the peninsula. For the most recent research has fully confirmed the somewhat vague statements of earlier writers regarding the presence in this region of a Negroid element differing fundamentally from the Malay type, and apparently to be affiliated to the Negrito of the Andaman Islands and Philippines. "Purely anthropological observations and considerations lead me to accept the supposition of a 'Melanesian' element (a remnant of the original race), which through intermixture with the Malays is being more and more supplanted. . . . . In the mountains of Pahang and Kelantan as far as Sengora and Ligor, I have discovered a Melanesian[2] population. This people undoubtedly belongs to the Melanesian stock" (Miklucho Maclay in *Ethnologische Excursion in Johor*).[3]

The Malay and Negrito aborigines are collectively known to the civilized Malays as Semang and Sakei[4] respectively, although much confusion seems to have arisen in the use of these terms, nor is this surprising, seeing that the two races themselves, who have been in contact for ages, have become largely intermingled and assimilated in customs, and even in speech. The original Negrito dialects, which Maclay has compared with those of the Philippines, are everywhere yielding to the Malay, which is spoken throughout the peninsula with little dialectic variety as far as 6° and 7° N., where it is replaced by Siamese. The aborigines, who are said not to number altogether more than some 10,000, are divided into a great many tribes, of which the best known are the Jakuns, widespread in the south, the Udai, Básisi, Sabimba, Mintira (Mantra), and Hala. All are in a very low state of culture, holding aloof from the settled populations, living entirely on the chase, and pursuing the game with poisoned arrows. It is noteworthy that even the more or less civilized Malays, especially of Rambau and other inland states, still hold to the tribal organization, the very names of many of their tribes, such as the Anak Achi ("children of Achín") and Sri Lummah Menangkabau, betraying their comparatively recent migration from Sumatra.

Other ethnical elements in the peninsula are the Bugis from Celébes, formerly powerful on the west coast; the "Moors" (Arabs), now mostly absorbed by the civilized Malays; the Klings[5] from India, chiefly traders in the seaports; the Topas (Topazio), half-caste Portuguese Christians, still numerous especially in Malacca territory, a few Europeans, Battas, and African slaves; and, lastly, the Chinese, by far the most numerous of all, who are gradually converting the Malay peninsula into a second China. They have already monopolized the mining and agricultural industries, as well as the retail trade and local shipping.

Although vaguely known to the ancients as the Aurea Chersonesus, and even by them already described as a "Regio Latronum," or piratical land, the Malay peninsula possesses no historic traditions earlier than the 13th century. According to the native writers the first settlement was made at Singa-pura, or the "Lion City," about 1250 by emigrants from the banks of a river Maláyu in Sumatra. Expelled from Singapore by the Javanese king Majapáhit, the colonists founded the city of Malacca on the south-west coast of the mainland in 1253. From this point the cultured and Mohammedan Malays of Sumatra are supposed to have rapidly spread over the whole peninsula, where they had already established a number of petty piratical states, when the Portuguese under Albuquerque reached Malaysia and reduced Malacca in 1511. Being thus, so to say, taken on the flank by the Europeans, while their progress northwards was barred by the Siamese continually pressing forward from Indo-China, the Malays of the peninsula, ever prone to piracy and lawlessness, have remained in a more or less unsettled state almost down to the present time. The Portuguese held Malacca for one hundred and thirty years, when they were supplanted in 1641 by the Dutch, who yielded in 1795 to the English, and finally in 1824 surrendered all their possessions on the mainland to Great Britain in exchange for Bencoolen in Java. Penang and Singapore had already been occupied by the British, who, by the suppression of piracy and the old monopolies, the proclamation of free trade principles, the example of a wise administration and treaties with the surrounding states, have gradually laid a solid foundation for the future prosperity of this distracted land. (A. H. K.)

MALAYS (Orang Maláyu, "Malay Men"), the dominant people in Malacca and the Eastern Archipelago (hence often called Malaysia), where they are diversely intermingled with other races, and where they have represented the local cultured element for over two thousand years. The Malays proper, that is, those who call themselves by this name,[6] who speak the standard Malay language, and who possess a common sentiment of racial unity, are found in compact masses chiefly in the Malay peninsula as far north as 8° or 9° N. lat., in the adjacent islands of Penang, Bintang, Lingen, &c., and in Sumatra, of which they occupy fully one half, mainly in the south, along the east coast, and on parts of the west coast. In these lands

[1] The horrors attending the reduction of Kedah in 1821 were caused chiefly by the ferocity of the Samsams of Ligor in the Siamese service.

[2] This writer applies the term "Melanesian" to all the dark races of the Oceanic area, and not merely to the natives of the Melanesian Archipelago.

[3] See also the *Field*, April 23, 1878; *Journal of the Straits Branch of the Roy. As. Soc.* for 1878–81, *passim*; and the paper of Mr Daly, who says, "The true Orang Sakei is a Negrito, and reminds one of the Papuans of New Guinea, whom I have seen in Torres Straits," p. 409.

[4] The aborigines of the neighbouring island of Billiton are also collectively known as *Sakah* (*Annales de l'Extrême Orient*, 1879, p. 130).

[5] The term *Kling*, a corrupt form of Telinga (Telugu), is applied throughout Malaysia to all the natives of India settled in that region.

[6] The origin of this word has given rise to much controversy. Its derivation from the Javanese *ma-layu*, to run or flee, must be rejected as grammatically impossible, for this is a true *verbal* form, whereas the national name is strictly *adjectival*, hence always accompanied by a noun. Valentyn points out (*Beschryvinge van Sumatra*, p. 13) that the name is specially applied in Sumatra to the great Súngei-págú-Maláyu tribe of the Súngei-págú auriferous district, and it seems on the whole most probable that it was originally the name of some local tribe, which rose to pre-eminence.

alone they are really indigenous, and regard themselves as the aboriginal population. Elsewhere they are met in scattered communities chiefly round the coast of Borneo, in the Sulu Archipelago, in Tidor, Ternate, and some other members of the Molucca group, where they are held to be intruders or immigrants from Sumatra.

Long considered as an independent division of mankind, the Malays are now more generally affiliated to the Mongol stock, of which A. R. Wallace, De Quatrefages, and other eminent naturalists regard them as a simple variety more or less modified by mixture with other elements. "The Malayan race, as a whole, undoubtedly very closely resembles the East-Asian populations from Siam to Manchuria. I was much struck with this when in the island of Bali I saw Chinese traders who had adopted the costume of that country, and who could then hardly be distinguished from Malays; and, on the other hand, I have seen natives of Java who, as far as physiognomy was concerned, would pass very well for Chinese."[1] In fact, the typical Malay can scarcely be distinguished anthropologically from the typical Mongolian. He is described as of low stature, averaging little over 5 feet,[2] of olive-yellow complexion inclining to light brown or cinnamon, brachycephalous, with somewhat flat features, high cheek bones, black and slightly oblique eyes, small but not flat nose, dilated nostrils, mouth wide but not projecting, hands and feet small and delicate, legs very thin and weak, coarse black hair, always lank and round in section, scant or no beard.[3]

The departure from this description so frequently noticed in the archipelago must be attributed to intermixture with the black Papúan stock in the east, and with a distinct pre-Malay Caucasic element in the west. The presence of this "Indonesian" element, as it is called by Dr Hamy, may now be regarded as an ascertained fact, the recognition of which will help to remove many of the difficulties hitherto associated with the natural history of the Malay race. It at once explains, for instance, the apparent discrepancy between the foregoing description of the ordinary Malay and that of the Battas, Orang Kabu, and many other Sumatran and Bornean peoples described as tall and robust, with regular features, symmetrical figure, light complexion, brown and wavy hair, and general European appearance.[4]

These considerations also enable us to fix the true centre of dispersion of the Malay race rather in Malacca than in Sumatra, contrary to the generally received opinion. If they are to be physically allied to the Mongol stock, it is obvious that the earliest migration must have been from High Asia southwards to the peninsula, and thence to Sumatra, possibly at a time when the island still formed part of the mainland. The national traditions of a dispersion from Menangkabo or Palembang in South Sumatra must accordingly be understood to refer to later movements, and more especially to the diffusion of the civilized Malay peoples, who first acquired a really national development in Sumatra in comparatively recent times. From this point they spread to the peninsula, to Borneo, Sulu, and other parts of Malaysia, apparently since their conversion to Islam, although there is reason to believe that other waves of migration must have reached Further India and especially Camboja, if not from the same region at all events from Java, at much earlier dates. The impulse to these earlier movements must be attributed to the introduction of Indian culture through the Hindu and Buddhist missionaries, perhaps two or three centuries before the Christian era. During still more remote prehistoric times various sections of the Malay and Indonesian stocks were diffused westwards to Madagascar, where the Hovas, of undoubted Malay descent, still hold the political supremacy, and eastwards to the Philippines, Formosa, Micronesia, and Polynesia. This astonishing expansion of the Malaysian peoples throughout the Oceanic area is sufficiently attested by the diffusion of a common Malayo-Polynesian speech from Madagascar to Easter Island, and from Hawaii to New Zealand. See POLYNESIA.

The Malays proper have long been divided socially into three distinct groups,—the *Orang Benúa*, or "Men of the Soil," that is, the uncivilized wild tribes; the *Orang-laut*, or "Men of the Sea," that is, the semi-civilized floating population; and the *Orang Maláyu*, or "Malay Men," that is, the civilized Malays with a culture, a literature, and a religion. The Orang Benúa, called also *Orang Gunung*, or "Highlanders," and sometimes even *Orang-utan*, or "Wild Men," constitute the aboriginal Malay element, the "raw material," so to say, of the race, which has hitherto remained wholly unaffected by foreign influences, and which is still grouped in small tribes at a very low stage of culture, living nearly exclusively by the chase, and almost destitute of all social organization. They are found chiefly in the more inaccessible wooded uplands of Malacca and Sumatra, in the former region more or less intimately associated for ages with the Negrito tribes, and in the latter island apparently the sole occupiers of the land from the first. Intermediate between the Orang Benúa and Orang Maláyu are the Orang-laut, the "Sea Gipsies" of English writers, who still occupy the same low social position that they held when the Portuguese first reached Malaysia. They were then described by De Barros under the name of Cellates, or "people of the Straits," as "a vile people dwelling more on the sea than on the land," and "living by fishing and robbing"; and this description is still largely applicable, although piracy is now all but suppressed in the Eastern waters. The Bajau and Millanau of the Sulu Archipelago and neighbouring coast lands also belong to this class of sea nomads. Lastly, the Orang Maláyu are that section of the race which, under the influence first of the Hindus and then of the Arabs, has developed a national life and culture, and which has founded more or less powerful political states in various parts of the archipelago. But here again it is necessary to distinguish between the civilized Malays proper, and the other civilized branches of the race, to whom the term Malay is never applied, and who speak languages which, while belonging to the common Malay linguistic family, differ greatly from the standard Malay speech. The chief divisions of all these civilized communities are as under:—

Orang Maláyu: Menangkabo, Palembang, and Lampong in Sumatra; petty states of the Malay Peninsula; Borneo; Tidor; Ternate.
Sumatran group: Achinese, Rejangs, Passumahs.
Javanese group: Javanese proper, Sundanese, Madurese, Balinese.
Celebes group: Bugis, Mangkassara, and others.
Philippine group: Tagalas, Bisayans, Bicol, Sulu, and others.
Outlying groups: Hovas of Madagascar, Formosan Islanders.

In all these the distinctly Malay physical type decidedly predominates, whereas elsewhere in the archipelago the so-called Malays are often rather "Indonesians," in whom the distinctly Caucasic physical type predominates. Such especially are the Battas and Orang Kubu of Sumatra, the Nias and Mentawey islanders, the Kayans, and many of the Dyak tribes of Borneo.[5]

In their temperament no less than in their features the Malays still betray their Asiatic origin. They are described as of a taciturn, undemonstrative disposition, little given to outward manifestations of joy or sorrow, yet extremely courteous towards each other, and as a rule kind to their women, children, and domestic animals. Slow and deliberate in speech, neither elated by good nor depressed by bad fortune, normally impassive and indolent, they are nevertheless capable of the greatest excesses when their passions are roused. Under the influence of religious excitement, losses at gambling, jealousy or other domestic troubles, they are often seized by the so-called "amok" fever, when they will rush wildly through the crowded streets armed with their sharp krisses, cutting down all who cross their path with incredible fury and without the least discrimination. Amongst the practices and propensities which connect them with the Mongoloid inhabitants of Indo-China the most striking are pile-building, especially in Java and Borneo; cock-fighting, universal throughout the archipelago; a pronounced taste for putrescent fish, with a corresponding dislike of milk; head-hunting (Borneo and Celebes); large ear-ornaments, greatly distending the lobe; husband entering the wife's family, and father

[1] Wallace's *Malay Archipelago*, 5th ed., p. 591.
[2] Müller says 4 ft. 6 in. to 5 ft.; Wallace 5 ft. 2 in. to 5 ft. 4 in.; Flower 5 ft. 3 in.; others 5 ft.
[3] See Dr A. B. Meyer, *Minahassa auf Celebes*, Berlin, 1876, p. 7.
[4] See Schouw-Santvoort, in *Annales de l'Extrême Orient*, 1878–79, p. 148; and Montano, *Proc. Roy. Geol. Soc.*, 1881, p. 593.
[5] See Carl Bock's *Head-Hunters of Borneo*, p. 59.

exchanging his own for his child's name; counting by numeral auxiliaries, such as pebble, chief, log, mountain, feather, &c., according to the nature of the object.[1]

The race is on the whole of a sluggish intellect, inferior in natural intelligence even to the surrounding Papúan populations. Dr Montano tells us that in the girls' school at Malacca, conducted by the Roman Catholic sisters, the Chinese children take the first, the Mantras (aborigines) the second, and the Malays the last place in order of capacity.[2] Unaided by foreign influences they never attained a higher culture than that of the "Sea Gipsies"; and for their letters, most of their arts, and their religions they are indebted either to the Hindus or the Arabs. (A. H. K.)

Malay Language and Literature.

The Malay language is a member of the Malayan section of the Malayo-Polynesian class of languages, but it is by no means a representative type of the section which has taken its name from it. The area over which it is spoken comprises the peninsula of Malacca with the adjacent islands (the Rhio-Lingga Archipelago), the greater part of the coast districts of Sumatra and Borneo, the seaports of Java, the Sunda and Banda Islands. It is the general medium of communication throughout the archipelago from Sumatra to the Philippine Islands, and it was so upwards of three hundred and fifty years ago when the Portuguese first appeared in those parts.

There are no Malay manuscripts extant, no monumental records with inscriptions in Malay, dating from before the spreading of Islam in the archipelago, about the end of the 13th century. By some it has been argued from this fact that the Malays possessed no kind of writing prior to the introduction of the Arabic alphabet (W. Robinson, J. J. de Hollander); whereas others have maintained, with greater show of probability, that the Malays were in possession of an ancient alphabet, and that it was the same as the Rechang (Marsden, Friederich), as the Kawi (Van der Tuuk), or most like the Lampong (Kern),—all of which alphabets, with the Battak, Bugi, and Macassar, are ultimately traceable to the ancient Cambojan characters. With the Mohammedan conquest the Perso-Arabic alphabet was introduced among the Malays; it has continued ever since to be in use for literary, religious, and business purposes. Where Javanese is the principal language, Malay is sometimes found written with Javanese characters; and in Palembang, in the Mĕnangkabo country of Middle Sumatra, the Rechang or Renchong characters are in general use, so called from the sharp and pointed knife with which they are cut on the smooth side of bamboo staves. It is only since the Dutch have established their supremacy in the archipelago that the Roman character has come to be largely used in writing and printing Malay. This is also the case in the Straits Settlements.

By the simplicity of its phonetic elements, the regularity of its grammatical structure, and the copiousness of its nautical vocabulary, the Malay language is singularly well-fitted to be the *lingua franca* throughout the Indian archipelago. It possesses the five vowels *a*, *i*, *u*, *e*, *o*, both short and long, and one pure diphthong *au*. Its consonants are *k*, *g*, *ng*, *ch*, *j*, *ñ*, *t*, *d*, *n*, *p*, *b*, *m*, *y*, *r*, *l*, *w*, *s*, *h*. Long vowels can only occur in open syllables. The only possible consonantal nexus in purely Malay words is that of a nasal and mute, a liquid and mute and vice versa, and a liquid and nasal. Final *k* and *h* are all but suppressed in the utterance. Purely Arabic letters are only used in Arabic words, a great number of which have been received into the Malay vocabulary. But the Arabic character is even less suited to Malay than to the other Eastern languages on which it has been foisted. As the short vowels are not marked, one would, in seeing, *e.g.*, the word *bntng*, think first of *bintang*, a star; but the word might also mean a large scar, to throw down, to spread, rigid, mutilated, enceinte, a kind of cucumber, a redoubt, according as it is pronounced *bantang*, *banting*, *bentang*, *buntang*, *buntung*, *bunting*, *bonteng*, *benteng*.

Malay is essentially, with few exceptions, a dissyllabic language, and the syllabic accent rests on the penultimate unless that syllable is open and short; *e.g.*, dātang, namāña, bĕsár, diumpatkaññālah. Nothing in the form of a root word indicates the grammatical category to which it belongs; thus, *kāsih*, kindness, affectionate, to love; *ganti*, a proxy, to exchange, instead of. It is only in derivative words that this vagueness is avoided. Derivation is effected by infixes, prefixes, affixes, and reduplication. Infixes occur more rarely in Malay than in the cognate tongues. Examples are—*gūruh*, a rumbling noise, *gumūruh*, to make such a noise; *tunjuk*, to point, *telunjuk*, the forefinger; *chūchuk*, to pierce, *cherūchuk*, a stockade. The import of the prefixes—mĕ (mĕng, mĕñ, mĕn, mĕm), pĕ (pĕng, pĕñ, pĕn, pĕm), bĕr (bĕl), pĕr, pĕl, ka, di, tĕr,—and affixes—an, kan, i, lah—will best appear from the following examples: root word *ājar*, to teach, to learn; *mĕngājar*, to instruct (expresses an action); *bĕlājar*, to study (state or condition); *mĕngajāri*, to instruct (some one, trans.); *mĕngājarkan*, to instruct (in something, causative); *pĕngājar*, the instructor; *pĕlājar*, the learner; *pĕngajāran*, the lesson taught, also the school; *pĕlajāran*, the lesson learnt; *diājar*, to be learnt; *tĕrājar*, learnt; *tĕrājarkan*, taught; *tĕrajāri*, instructed; [*pĕrāja* (from *rāja*, prince), to recognize as prince; *pĕrajākan*, to crown as prince; *karajāan*, royalty]; *ājarkanlah*, teach! Examples of reduplication are—*ājar-ājar*, a sainted person; *ājar-bĕrājar* (or *bĕlājar*), to be learning and teaching by turns; similarly there are forms like *ājar-mĕngājar*, *bĕrājar-ajāran*, *ājar-ajāri*, *mĕmpĕrājar*, *mĕmpĕrājarkan*, *mĕmpĕrajāri*, *tĕrbĕlājarkan*, *pĕrbĕlājarkan*, &c. Altogether there are upwards of a hundred possible derivative forms, in the idiomatic use of which the Malays exhibit much skill. See especially H. von Dewall, *De vormveranderingen der Maleische taal*, Batavia, 1864; and J. Pijnappel, *Maleisch-Hollandsch Woordenboek*, Amsterdam, 1875, "Inleiding." In every other respect the language is characterized by great simplicity and indefiniteness. There is no inflexion to distinguish number, gender, or case. Number is never indicated when the sense is obvious or can be gathered from the context; otherwise plurality is expressed by adjectives such as *sagāla*, all, and *bāñak*, many, more rarely by the repetition of the noun, and the indefinite singular by *sa* or *sātu*, one, with a class-word. Gender may, if necessary, be distinguished by the words *laki-lāki*, male, and *pĕrampūan*, female, in the case of persons, and of *jantan* and *bĕtīna* in the case of animals. The genitive case is generally indicated by the position of the word after its governing noun. Also adjectives and demonstrative pronouns have their places after the noun. Comparison is effected by the use of particles. Instead of the personal pronouns, both in their full and abbreviated forms, conventional nouns are in frequent use to indicate the social position or relation of the respective interlocutors, as, *e.g.*, *hamba tuan*, the master's slave, *i.e.*, I. These nouns vary according to the different localities. Another peculiarity of Malay (and likewise of Chinese, Shan, Talaing, Burmese, and Siamese) is the use of certain class-words or coefficients with numerals, such as *orang* (man), when speaking of persons, *ekor* (tail) of animals, *kĕping* (piece) of flat things, *bīji* (seed) of roundish things; *e.g.*, *līma bīji tĕlor*, five eggs. The number of these class-words is considerable. Malay verbs have neither person or number nor mood or tense. The last two are sometimes indicated by particles or auxiliary verbs; but these are generally dispensed with if the meaning is sufficiently plain without them. The Malays avoid the building up of long sentences. The two main rules by which the order of the words in a sentence is regulated are—subject, verb, object; and qualifying words follow those which they qualify. This is quite the reverse of what is the rule in Burmese.

The history of the Malays amply accounts for the number and variety of foreign ingredients in their language. Hindus appear to have settled in Sumatra and Java as early as the 4th century of our era, and to have continued to exercise sway over the native populations for many centuries. These received from them into their language a very large number of Sanskrit terms from which we can infer the nature of the civilizing influence imparted by the Hindu rulers. Not only in words concerning commerce and agriculture, but also in terms connected with social, religious, and administrative matters, that influence is traceable in Malay. See W. E. Maxwell, *Manual of the Malay Language*, 1882, pp. 5–34, where this subject is treated more fully than by previous writers. This Sanskrit element forms such an integral part of the Malay vocabulary that in spite of the subsequent infusion of Arabic and Persian words adopted in the usual course of Mohammedan conquest it has retained its ancient citizenship in the language. The number of Portuguese, English, Dutch, and Chinese words in Malay is not considerable; their presence is easily accounted for by political or commercial contact.

The Malay language abounds in idiomatic expressions, which constitute the chief difficulty in its acquisition. It is sparing in the use of personal pronouns, and prefers impersonal and elliptical diction. As it is rich in specific expressions for the various aspects of certain ideas, it is requisite to employ always the most appropriate term suited to the particular aspect. In Maxwell's *Manual*, pp. 120 *sq.*, no less than sixteen terms are given to express the different kinds of striking, as many for the different kinds of speaking, eighteen for the various modes of carrying, &c. An unnecessary distinction has been made between *High Malay* and *Low Malay*. The latter is no separate dialect at all, but a mere brogue or jargon, the medium of intercourse between illiterate natives and Europeans too indolent to apply themselves to the acquisition of the language of the people; its vocabulary is made up of Malay words, with a conventional admixture of words from other languages; and it varies, not only in different localities, but also in proportion to the individual speaker's acquaintance with Malay proper. The use is different as regards the term *Jāwī* as applied to the Malay language. This has its origin in the names Great Java and Lesser Java, by which the mediæval Java and Sumatra were called, and it accordingly means the language spoken along the coasts of the two great islands.

Malay is probably spoken with greatest purity in the Rhio-Lingga Archipelago and in the independent states of Perak and

[1] Col. Yule, in *Jour. Anthrop. Soc.* for February 1880.

[2] *Jour. d'Anthropologie* for March 1882.

Kedah, on the western coast of the peninsula of Malacca. In other states of the peninsula (Johor, Tringganu, Kelantan) dialectical divergencies both as to pronunciation and the use of words have been noted. The most important and the most interesting of all the Malay dialects is that of Menangkabo (Menangkarbau) in the residency of Padang and in Upper Jambi, in Central Sumatra. It abounds in diphthongs, and prefers vocalic to consonantal terminations, thus changing final *al* and *ar* into *a'*, *il* and *ir* into *iye*, *ul* and *ar* into *uwe*, *as* and *at* into *e'*, *us* into *uwi*; final *a* mostly passes into *ō*, so that for *sudāra* and *sudāgar* they say *sudĕrō*, *sudĕgō*; the emphatic *-lah* is turned into *-malah* or *malah há*; the prefixes *bĕr*, *pĕr*, *tĕr* are changed into *bă*, *pă*, *tă*, or *bără*, *pără*, *tără*. Among other changes in pronunciation may be noted *ūrang* for *orang*, *mungko* for *maka*, *lai* for *lāgi*; they use *nan* for *yang*, *na'* for *hendak*, *deh* for *oleh*, *ba'* for *bāgai*, *pai* for *pergi*, *ko'* for *jikalau*, &c. In some districts of Menangkabo (Palembang, Lebong) the Renchong character is in general use in writing this dialect, for which purpose it is far better suited than the Arabic. As early as 1822 a small tract on the customs and traditions of Moko-Moko, in this dialect, was printed with a translation at Bencoolen. But it is only in recent years that the Dutch have commenced to pay the dialect the attention it deserves, by publishing texts, with transliteration and translations, and supplying other materials for its investigation. See the *Transactions* and *Journal* of the Asiatic Societies of Batavia and the Hague, the *Indische Gids*, and more especially the philological portion, by A. L. van Hasselt, of *Midden-Sumatra*, iii. 1 (Leyden, 1880), where also the best and fullest account of the Renchong character is to be found. Of other Malay dialects in Sumatra, only the one spoken at Achih (Achin) deserves mention; in Java the Batavian dialect shows the most marked peculiarities. The numerous and greatly divergent dialects spoken in the Molucca Islands (valuable information on which has been supplied by F. S. A. de Clercq, G. W. W. C. van Hoevell, and A. van Ekris) and in Timor differ so materially from the Malay of the peninsula and of Menangkabo that they cannot be called Malay dialects at all; whereas the Malay spoken in some parts of the Minahassa (Celebes) scarcely differs from Malay proper.

There is no grammar of Malay by a native writer with the sole exception of a small tract of 70 pages, entitled *Bustānu 'lkātibīn*, by Rāja Ali Hajji of Rhio, which was lithographed in the island of Peñengal in 1857. A. Pigafetta, who accompanied Magellan in his first voyage round the globe, was the first European whose vocabulary of Malay words (450) has come down to us. Next in the field were the Dutch, who provided a medium of intercourse between their traders and the Malays. F. Houtman's *Vocabulary and Conversations, in Dutch, Malay, and Malagasy*, appeared at Amsterdam in 1603; and it may be noted that the Malay spoken in those days does not appear to have materially altered since. The same dialogues appeared in English and Malay in 1614. Since then numerous grammars, dictionaries, and conversation books have been brought out by English and Dutch writers. As the best helps at present available for the study of Malay may be recommended W. E. Maxwell's *Manual of the Malay Language*, London, 1882 (especially valuable for its full treatment of the idioms); P. Favre, *Grammaire de la langue Malaise*, Vienna and Paris, 1876; and *Dictionnaire Malais-Français, ib.*, 1875, 2 vols.; *Dictionnaire Français-Malais, ib.*, 1880, 2 vols.; J. J. de Hollander, *Handleiding bij de beoefening der Maleische taal en letterkunde*, Breda, 1882; J. Pijnappel, *Maleische Spraakkunst*, Hague, 1866; and *Maleisch-Hollandsch Woordenboek*, Amsterdam, 1875. The printing of Von Dewall's *Dictionary*, edited by H. N. van der Tuuk, is still in progress at Batavia.

Literature.—There are two kinds of Malay popular literature—the one in prose, the other in poetry. The former comprises the proverbs, the latter the "pantuns." "Agriculture, hunting, fishing, boating, and wood-craft are the occupations or accomplishments which furnish most of the illustrations, and the number of beasts, birds, fishes, and plants named in a collection of Malay proverbs will be found to be considerable" (W. E. Maxwell, *Malay Proverbs*). H. C. Klinkert published a collection in the *Bijdragen tot de taalkunde van N. I.* (Journal of the Asiatic Society of the Hague) for 1866, pp. 39-87. See also J. Habbema on the Menangkabo proverbs, in vols. xxv. and xxvi. of the Batavian *Tijdschrift*, and Favre's *Dictionnaire Malais-Français, passim.* The pantuns are improvised poems, generally (though not necessarily) of four lines, in which the first and third and the second and fourth rhyme. They are mostly love poems; and their chief peculiarity is that the meaning intended to be conveyed is expressed in the second couplet, whereas the first contains a simile or distant allusion to the second, or often has, beyond the rhyme, no connexion with the second at all. The Malays are fond of reciting such rhymes "in alternate contest for several hours, the preceding pantun furnishing the catchword to that which follows, until one of the parties be silenced or vanquished." See T. J. Newbold, *Account of the British Settlements in the Straits of Malacca*, vol. ii. 346; Klinkert in the *Bijdragen* for 1868, pp. 309-70; L. K. Harmsen in the *Tijdschrift*, vol. xxi. pp. 480-533 (Menangkabo). If the Malays have kept entirely aloof from the influences of Islam in this the most characteristic part of their literature, they have almost equally preserved their independence in the other departments. Not that this may be considered entirely to their credit; for, if they had endeavoured to infuse into their writings some of the spirit of Arabic and Persian historiography, poetry, and fiction, it could not but have benefited the character of their own literary productions. As it is, their histories and chronicles are a strange motley of truth and fiction; their poems and novels lack coherence and imagination, and are singularly monotonous and devoid of that spirit of chivalry which pervades the corresponding branches of literature among the leading nations of Islam. As Malay copyists are much given to making arbitrary changes, it happens that no two MSS. agree, and that of many a popular work different recensions exist, which, moreover, often go by different names. This circumstance greatly tends to increase the difficulties of editing Malay texts. Works on specially Mohammedan subjects (theology, law, ethics, mysticism) are of course only imitations of Arabic or Persian originals; there are also numerous novels and poems treating of purely Mohammedan legends. But not only is there traceable in many of these a slight undercurrent of Hinduism and even pre-Hinduism; the Malays possess also, and indiscriminately read along with their Mohammedan books, quite as many works of fiction of purely Hindu origin. The want, however, of political cohesion, and of a national spirit among tribes so scattered as the Malays are, which could have favoured the growth of a national epic or national songs, sufficiently accounts for the absence from their literature of any productions of this class, such as exist in Bugi and Macassar literature. The most popular of their poetical productions are the *Sha'ir Ken Jambūhan*, *Sha'ir Bidāsāri*, *Sha'ir Jauhar Mānikam* and *Sha'ir 'Abdu'lmulūk*, all of which have been printed. Among the prose works there are various collections of local laws and customs (*undang-undang*), chronicles (such as the *Sajarat malāyu*), books on ethics (the best are the *Makota sagāla raja-rāja*, and the *Bustānu'ssalātīn*, and a very large number of works of fiction and legendary lore, some of which possess much descriptive power. They all bear the title Hikāyat, and the following are the best-known: *H. Hang Tūah*, *H. Hamzah*, *H. Ismā Yatīm*, *H. Jumjumah*, *H. Bakhtiyār* (*Sādah Bakhtīn*, *Gholām*), *H. Sīmiskin*, *H. Sultān Ibrāhīm*, *H. Sri Rāma*, *H. Pandāwa līma.* Several of these and many other works not mentioned here have appeared in print (with or without translation) chiefly in Holland, Batavia, and Singapore, and extracts have been given in the various Malay chrestomathies by Dulaurier, De Hollander, Niemann, Van der Tuuk, Grashuis, and in Marsden's *Malay Grammar.* The best recent Malay writer was 'Abdullah ibn 'Abdelkādir Mūnshi of Singapore, who died, it is said of poison, at Mecca, some eight and twenty years ago. His autobiography, "journey to Kelantan," and "pilgrimage to Mecca" are patterns of Malay style, though the author's contact with educated Europeans is traceable in them, while his translation (from the Tamil version) of the *Panchatantra* is free from such influence.

Malay literature is fairly represented in England in the British Museum, the India Office, and the Royal Asiatic Society, and descriptive catalogues of the Malay MSS. in each of these libraries are available. See Niemann in the *Bijdragen*, iii. 6, p. 96-101; Van der Tuuk in *Tijdschrift voor Ned. Indië* for 1849, i. p. 385-400, and in the *Journal of the Royal Asiatic Society*, new series, ii. p. 85-135. An account of the Leyden collection, by J. Pijnappel, is given in the *Bijdragen*, iii. 5, p. 142-178. The finest collection of Malay MSS., upwards of 400 volumes, is in the library of the Asiatic Society of Batavia. See L. W. C. van den Berg, *Verslag van eene verzameling Maleische, &c., handschriften*, Batavia, 1877. If it had not been for the loss, by fire, on their passage from India, of three hundred Malay MSS., the property of the late Sir T. S. Raffles, England would now boast of the largest assemblage of Malay MSS. in the world. On Malay literature in general compare G. H. Werndly, *Maleische Spraakkunst*, Amsterdam, 1736, pp. 227-357; E. Jacquet in the *Nouveau Journal Asiatique*, vol. ix. (1832), pp. 97-132, and 222-253; T. J. Newbold, *British Settlements in the Straits of Malacca*, 1839, vol. ii. pp. 215-368; E. Dulaurier, *Mémoire, lettres, et rapports*, Paris, 1843; J. J. de Hollander, *Handleiding bij de beoefening der Maleische taal en letterkunde*, Breda, 1882, pp. 277-388; and G. K. Niemann, in *Bijdragen*, iii. 1 (1866), pp. 113-46, 333 *sq.* (R. R.)

MALCOLM, Sir John, G.C.B. (1769-1833), soldier, diplomatist, administrator, and author, was born at Burnfoot of Esk, near Langholm, Dumfriesshire, Scotland, on May 2, 1769. At the age of twelve he received a cadetship in the Indian army, and in April 1783 he landed at Madras, shortly afterwards joining his regiment at Vellore. In 1792, having for some time devoted himself to the study of Persian, he was appointed to the staff of Lord Cornwallis as Persian interpreter, but two years afterwards was compelled by ill-health to leave for

England. On his return to India in 1796 he became military secretary to Sir Alured Clarke, commander-in-chief at Madras, and afterwards to his successor General Harris; and in 1798 he was appointed by Lord Wellesley assistant to the resident at Hyderabad. In the last-mentioned capacity he highly distinguished himself by the manner in which he gave effect to the difficult measure of disbanding the French corps in the pay of the nizam. In 1799, under the walls of Seringapatam, began his intimacy with Colonel Arthur Wellesley, which in a short time ripened into a life-long friendship; in the course of the same year he acted as first secretary to the commission appointed to settle the Mysore government, and before its close he was appointed by Lord Wellesley to proceed as envoy to the court of Persia for the purpose of counteracting the policy of the French by inducing that country to form a British alliance. Arriving at Teheran in December 1800, he was successful in negotiating favourable treaties, both political and commercial, and returned to Bombay by way of Baghdad in May 1801. He now for some time held the interim post of private secretary to Lord Wellesley, and in 1803 was appointed to the Mysore residency. At the close of the Mahratta war, in 1804, and again in 1805, he negotiated important treaties with Sindhia and Holkar, and in 1806, besides seeing the arrangements arising out of these alliances carried out, he directed the difficult work of reducing the immense body of irregular native troops. In 1808 he was again sent on a mission to Persia, but circumstances prevented him from getting beyond Bushire; on his reappointment in 1810, he was successful indeed in procuring a favourable reception at court, but otherwise his embassy, if the information which he afterwards incorporated in his works on Persia be left out of account, was (through no fault of his) without any substantial result. He sailed for England in 1811, and shortly after his arrival in the following year was knighted. His intervals of leisure he devoted to literary work, and especially to the composition of a *History of Persia*, which was published in two quarto volumes in 1815. On his return to India in 1817 he was appointed by Lord Moira his political agent in the Deccan, with eligibility for military command; as brigadier-general under Sir T. Hislop he served against the Mahrattas and Pindharis, and took a distinguished part in the victory of Mehidpur (December 21, 1817), as also in the subsequent work of following up the fugitives, determining the conditions of peace, and settling the country. In 1821 he returned once more to England, where he remained until 1827, when he was appointed to the Bombay government. His influence in this office was directed to the promotion of various economical reforms and useful administrative measures. Leaving India for the last time in 1830, he shortly after his arrival in England entered parliament as member for Launceston, and was an active opponent of the Reform Bill. He died of paralysis on May 30, 1833.

Besides the work mentioned above, Sir John Malcolm published *Sketch of the Political History of India since . . .* 1784, in 1811 and 1826; *Sketch of the Sikhs*, 1812; *Observations on the Disturbances in the Madras Army in* 1809, 1812; *Persia, a Poem*, anonymous, 1814; *A Memoir of Central India*, 2 vols., 1823; and *Sketches of Persia*, anonymous, 1827. A posthumous work, *Life of Robert, Lord Clive*, appeared in 1836. See *Life and Correspondence of Major-General Sir John Malcolm, G.C.B.*, by J. W. Kaye, 2 vols., 1856.

MALDAH, a district in the lieutenant-governorship of Bengal, India, between 24° 29′ 50″ and 25° 32′ 30″ N. lat., and 87° 48′ and 88° 33′ 30″ E. long., the Ganges river forming the continuous west and south-west boundary. The administrative headquarters are at English Bázár. The district, of which the area is 1813 square miles, is divided into two almost equal parts by the Mahánandá river, flowing from north to south. The western tract between the Mahánandá and the main stream of the Ganges is a low-lying alluvial plain of sandy soil and great fertility. The eastern half is an elevated region broken by the deep valleys of the Tángan and Purnábhábá rivers and their small tributary streams. The soil of this district is a hard red clay; and the whole is overgrown with thorny tree jungle known as the *kátál*. Agricultural prosperity centres on the Mahánandá, where mango orchards and high raised plots of mulberry land extend continuously along both banks of the river. The Ganges nowhere intersects the district, but skirts it from its north-western corner to the extreme south. The Mahánandá flows in a deep well-defined channel through the centre of the district, and joins the Ganges at the southern corner. Its tributaries are the Kalindri on the right, and the Tángan and Purnábhába on the left bank.

The population in 1881 was 710,310 (347,055 males and 363,255 females). In 1872 the number of inhabitants was 671,974,—355,276 Hindus, 307,460 Mohammedans, 9195 aborigines, and 43 Christians. The male adult agriculturists numbered 134,358. Only two towns then contained upwards of 5000 inhabitants, viz., English Bázár or Angrazábád, 12,859, and Maldah, 5262. The most important centres of commerce are Haiatpur on the Ganges, and Rohanpur on the Purnábhábá, just above the confluence of that river with the Mahánandá. Rice constitutes the staple crop, and occupies about 53 per cent. of the total cultivated food crop area. The miscellaneous crops include indigo, mulberry, and mangoes. The average rate of rent may be put at over 4s. an acre. There is little that is peculiar in the land tenures of the district, except the existence of several large rent-free estates, granted as endowments to Mohammedan *fakírs*. Among cultivating tenures, the *hal hásilá* deserves notice, under which the annual rent varies according to the nature of the crop raised. This tenure is most common in the backward parts of the district, and one of its incidents is that it allows a certain proportion of the village lands to lie fallow. Maldah is liable to some extent to the calamities of flood and drought; but the means of communication by river are sufficiently ample to prevent scarcity from intensifying into acute distress. The two staple manufactures are silk and cotton. Brass ware of excellent quality is manufactured at Nawábganj, and paper in certain villages. The principal exports are rice, silk, indigo, brass ware, and mango fruit. The imports comprise cotton cloth, salt, sugar, spices, and betel-nuts. The net revenue of the district in 1880–81 amounted to £60,674, of which £37,998 was derived from the land tax, and £11,538 from excise. Education was afforded in 1872 by 170 schools, attended by 4207 pupils. The average annual rainfall of the district is returned at 54·56 inches. The chief epidemic diseases are malarious fever, cholera, and small-pox.

Maldah supplied two great capitals to the early Mohammedan kings of Bengal; and the sites of Gaur and Panduah exhibit the most interesting remains to be found in the lower Gangetic valley. See GAUR, vol. x. p. 112 *sq.* The connexion of the East India Company with Maldah dates from a very early period. As far back as 1686 there was a silk factory there. In 1770 English Bázár was fixed upon for a commercial residency, the buildings of which at the present day form both the public offices and private residence of the collector.

MALDEN, a city of the United States, in Middlesex county, Massachusetts, situated on the Malden river, 5 miles north of Boston. Malden was settled in 1634, being then known as the village of Mystic Side. It was incorporated as a town under the name of "Mauldon" in 1649, and became a city in 1882. It is a place of considerable industry, producing india-rubber boots and shoes, leather, lasts, sandpaper, &c. There are Turkey red dye-works; and the U. S. Government has a depôt where large quantities of saltpetre are stored. Judson, the apostle of Burmah, was born in the town in 1788. The population has increased from 7367 in 1870 to 12,017 in 1880.

MALDIVE ISLANDS, a remarkable archipelago in the Indian Ocean, the northern extremity of which is 7° west of Ceylon, and which extends in length from north to south, from 7° 7′ N. lat. to 0° 42′ S., a space of 540 British miles (or about as far as from Kirkwall in Orkney to Dover), and is limited in width by the meridians 72°

27′ and 73° 50′.[1] The strange appearance which this group assumes in the old maps of the 16th and 17th centuries (see fig. 2, from *Mappemonde*, cited on p. 329) is entirely inaccurate in detail, but hardly so singular as the reality exhibited by modern surveys.

The archipelago is in some respects one of the most distinctly typical examples of a great aggregation of coral islands; indeed the technical name adopted by modern science for the annular coral formation which they exhibit (viz., *atoll*) has been taken from the language of these islands.[2] For Mr Darwin's theory of such formations see vol. vi. p. 378. Objections to this have recently been raised by Mr John Murray, but these do not affect the description.[3]

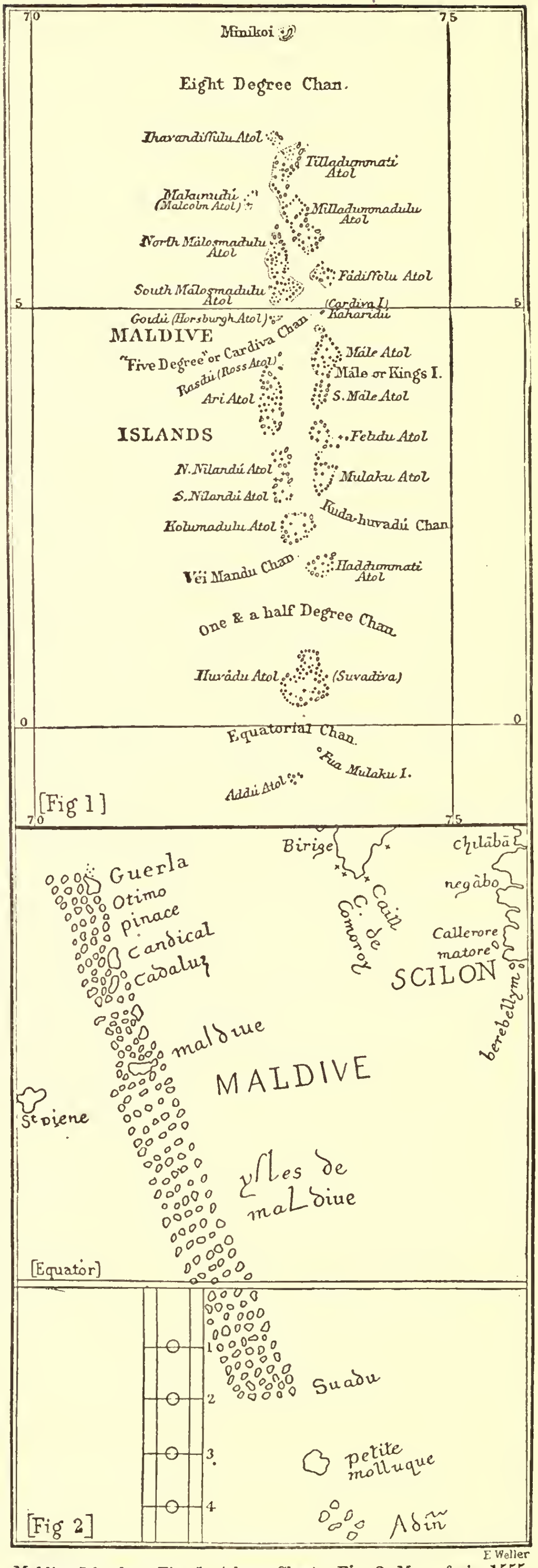
The Maldive archipelago in plan may be compared to a chain suspended from a peg, each link of which chain is an irregularly elliptical chaplet of islets, the greater axes of these quasi-ellipses varying from about 90 miles downwards. Taking separately any one of these chaplets (or *atolls*), we now know it to be the nearly level summit of a submarine table-mountain, rising abruptly from the unfathomable ocean, and approaching the surface within a distance which varies in different atolls from 20 to 45 fathoms. The quasi-elliptical margin of the atoll is fringed, and the central expanse of its area is more or less sparsely studded, "with oval basins of coral-rock just lipping the surface of the sea, and each containing a lake of clear water" (Darwin). These small oval basins, or ring-shaped reefs and islets, are in fact essentially miniatures of the atoll itself.

The general impression made by the Maldive atoll is vividly drawn by the French adventurer Pýrard de la Val (1602–7):

> "Each *atollon* is detached, and contains within it a great multitude of small islands. It is a marvel to see one of these *atollons*, compassed all round by a great bank of stone, insomuch that no art of man could so well enclose with walls an equal space of ground. . . . . Looking from the middle of an atollon you see all round you that great bank of stone encircling the isles and defending them against the violence of the sea. And it is a fearful thing even for the boldest to draw near this bank and see the waves come on and break furiously all round . . . . so that you see all round you as it were a whitened wall."

Though the barrier reef, or *banc de pierre*, of which Pyrard speaks, exists in most of the atolls, there is none in the most northerly of the great atolls (Tiladummati and Milladummadu, two divisions of one atoll). In this there are broad and safe navigable channels, from 1 to 2 miles wide, between all the islands forming the chaplet. A vessel can enter the atoll by any one of these channels, and steer within it in any direction, anchoring anywhere on a sandy bottom in 20 to 25 fathoms. In the more southerly atolls entrance channels are only found at occasional intervals, though in all they are pretty numerous. Thus in Suadiva, the most southerly of the large atolls (50 miles from north to south, 36 miles from east to west), which has a barrier reef on great part of its contour, there are forty-two channels by which a ship can enter the lagoon.

It is observed that in the double part of the chain of atolls the openings are most numerous on those sides which are in juxtaposition. Thus on the three atolls of



Maldive Islands. Fig. 1, Admy. Chart; Fig. 2, Map of *cir.* 1555

[1] The solitary island of Minucoy (*Minakai*), lying 70 miles north of the Maldives (med. lat. 8° 16′ 30″ N.; population 3000), pertains to these islands by the race and language of its people, but, as it has long belonged to the raja of Cannanore, it is usually classed with the Laccadives.

[2] Mald. *atolu*. The word *atollon* is already defined as a generic expression in Zeidler's *Universal Lexicon*, 1732 ("a name applied to such a place in the sea as exhibits a heap of little islands lying close together, and almost hanging on to each other"). *Atolu* is probably connected with the Singhalese prep. *etula*, "inside" (Bell).

[3] See *Proc. Roy. Soc. Edin.*, 1879–80, No. 107.

Ari and North and South Nilandu there are on the inner or eastern side seventy-three deep-water channels through the barrier, on the outer or western side only twenty-five; whilst on the atolls of South Mâlé, Felidû, and Mulaku, which lie facing the three former, there are on the inner or western side fifty-six deep-water openings, and on the outer or eastern side only thirty-seven. These differences are doubtless due to differences in the action of the sea caused by the juxtaposition of the two rows of atolls, and analogous facts are observed elsewhere in atolls exposed to trade-winds.

Immediately outside of the great chaplets or atolls the figures of the soundings rise suddenly. Thus at Ihavandiffulu (Heawandoo of charts), the most northerly atoll, close to the margin of the reef the line gave 50 and 60 fathoms, and at 300 yards distance there was no bottom with a 300-fathom line. And this sudden increase of depth applies to the deep channels between the atolls as much as to the ocean east and west of them.

We have spoken of the small reefs, which fringe the atolls and dot their area, as also ring-shaped. This is the type, but it is not universal. The charts show that where the channels or breaches through the marginal reef of the atoll are few or narrow there are no minor annular reefs (*e.g.*, in Suadiva); where the channels are somewhat broader, the intercepted portions of reef are annular, but not the reef in the central area; where the channels are broadest, almost every reef throughout the atoll is more or less perfectly annular. The depth of the lagoon within these rings is generally 5 to 7 fathoms, but sometimes, as in Ari atoll, it reaches 12 fathoms. The outer margin of the rings is bordered with living coral, within which is a flat surface of coral-rock. On this flat, sand partially indurated, and fragments of coral, &c., have accumulated, and been converted into islets clothed with vegetation. Such islets sometimes fill the whole ring of reef, and sometimes are mere strips occupying a segment of it. Obviously the whole aggregate of actual dry land in such an archipelago is infinitesimal compared with the area of the atolls. The highest part of the islands is generally about 6 feet above water. Moresby found the surface-sand usually about 3 feet thick, the upper part partially mixed with vegetable matter so as to form a light soil; below this a white compact sand, and then a soft sandstone 2 feet thick, below which it softened to sand again, and fresh-water appeared.

All the islands of any extent are well clothed with wood, including many fine large trees and the ordinary shrubs of the Ceylon coast-jungle; where the jungle has been cleared, grass grows luxuriantly. But the cocoa-palm is the characteristic tree; and, low as the islands are, being covered with these, they can be seen from a masthead at 15 miles. The appearance they present is that of a tuft or line of trees rising out of the water.

A good deal of vicissitude seems to go on in the formation of new islets and decay of old ones, of which our survey-officers met with various instances.

All the inhabited islands, and some besides, afford fresh water. But the quality of water varies; and it is not uncommon to see two wells within a few feet of each other, one brackish and the other excellent. None of the wells are more than 6 feet deep.

The whole archipelago has from the earliest reports of it formed a little kingdom. Physically the number of atolls may be reckoned as nineteen, besides some solitary islands; but administratively these are grouped into thirteen, and the term atoll has been transferred to this division. We give in the following table the list of these (political) atolls, in a second column the spelling of the marine charts, and in a third the list of atolls as given by Pyrard de la Val, in the beginning of the 17th century.

Names of Atolls.	As in Moresby's Charts, 1837.	As in Pyrard de la Val.
1. Tilladummatî.	Tilla Dou Matte.	Tilla dou matis.
2. Miladummadulu,[1] or Miladummadu.	Milla Dou Madou.	Milla doue madoue.
3. Fâdiffolu.	Paddipholo.	Padypolo.
4. Malosmadulu.	Mahlos Mahdou.	Malos madou.
5. Mâlé.	Mālé.	Malé Atollon.
6. Ari.	Ari.	Ariatollon.
7. Felidu.	Phah-Lee-doo.	Poulisdous.
8. Mulaku.	Moloque.	Molueque.
9. Nilandu.	Nillandoo.	Nillandous.
10. Kolumadulu, or Kolumandu.	Collomandoo.	Collomadous.
11. Haddummatî.	Adou Matte.	Adou matis.
12. Suvâdiva, or Huvâdu.	Suadiva, or Hooah-doo.	Souadou.
13. Addu, which includes the island of Fua Mulaku.	Addoo (and Phooa Moloku Island).	Addou and Poua Molueque.

The list from Pyrard shows that the division in the beginning of the 17th century was identical with what it now is. But we may gather that it is substantially of much greater antiquity, from the statement of Ibn-Batuta (*c.* 1343), who says the islands were divided into *aklîm* (κλίματα), each under a governor. He mentions eleven of these:—Bâlibûr, Kannalûs, Mahal, Tilâdîb, Karaîdû, Tîm, Tiladummati, Hiladummati, Barîdû, Kandakal, Mulûk,—of which indeed the names of only seven, viz., (1) Tiladummati, (2) Heladummati, (3) Bâlibûr, (5) Mahal, (7) Barîdû, (8) Mulûk, (12) Suweid, can be identified with those of the existing divisions. But another, Karaîdû, no doubt represents Karadîva, a well-known solitary island north of Mâlé atoll; Kandakal is an island of the Miladummadu atoll, called in the charts Condaicoll; Tîm appears near the north of Tilladummati as Oteim; and the three—Kannalûs, Kandakal, and Tîm—are presented prominently as the islands Camdalus, Camdicall, and Otimo in the *Mappemonde* made for Henry II. of France (*c.* 1555, see Jomard's *Facsimiles*, livr^n. vi., copied in fig. 2 *supra*; and compare *Portolano* of 1570, copied in Mr Birch's translation of Albuquerque's *Commentaries*). Possibly, therefore, the Moorish traveller had substituted true names of islands which he remembered for the names of atolls which he had forgotten.

The Maldives are inhabited by a people of old civilization, professing Islam, and ruled by a sultan of ancient lineage. What the number of islands may be we cannot say. They are popularly estimated at 12,000, as appears by the ancient style of the sultan as "king of 12,000 islands and 13 atolls." (See also *Marco Polo*, 2d ed., 1875, ii. 417–19.) Those marked with names in the British survey amount to 602, and the inhabited islands to 178. The men are of a darkish copper colour, short stature (5 feet 2 inches), and poor physique, but oval contour of face, pleasing expression, and large bright eyes, suggesting resemblance to both the Singhalese and Malabar people. The women are fairer than the men, with regular features and clean healthy aspect. A few of the people bear signs of African mixture, easily accounted for; and probably the blood of the small communities has been tinged by the occasional settlement of other foreigners. The people are decidedly unwarlike; and there is hardly any crime of violence among them. They are said to be lax in morals and conversation; but otherwise their character and disposition have favourably impressed visitors. Though suspicious of strangers, they are hospitable; and among themselves they are kindly, and affectionate to their kindred and in attendance on the sick. They are very cleanly in person

[1] The frequent termination *du* represents the Singh. *dúva*, *díva*, and Sansk. *dvípa*, "island." Bell takes *madulu* for Sansk. *maṇḍala*, "region." Qu. *mahâ-atoḷu*, "great atoll"?

and domestic habits. The population has been guessed in some books at 200,000; almost certainly one-tenth of that number would be an ample estimate. Moresby states the population of 98 islands, and the aggregate is 11,310. In the same proportion 178 islands would give 20,543; but the aggregate quoted includes the King's Island, which is much above the average in population.

The language is undoubtedly a dialect of Singhalese approaching the old *Elu*, but indicating a separation of ancient date, and it is more or less Mohammedanized. Nothing at present can be said of grammar. But Mr Albert Gray has drawn out in parallel columns the Maldivian words given by Pyrard with the modern Singhalese equivalents (see *Jour. Roy. As. Soc.*, quoted at end). A cursory analysis of the list (which contains 275 words) gives the following result:—

1.	Words evidently to be explained by Singhalese	58·0 per cent.
2.	,, less evidently ,, ,,	2·2 ,,
3.	Persian and Arabic	10·6 ,,
4.	Malay	1·9 ,,
5.	Tamil	1·1 ,,
6.	Portuguese	1·1 ,,
7.	Sanskrit or Pali, not Singhalese	0·8 ,,
8.	Undetermined	24·3 ,,

Combining 1, 2, and 7, we have 61 per cent. of words of Singhalese or Sanskrit origin. And an analysis by Mr Bell of one of the sultan's letters to the Ceylon Government gives 65 per cent. of such words.

The origin of the name *Mal-dîva* or *Mâldîva* is obscure. Dîva is a familiar word in the Indian *prakrits* (Sansk., *dvîpa*; Pali, *dîpo*) for an island. By a form of this word the people formerly designated themselves and their country, and this survives in letters of last century from the sultan to the Ceylon Government, in which he designates his kingdom as *Diveḥi Râjjé*, and his subjects as *Diveḥi mîhun*, "island people." There is a very old example of this use in Ammianus Marcellinus, who, in reference to the alleged excitement in the East at the accession of Julian, says that missions were prepared "*ab usque* Divis *et* Serendivis," from the people of the *Dîvas* and of *Serendîva* or Ceylon. And this is the name *Dîva* or *Dîba-jât* (Pers. plural form) by which these islands are described by the early Arabian geographers. The first literary use of the whole name is Ibn Batuta's *Dhîbat-al-Mahal* (14th century), an Arabized form, sometimes used (*Mahal-dîb*) by the people now, though the proper form seems to be *Malé*. *Malé-diva* may possibly, as Bishop Caldwell (comp. *Grammar*, 2d ed., Introd. p. 28) and others have suggested, have meant the "islands of Malé" or Malabar. On the other hand *Mâlâ* (Sansk.), "a chaplet" or "row," is not an impossible etymology considering how naturally the word "chaplet" occurs in the endeavour to describe an atoll. But these are conjectures. Under the sultan (who styles himself on coinage "Lord of Land and Sea") there used to be six recognized viziers or councillors (but this system is now obsolete), besides a chief of law and religion called *fandiari*. Over each of the thirteen atolls is a king's agent, called *atoḷu-veri*, who collects the revenue. This official is often one of the royal family, or a vizier's son, and often resides at Mâlé, employing a deputy. On each island is a headman called *rarḥu-veri*. There is also on each island containing forty inhabitants a *kâtibu* (Ar., *kâtib*, "scribe"), who acts as judge and minister, celebrating marriages, &c. Pyrard calls him the *curé*.

Some of the oldest accounts of these islands represent them as always governed by a woman,—a notion which probably arose among the Mohammedan visitors from finding that female heirs were not precluded from succession. Just the same notion was held about Achîn in the 17th century, because there chanced to reign there several female sovereigns in succession (see vol. i. p. 97). We do find females nominally reigning on the Maldives on two of the rare occasions when we have glimpses of their state, viz., in the time of Ibn Batuta, and again in the last century.

Islam is universally professed by the people, nor is there tradition of any other religion, though there are a variety of Pagan superstitions and some doubtful traces of Buddhism. Thus the *Bo-tree* (or pippal), so sacred among the Buddhists of Ceylon, is still cherished near mosques. Pyrard de la Val was informed that the conversion to Islam took place two centuries at most before his time, *i.e.*, about 1400. But, unless there was a decay and revival, we know this to be wrong, as the islanders were Mohammedan in the time of Ibn Batuta (1343). And this traveller tells that the father of one of his wives in the islands had for his grandfather (though the word used may mean "ancestor" only) the Sultan Dâûd, who was grandson of Ahmed Shanû-râza, the first king who adopted Islam. Accepting the meaning of "grandfather," this would carry the conversion back to about 1200, a probable epoch, for about that time there was a considerable outburst of missionary zeal in Islam, which led to the conversion of the coast states of Sumatra, &c. Ibn Batuta records an inscription on the Jami Mosque of the King's Island which ran:— "Sultan Ahmed Shanû-râzah embraced Islam at the hands of Abu 'l Baraḳât the Berber from the West"; but no date is given.

We have mentioned the occurrence of the name *Divi* in Ammianus. At an earlier date Ptolemy notices the numerous islands lying in front of Taprobane, alleged to number 1378. It is possible also that the *Maniolæ* of the same geographer may constitute a duplicate indication of the Maldives. For in the gossip of Palladius about India (see C. Müller's *Pseudo-Callisthenes*, p. 102) this name *Maniolæ* is applied to a group of islands, 1000 in number, that lay near Taprobane, and respecting which the old fable of the magnetic rock was current, which Ptolemy also connects with the *Maniolæ*.

Cosmas (*c.* 545) shows distinct knowledge of the Maldives (without naming them) as numerous close-set small islands round Sielediba or Taprobane, in all of which were found cocoa-nuts and fresh water. Passing next to the Arabian notices translated by Renaudot and Reinaud, which date from 851, and to the work of Mas'ûdi in the next century, we find tolerably correct accounts of the *Dîbas*, said to be 1900 in number. Al Birûni's account (*c.* 1030) of the islands is marked by his usual perspicacity and accuracy. The *Dîvas* are islets which form themselves in the sea, appearing like a ridge of sand, extending and uniting till they present a solid aspect. But also with time some decompose and melt away in the sea, whilst the inhabitants transfer their cocoa-trees and possessions to an island which is waxing instead of waning,—circumstances corroborated by modern observation.

All the old authors speak of coir (the fibre of the cocoa-nut husk) as one of the staple products of these islands, and the importance of this article for marine equipment led the Portuguese about 1518 to establish a factory on the Maldives. João Gomez, the head of the settlement, was at first well received, but his arrogant and violent conduct gave great offence to the Mohammedan traders from Cambay, who brought an armed flotilla against the Portuguese and put them all to death. The Portuguese several times renewed the attempt to establish themselves on the islands, and maintained a garrison for some time, but these endeavours had no permanent result. The islanders were also frequently subject to raids at the hands of the Mopla pirates of Malabar, and sometimes also, it would seem, to maltreatment from the crews of European vessels. The MS. diary of Mr (afterwards Sir William) Hedges, who passed through the Maldives in 1685, says: "We putt out a piece of a Red Ancient to appear like a Moor's Vessell: not judging it safe to be known to be English; Our Nation having lately gott an ill Name by abusing ye Inhabitants." Such circumstances probably led the islanders to place themselves in relation with the rulers of Ceylon; and in 1645 occurs the first record of the embassy from the sultan of the Maldives to the Dutch governor at Colombo, which has continued to the present day, under Dutch and English, to arrive annually, bringing some poor offering, as a vague token of homage and claim of protection. The last political trouble of which we have notice occurred in the middle of last century. In 1753 the chief minister conspired to hand over the islands to the Ali raja of Cannanore. A Mopla force occupied Mâlé, and carried off the sultan. The traitor himself was rewarded by being thrown into the sea. The oppression of these foreigners made the islanders rise and expel them. The sultan never returned, and a minister who had ruled on his behalf assumed the kingdom in 1760. In 1754 Dupleix occupied Mâlé with a small French detachment, which remained several years. In 1811 the sultan wrote to the governor-general (Lord Minto) to complain of the violent conduct of the officers of a ship under British colours which had been wrecked on the islands. Lord Minto sent back a courteous answer with presents. There have been no other events during the British rule in Ceylon, and the last sultan, Mohammed Moidin, reigned without dispute from 1835 to 1882.

We have only three substantial accounts of the Maldives from actual residence:—(1) that of the Moor Ibn Batuta, who lived upon them more than a year (1343-44), and filled the office of cadi; it contains much curious detail; (2) the narrative of François Pyrard de la Val, a French adventurer on board a ship of St Malo, which was wrecked on a reef of the Malosmadulu atoll in 1602, and who was detained five years on the islands,—a book of the greatest interest and accuracy, and by far the best account of these islands in existence; (3) a memoir by two officers of the Indian navy, Lieut. Young and Mr Christopher, who had been employed in the survey of the islands under Captain R. Moresby in 1834-35, and who volunteered to remain behind at Mâlé, in order to acquire a knowledge of the language, customs, &c., of the inhabitants,—a laudable effort, but the result of it was marred somewhat by the illness which prostrated both officers.

The sultan's residence and the capital of the kingdom is the island of Mâlé, which lies near the middle of the archipelago on the east side. It is about 1 mile long by ¾ mile wide, and contains a population approaching 2000. It has been at one time encompassed with walls and bastions, but these continue in repair only on the north and west. On the north too is an old fort, apparently of Portuguese construction, with a few old guns. On the north and west sides also advantage has been taken of the encircling reef as the base of a wall which has been built up so as to form the lagoon into a harbour for small craft, having a depth of 6 to 12 feet, and a width of 150 yards. The town is laid out in long regular streets at right angles, shaded with trees; the houses are in "compounds," with high fences excluding the street, and are surrounded with fruit trees and flowers. The sultan's palace, a large upper-roomed house, occupies with its appurtenances an area of ¼ square mile, enclosed by a shallow ditch now choked with vegetation. The houses generally are large cottages of about 28 feet by 12, formed of substantial wooden frame, with peaked roofs thatched with cocoa-leaves; the walls are matted with cocoa-leaves, but sometimes planked. There are several mosques, and at least one minaret, about 40 feet high, for the call to prayer. Stone-built houses, common in Pyrard's time, are so no longer; there is now but one. There are marked distinctions of rank among the people. At least six classes (we hardly know whether to call them castes) are recognized, of whom the two highest form a pure aristocracy. The sixth class, called *Kallo* ("black"?), consists of the common people generally, of whom the toddy-drawers are regarded as the lowest.

The employments of the common people are fishing, gathering cocoa-nuts and cowries, weaving, and toddy-drawing. Women beat the cocoa-fibre and twist it into yarn, make mats, prepare breadfruit by slicing and drying in the sun, spin and dye cotton thread, make sweetmeats of cocoa-nut and palm-sugar. Women are not secluded or veiled as in typical Moslem countries.

Rice, the staple of food, is imported. Other chief food is fish (chiefly dried bonito), breadfruit prepared in various ways, cocoa-nut, and a few fruits and vegetables. There are a few sheep and cattle on Mâlé island, which are occasionally slaughtered.

From the earliest notices the production of coir, the collection of cowries, and the weaving of excellent textures on these islands have been noted. This last, and that of fine mats are the only manufactures in which skill is shown. The mats seem to be now produced only in Suadiva atoll; the cloth chiefly, but not solely, in Malosmadulu atoll.

The chief exports of the islands, besides coir and cowries (a decreasing trade), are cocoa-nuts, *copra* (*i.e.*, cocoa-nut husk), tortoise-shell, and dried bonito-fish. An enormous amount of this last was formerly carried to Ceylon and Sumatra, the latter being supplied by traders who came from Chittagong. It has been known over the East from time immemorial as *koboli-mâs*, a corruption apparently of the Maldivian *kalû-bili-mâs*, "black bonito fish," sometimes further corrupted to *gomulmutch*.

Native vessels of 80 to 200 tons burthen make annual trips to Calcutta towards the end of the south-west monsoon, returning with the north-east monsoon in December. After leaving the Maldives they sight no land till Jagannâth. They carry thither the articles named above, and bring back rice, cotton stuffs, and sundries. These long voyages are not confined to the craft of the capital. Moresby, in 1834-35, found that a small island in the North Nilandu atoll sent annually to Bengal five or six boats of 80 to 100 tons each. On the same island there was a kind of navigation school, and the natives made and repaired some kind of nautical instruments. The old cash of the Maldives was the curious *lârîn* or "fish-hook money" made of a bent rod of silver. This has been long replaced by coins of base metal bearing the same name. The Anglo-Indian rupee is current for larger payments, and cowries are still used to some extent.

Two alphabets are known on the islands (besides the Arabic, which appears on tombstones and in other inscriptions). The first is an ancient alphabet, known as *Divehi Hakura*, "island letters." This in 1835 still survived in the southern atolls, and orders for these were written in it. It is written, like all the Indian alphabets, from left to right, and is evidently (by comparison with plate xvii. in Dr Burnell's *Elements of South Indian Palæography*) a form (with additional letters) of the old Tamil character (700 to 1300 A.D.) called in Malabar *Vatteluttu*, or "round hand."[1] The modern Maldive writing, called *Gabali Tana*, is usually[2] written from right to left, like Arabic. It is said to have been introduced in the 16th century, and has gone through several variations. Some of the letters are modified from the Arabic character, and nine of them are the Arabic numeral digits. On the other hand numerals are represented by letters of the alphabet. The former system of reckoning was duodecimal, but this is dying out.

Nothing is accurately known of the flora of the islands, and Kew possesses no illustration of it. Among larger trees are mentioned the banyan, pippal, breadfruit, tamarind, and a large tree called *kandu*, affording a very light wood used for rafts, floats, &c.; also species of pandanus. The castor-oil tree is abundant, though not used. The cocoa-nut of the islands, though of fine quality, is very small, not much larger than an orange. The tree itself furnishes the only indigenous wood used for boat-building. The *dumbari* (*Calophyllum inophyllum*) and *kuradi* (*Pemphis acidula*) are used in minor wood-work. A tuber, grated and steeped in water to remove its acridity, is made into flour,—perhaps a *Colocasia*, which Ibn Batuta mentions (*al-kalakâs*) as used to make a kind of vermicelli. They have also sweet potatoes, pine-apples, pomegranates (bearing fruit throughout the year), plantains, and most of the other tropical or subtropical Indian fruits, chillies, a few areca trees, &c. The double cocoa-nut of the Seychelles Islands (fruit of *Lodoicea Sechellarum*) used to be cast up on the islands, and was believed to be a submarine pro-

[1] The resemblance to this is much closer than to the old Singhalese with which it is compared in Mr Albert Gray's valuable paper already referred to.

[2] "Usually"; but a Maldivian skipper who gave James Prinsep information wrote it from left to right (see *Jour. As. Soc. Bengal*, v. 794).

duction,—hence called the sea cocoa-nut. It was valued for imaginary qualities, and exported to India. The Portuguese long believed it to be a product of these islands, and called it the Maldive cocoa-nut.

Animals are few. Those named are rats, numerous and destructive, which climb the cocoa-trees and devour the kernels; the large bat called in India "flying-fox," also said to destroy many small cocoa-nuts; tortoises; a small snake said to be harmless, &c. Domestic animals are rare; a few goats and cattle are reared on Mâlé.

The climate is not oppressive or disagreeable, but is very unhealthy for strangers, whether Asiatic or European. Ibn Batuta says every visitor was attacked by violent fever; Pyrard says the same; and this was substantially the experience of the survey officers and crews in 1834–35. The native crews also suffered much from the disease called *beri-beri* (which has dropsical symptoms, and is often fatal) and from violent bowel-complaints.

A complete report on the Maldives has recently been prepared by Mr H. C. P. Bell of the Ceylon civil service, who has visited the islands, and this is now being printed at Colombo. Mr Bell kindly enabled the present writer to see a copy before this article went to press, and many valuable facts have been added from it. Other materials used have been—Darwin, *The Structure and Distribution of Coral Reefs*, 1842; *Voyage de François Pyrard de la Val*, Paris, 1679 (previous editions 1611, 1615–16, 1619); *Voyages d'Ibn Batoutah*, trans. of Defrémery and Sanguinetti, tom. iv., Paris, 1858; Hamilton, *Desc. of Hindostan*, ii. 299; Moresby, *Naut. Directions for the Maldiva Islands*, &c., 1840; Young and Christopher, in *Trans. Bomb. Geog. Soc.*, vol. i. pp. 54–86; also see *ibid.* p. 102 and p. 313; *Trans. Roy. Geog. Soc.*, vol. ii. pp. 72–93; also vol. v. p. 398; *Jour. As. Soc. Bengal*, vol. v. p. 794; *Jour. Roy. As. Soc.*, vol. vi. pp. 42–76; *ibid.*, new series, vol. x. pp. 173–209 (paper by Mr Albert Gray), &c. (H. Y.)

MALDON, a municipal and parliamentary borough and seaport town of Essex, England, is situated on an acclivity rising from the south side of the Blackwater, 44 miles east-north-east of London and 16 south-west from Colchester. It consists principally of one main street with several cross streets at right angles. The church of All Saints, dating from 1056, is a spacious edifice consisting of chancel, nave, and aisles, with a triangular tower at the west end surmounted by an hexagonal spire. The church was restored in 1867, and new windows were added in 1877. St Mary's Church is also of very early origin, and was restored in the 17th century. The other public buildings are the grammar school, founded in 1547; the town-hall, formerly D'Arcy's tower, built in the reign of Henry VI.; and the public-hall, 1859. There are manufactures of crystallized salt, as well as breweries, iron foundries, and some shipping. The population of the municipal borough (3508 acres) in 1871 was 5586, and in 1881 it was 5476. That of the parliamentary borough (5177 acres) in the same years was 7151 and 7128.

Maldon, which is a very ancient town, is supposed to have received its name, meaning "cross hill," from a cross at one time erected on the eminence. From remains found in the neighbourhood there is no doubt that the place was of some importance in the time of the Romans, but the supposition that it was *Camulodunum* is not sufficiently established. On the western side of the town there are also traces of a large camp, but whether the work is of Roman, Saxon, or Danish origin it is impossible to say. The oldest historical mention of the town is in 913, when Edward the Elder encamped near it to impede the progress of the Danes. The town received its first charter from Henry II., and in 1553 it was incorporated by Queen Mary. From the time of Edward III. it returned two members to parliament, but since 1867 only one member.

MALEBRANCHE, Nicolas (1638–1715), a well-known disciple of Descartes, was the youngest child of Nicolas Malebranche, secretary to Louis XIII., and Catherine de Lauzon, sister of a viceroy of Canada, and was born at Paris on August 6, 1638. Of an extremely feeble constitution and somewhat deformed habit of body, he received his elementary education in Latin and Greek from a domestic tutor, and only left home when sufficiently advanced to enter upon a course of philosophy at the Collége de la Marche, and subsequently to study theology at the Sorbonne. He had resolved to enter the church, but his retiring and studious disposition led him to decline a stall in Notre Dame, and in 1660 he joined the Congregation of the Oratory. Both his ecclesiastical superiors and himself appear to have experienced considerable difficulty for some time in ascertaining what his special talents were, if they existed at all. He was first advised by Père Lecomte to devote himself to ecclesiastical history, and he accordingly set about a laborious perusal of the works of Eusebius, Socrates, Sozomen, and Theodoret, but it was found that "the facts refused to arrange themselves in his mind, and mutually effaced one another." Afterwards Richard Simon undertook to teach him Hebrew and Biblical criticism, but with no better success. At last having accidentally, in 1664, fallen upon one of the works of Descartes (the *Traité de l'Homme*), Malebranche was forthwith alive to his true vocation. So overpowered was he by the novelty and luminousness of the ideas, and by the solidity and coherence of the principles of his author, that (it is said) he was repeatedly compelled by violent palpitations of the heart to lay aside his reading. Malebranche was from that hour consecrated to philosophy, and especially to that of Descartes; and after ten years' study of the works of his master he produced, in 1674, the famous *Recherche de la Vérité*, which was followed at intervals by other works, both speculative and controversial, the titles of which are given below. Like most of the great metaphysicians of the 17th century, Malebranche interested himself also in questions of mathematics and natural philosophy, and in 1699 he was admitted an honorary member of the Academy of Sciences. During his later years his society was much courted, and he received many visits from foreigners of distinction. His death took place on October 13, 1715; according to Stock, the biographer of Berkeley, it was hastened by an excited metaphysical argument into which he had been drawn in the course of an interview sought by that philosopher. For a critical account of Malebranche's place in the history of philosophy, see Cartesianism (vol. v. p. 148 *sq.*).

The following is a list of his principal works:—*De la Recherche de la Vérité, ou l'on traite de la nature de l'esprit de l'homme, et de l'usage qu'il en doit faire pour éviter l'erreur dans les sciences* (1674, 6th ed. 1712; Latin translation by J. Lenfant at Geneva in 1685; two English translations, the second by Taylor in 1712; translations also into German, Dutch, and modern Greek); *Conversations Chrétiennes, dans lesquelles on justifie la Vérité de la Religion et de la Morale de Jesus Christ* (1676, and frequently); *Traité de la Nature et de la Grace*, 1680; *Méditations Chrétiennes et Métaphysiques*, 1683; *Traité de la Morale*, 1684; several polemical works against Arnauld from 1684 to 1688; *Entretiens sur la Métaphysique et la Religion*, 1688; *Traité de l'Amour de Dieu*, 1697; *Entretien d'un Philosophe Chrétien et d'un Philosophe Chinois sur l'existence et la nature de Dieu*, 1708; *Réflexions sur la Prémotion Physique*, 1715. A convenient edition of the *Œuvres choisies de Malebranche*, in two volumes, with an introduction, was published by Jules Simon in 1846.

MÁLER KOTLA, a native state in the Punjab, India, situated between 30° 24′ and 30° 41′ N. lat., and between 75° 42′ and 75° 59′ 15″ E. long., with an estimated area of 165 square miles, and an estimated population of 91,560. The chief products are cotton, sugar, opium, aniseed, tobacco, garlic, and grain. The gross revenue is £25,893. The nawáb exercises complete jurisdiction, and receives a compensation of £250 per annum in perpetuity from the British Government, on account of loss of revenue caused by the abolition of customs duties. Máler Kotla town is situated 30 miles south of Ludhiána.

The nawáb or chief is of Afghán descent; his family originally came from Cabul, and occupied positions of trust in Sirhind under the Mughal emperors. They gradually became independent as the Mughal empire sank into decay in the course of the 18th century.

In General Lake's campaign against Holkar in 1805 the nawáb of Máler Kotla sided with the British. After the subjugation and flight of Holkar, the English Government succeeded to the power of the Mahrattas in the districts between the Sutlej and the Jumna; and in 1809 its protection was formally extended to Máler Kotla, as to the other cis-Sutlej states against the formidable encroachments of Ranjít Sinh. In the campaigns of 1806, 1807, and 1808 Ranjít Sinh had made considerable conquests across the Sutlej; in 1808 he marched on Máler Kotla, and demanded a ransom of £10,000 from the nawáb. This led to the interference of the British, who addressed an ultimatum to Ranjít Sinh, declaring the cis-Sutlej states to be under British protection. Finally the rájá of Lahore submitted, and the nawáb was reinstated in February 1809.

MALESHERBES, Chrétien Guillaume de Lamoignon de (1721–1794), minister and afterwards counsel for the defence of Louis XVI., came of a famous legal family, and was born at Paris on December 6, 1721. He too was destined for the legal profession, much to the surprise of Marcel, the famous dancing master, who declared that his pupil would never be able to dance well enough to be a soldier or a lawyer, and must therefore be a priest. The young lawyer soon proved his intellectual capacity, when he was appointed president of the *cour des aides* in the parlement of Paris in 1750 on the promotion of his father to be chancellor. One of the chancellor's duties was to control the press, and this duty was entrusted to Malesherbes by his father during his eighteen years of office, and brought him into connexion with the public far more than his judicial functions. To carry it out efficiently he kept in communication with the literary leaders of Paris, and especially with Diderot, and Grimm even goes so far as to say that "without the assistance of Malesherbes the *Encyclopédie* would probably never have been published." Though he met with abuse from all sides, there can be no doubt that it was the eminently judicious manner in which he carried out his objectionable duties which laid the foundation of his subsequent popularity. In 1771 he was called upon to mix in politics; the parlements of France had been dissolved, and a new method of administering justice devised by Maupeou, which was in itself commendable as tending to the better and quicker administration of justice, but pernicious as exhibiting a tendency to over-centralization, and as abolishing the hereditary "nobility of the robe," which, with all its faults, had from its nature preserved some independence, and been a check on the royal power. Malesherbes presented a strong remonstrance against the new system, and was at once banished to his country seat at St Lucie, to be recalled, however, with the old parlement on the accession of Louis XVI., and to be made minister of the *maison du roi* in 1775. He only held office nine months, during which, however, he directed his attention to the police of the kingdom, which came under his department, and did much to check the odious practice of issuing *lettres de cachet*. On retiring from the ministry with Turgot in 1776, he betook himself entirely to a happy country and domestic life. He had always been an enthusiastic botanist; his avenue at St Lucie was world famous; he had written against Buffon on behalf of the botanists whom Buffon had attacked, and had been elected a member of the Académie des Sciences as far back as 1750. He was now elected a member of the Académie Française, and everything seemed to promise a quiet and peaceful old age spent in the bosom of his family and occupied with scientific and literary pursuits, when the king in his difficulties wished for the support of his name, and summoned him back to the ministry in 1787. Again he held office but a short time, but returned to his country life this time with a feeling of insecurity and disquiet, and, as the troubles increased, retired to Switzerland. Nevertheless, in December 1792, in spite of the fair excuse his old age and long retirement would have given him, he voluntarily left his asylum and undertook with Tronchet and Desèze the defence of the king before the convention, and it was his painful task to break the news of his condemnation to the king. After this effort he returned once more to the country, but in December 1793 he was arrested with his daughter, his son-in-law M. de Rosambô, and his grandchildren, and on April 23, 1794, he was guillotined, after having seen all whom he loved in the world executed before his eyes for their relationship to him. Malesherbes is one of the sweetest characters of the 18th century; though no man of action, hardly a man of the world, by his charity and unfeigned goodness he became one of the most popular men in France, and it was an act of truest self-devotion in him to sacrifice himself for a king who had done little or nothing for him. With reason does his statue stand in the hall of justice at Paris, for he is the greatest representative of that noble independence which should prevent any thought of self when a counsel is pleading his client's cause, however perilous such advocacy might be.

There are in print several scientific works of Malesherbes of varying value, of which the most interesting is his *Observations sur Buffon et Daubenton*, written when he was very young, and published with a notice by Abeille in 1798. There exist also his *Mémoire pour Louis XVI.*, his *Mémoire sur la liberté de la presse*, published 1809, and extracts from his remonstrances, published as *Œuvres choisies de Malesherbes* in 1809. For his life should be read the *Notice historique* of Dubois, the *Éloge historique* of Gaillard, and the interesting *Essai*, in 2 vols., 1818, of Boissy d'Anglas. There are also many *éloges* on him in print, of which the best-known is that of M. Dupin, which is interestingly reviewed with much light on Malesherbes's control of the press by Sainte-Beuve in the second volume of the *Causeries du Lundi*.

MALHERBE, François de (1555–1628), poet, critic, and translator, was born at Caen in 1555. His family was of some position, though it seems not to have been able to establish to the satisfaction of heralds the claims which it made to nobility older than the 16th century. The poet was the eldest son of another François de Malherbe, *conseiller du roi* in the magistracy of Caen. He himself was elaborately educated at Caen, at Paris, at Heidelberg, and at Basel. At the age of twenty-one he entered the household of Henri d'Angoulême, grand prior of France, the natural son of Henry II. He served this prince as secretary in Provence, and married there in 1581. It seems that he wrote verses at this period, but, to judge from a quotation of Tallemant des Réaux, they must have been very bad ones. His patron died when Malherbe was on a visit in his native province, and for a time he had no particular employment, though by some servile verses he obtained a considerable gift of money from Henry III., whom he afterwards libelled. He lived partly in Provence and partly in Normandy for many years after this event; but very little is known of his life during this period. It was in the year parting the two centuries (1600) that he presented to Marie de' Medici the first of his remarkable poems. But four or five years more passed before his fortune, which had hitherto been indifferent, turned. He was presented by his countryman, the cardinal Du Perron, to Henry IV.; and, though that economical prince did not at first show any great eagerness to entertain the poet, he was at last summoned to court and endowed after one fashion or another. His father died in 1606, and he came into his inheritance. From this time forward he lived at court, corresponding affectionately with his wife, but seeing her only twice in some twenty years. His old age was saddened by a great misfortune. His son, Marc Antoine, a young man of promise, perished in one of the frivolous but desperate duels which, common at all periods of French history, were never more frivolous or more desperate than in the 16th and the early 17th centuries. Marc Antoine de Malherbe fell in 1626. His father used his utmost influence to have the guilty parties (for more than one were concerned, and there are grounds for thinking that it was not a fair duel) brought to justice. But he died before the suit was decided (it is said in consequence of disease caught at the camp of La Rochelle, whither he had gone to petition the king), at Paris, on the 16th of October 1628, at the age of seventy-three.

The personal character of Malherbe was far from amiable. He was an obstinate solicitor of favours from the great, a morose and bearish companion to his equals, a loose liver at a time of life when loose living is especially unbecoming if not especially blameable, a jealous and unfair critic; but he exercised a great and enduring effect upon French literature, though by no means a wholly beneficial one. The lines of Boileau beginning *Enfin Malherbe vint* are rendered only partially applicable by the extraordinary ignorance of older French poetry which distinguished that peremptory critic. But the good as well as bad side of Malherbe's theory and practice is excellently described by his contemporary and superior Regnier, who was animated against him, not merely by reason of his own devotion to Ronsard, but because of a brutal act of discourtesy of which Malherbe had been guilty towards Regnier's uncle Desportes. These are the lines:—

> "Cependant leur savoir ne s'étend nullement
> Qu'a régratter un mot douteuse au jugement,
> Prendre garde qu'un *qui* ne heurte une diphthongue,
> Épier si des vers la rime est brève ou longue,
> Ou bien si la voyelle à l'autre s'unissant
> Ne rend point à l'oreille un vers trop languissant.
> . . . .
> C'est proser de la rime et rimer de la prose."

This is perfectly true, and from the time of Malherbe dates that great and deplorable falling off of French poetry in its more poetic qualities, which was not made good till 1830. Nevertheless the critical and restraining tendency of Malherbe was not ill in place after the luxuriant importation and innovation of the *Pléiade*; and if he had confined himself to preaching greater technical perfection, instead of superciliously striking his pen through the great works of his predecessors, he would have deserved wholly well. As it was his reforms helped to elaborate the kind of verse necessary for the classical tragedy, and that is the most that can be said for him. His own poetical work is scanty in amount, and for the most part frigid and devoid of inspiration. The beautiful *Consolation à Du Perrier*, in which occurs the famous line—

> Et, rose, elle a vécu ce que vivent les roses—

the odes to Marie de' Medici and to Louis XIII., and a few other pieces comprise all that is really worth remembering of him. His prose work is much more abundant, not less remarkable for care as to style and expression, and of greater positive value. It consists of some translations of Livy and Seneca, and of a very large number of interesting and admirably written letters, many of which are addressed to Peiresc, the man of science of whom Gassendi has left a delightful Latin life. It contains also a most curious commentary on Desportes, in which Malherbe's minute and carping style of verbal criticism is displayed on the great scale.

The chief authorities for the biography of Malherbe are the *Vie de Malherbe* of his friend and pupil Racan, and the long *Historiette* which Tallemant des Réaux has devoted to him. The standard edition is the admirable one of M. Ludovic Lalanne, 5 vols., Paris, 1862–69. Of the poems only, there is an excellent and handsome little issue in the *Nouvelle Collection Jannet*, Paris, 1874. (G. SA.)

MALINES. See MECHLIN.

MALLANWÁN, a town in Hardoi district, Oudh, India, situated on the Hardoi and Unas road, in 27° 2′ 10″ N. lat. and 80° 11′ 30″ E. long., with a population in 1869 of 11,670. Under native rule the town possessed considerable political importance, and upon the British annexation of Oudh it was selected as the civil head-quarters of the district, but was abandoned in favour of Hardoi town on the reoccupation of the province after the mutiny. The town has now but little trade, and a deserted indigo factory occupies the site of the old fort. Saltpetre and brass utensils are manufactured.

MALLEMUCK, from the German rendering of the Dutch *Mallemugge* (which originally meant small flies or midges that madly whirl round a light), a name given by the early Dutch Arctic voyagers to the FULMAR (vol. ix. p. 817 [1]), of which the English form is nowadays most commonly applied by our sailors to the smaller Albatroses, of about the size of a Goose, met with in the Southern Ocean—corrupted into "Molly Mawk," or otherwise modified. There is some difference of opinion as to the number of species of small Albatroses, and it is unfortunate that the results of the voyage of the "Challenger" do not clear up the doubts that have been expressed. Three species have been described and figured, the *Diomedea melanophrys* and *D. chlororhynchus* for a long while, while the third, *D. culminata*, was discriminated by Gould (*Proc. Zool. Society*, 1843, p. 107), who has stated that the difference between it and the second is so apparent that he had no difficulty in distinguishing them on the wing. Captain Hutton, on the other hand (*Ibis*, 1865, p. 283), considers all three to be specifically identical. Others, as appears by the *Report on the Birds* of the "Challenger" voyage (pp. 148, 149), while regarding *D. melanophrys* as distinct, would seem to unite *D. culminata* with *D. chlororhynchus*. The first of these birds, says Gould, is the commonest species of Albatros inhabiting the Southern Ocean, and its gregarious habits and familiar disposition make it well known to every voyager to or from Australia, for it is equally common in the Atlantic as well as the Pacific. The back, wings, and tail are of a blackish-grey, but all the rest of the plumage is white, except a dusky superciliary streak, whence its name of Black-browed Albatros, as also its scientific epithet, are taken. The bill of the adult is of an ochreous-yellow, while that of the young is dark. This species (supposing it to be one) is said to breed on the Falkland Islands and on Tristan da Cunha, but the latter locality seems questionable, for, according to Carmichael (*Trans. Linn. Soc.*, xii. p. 490), *D. chlororhynchus* is the bird of this group there found; while Professor Moseley (*Notes of a Naturalist*, p. 130) calls it *D. culminata.*[2] Whatever it may be, the excellent observer just named describes it as making a cylindrical nest of grass, sedge, and clay, with a shallow basin atop and an overhanging rim—the whole being about 14 inches in diameter and 10 in height. The bird lays a single white egg, which is held in a sort of pouch formed by the skin of the abdomen, while she is incubating. A few other details are given by him, but his visit was too hurried to enable him to ascertain the more important and interesting points in the economy of this Albatros which were neglected by his predecessor, Carmichael, during his four months' sojourn in 1816–17. *D. culminata* is said by Gould to be more plentiful in the Australian seas than elsewhere, numbers coming under his notice between Launceston and

[1] It was there erroneously stated that *Mallemuck* was a Dutch word, which it is not; and the correct German form, as given by Friderich Martens (*Spitzbergische oder Groenlandische Reise Beschreibung*, Hamburg, 1675, 4to, p. 68), is *Mallemucke*. The anonymous translation of this voyage, under the title of *An Account of several late Voyages and Discoveries to the South and North*, published in London in 1694 (p. 93), was probably the means of the name becoming known to Ray, in whose *Synopsis methodica Avium*, published in 1713, it appears (p. 130) as *Mallemuck*, and thereafter kept its place in English ornithological works.

[2] Mr Sclater with commendable caution assigns no specific name to the eggs of the *Diomedea* found breeding on this island and its neighbour (*Report, &c., ut supra*, p. 151).

Adelaide, and being also frequently observed by him between Sydney and the northern extremity of New Zealand, as well as in the same latitude of the Indian Ocean. He describes its bill as having the greyish-yellow ridge broad and flat, while that of *D. chlororhynchus* is laterally compressed and the ridge round. All these birds seem to have much the same habits. (A. N.)

MALLET, PAUL HENRI (1730–1807), born in Geneva in 1730, and educated there, became tutor in the family of the count of Calenberg in Saxony. In 1752 he was appointed professor of belles lettres to the academy at Copenhagen, but as the French language was then little known in Denmark he had but few students. He was naturally attracted to the study of the ancient literature and history of his adopted country, and in 1755 he published the first fruits of his researches, under the title —*Introduction à l'histoire de Danemarck où l'on traite de la religion, des mœurs, des lois, et des usages des anciens Danois.* A second part was issued in 1756, more particularly relating to the ancient literature of the country, and bearing the title—*Monuments de la mythologie et de la poesie des Celtes, et particulièrement des anciens Scandinaves.* In the same year a translation of the work appeared in Danish. This is the work by which the author is best known in Britain. Though intended only as a preliminary dissertation to the formal history of Denmark, by which it was followed, it has all the merits of an independent work, complete in itself, and presenting a general view of the civilization and culture, religion and customs, of the Scandinavian nations. A translation into English, with notes and preface, by Bishop Percy, was issued in 1770 under the title of *Northern Antiquities* (republished with additions in 1847). It had a wide circulation, and attracted much attention on account of its being the first (though a very defective) translation into French of the *Edda.* Mallet's dissertations and notes are vitiated by untenable theories as to the racial affinities of the early inhabitants of Scandinavia; but, judged by the standards of its time, his work was of great merit and usefulness. Its publication attracted the notice of the king to its author, and he was chosen as preceptor of the prince of Denmark. In 1760 he returned to Geneva, and became professor of history in his native city. While there he was requested by the czarina to undertake the education of the heir-apparent of Russia (afterwards the Czar Paul I.), but declined the honour. An invitation more congenial to his tastes led to his accompanying Lord Mountstuart in his travels through Italy and thence to England, where he was presented at court and commissioned to write the history of the house of Brunswick. He had previously received a similar commission from the landgrave of Hesse-Cassel for the preparation of a history of the house of Hesse, and both works were completed in 1785. The quietude of a literary life was rudely broken by the shock of the Revolution, to which he was openly hostile. His leanings to the unpopular side were so obnoxious to his fellow-citizens that he was obliged to quit his native country in 1792, and remained in exile till 1801. He died at Geneva, 8th February 1807.

A memoir of his life and writings by Simonde Sismondi was published at Geneva in 1807. Besides the *Introduction to the History of Denmark*, his principal works are—*Histoire de Danemarck*, 3 vols., Copenhagen, 1758–77; *Histoire de la maison de Hesse*, 4 vols., 1767–85; *Histoire de la maison de Brunswick*, 4 vols., 1767–85; *Histoire de la maison et des états de Mecklenbourg*, 1796; *Histoire des Suisses ou Helvétiens*, 4 vols., Geneva, 1803; *Histoire de la Ligue Hanséatique*, 1805.

MALLOW, botanically *Malva*, the typical genus of *Malvaceæ*, embracing about sixteen species of annual and perennial herbaceous plants, widely distributed throughout the northern hemisphere. The mallows possess the reniform one-celled anthers which distinguish the *Malvaceæ* from all other dichlamydeous exogens. The petals also are united by their base to the tube formed by the coalesced filaments of the stamens. The special characters which separate the genus *Malva* from others most nearly allied to it are the involucre, consisting of a row of three separate bracts attached to the lower part of the true calyx, and the numerous single-seeded carpels disposed in a circle around a central axis, from which they become detached when ripe. The flowers are mostly white or pinkish, never yellow, the leaves radiate-veined, and more or less lobed or cut. Three species are natives of Britain. The musk mallow (*Malva moschata*) is a perennial herb with five-partite, deeply-cut leaves, and large rose-coloured flowers clustered together at the ends of the branched stems, and is found growing along hedges and borders of fields, blossoming in July and August. It owes its name to a slight musky odour diffused by the plant in warm dry weather when it is kept in a confined situation. The round-leaved mallow (*Malva rotundifolia*) is a creeping annual, growing in waste sandy places, with roundish serrate leaves and small pinkish-white flowers produced in the axils of the leaves from June to September. It is common throughout Europe and the north of Africa, extending to western Asia. The common mallow (*Malva sylvestris*), the *mauve* of the French, is an erect biennial plant with long-stalked roundish-angular serrate leaves, and conspicuous axillary reddish-purple flowers, blossoming from May to September. Like most plants of the order it abounds in mucilage, and hence forms a favourite domestic remedy for colds and various other complaints affecting the mucous membrane. The aniline dye called mauve derives its name from its resemblance to the colour of this plant.

The marsh mallow (*Althæa officinalis*), the *guimauve* of the French, belongs to another genus having an involucre of numerous bracts. It is a native of marshy ground near the sea or in the neighbourhood of saline springs. It is an erect perennial herb, with somewhat woody stems, velvety, ovate, acute, unequally serrate leaves, and delicate pink showy flowers blooming from July to September. The flowers are said to yield a good deal of honey to bees. The root is used in medicine as a demulcent, on account of its containing more mucilage than the common mallow. It is supposed to form a chief ingredient in the well-known *pâte de guimauve* lozenges. The marsh mallow is remarkable for containing asparagin, $C_4H_8N_2O_3,H_2O$, which, if the root be long kept in a damp place, disappears, butyric acid being developed. The root also contains about 25 per cent. of starch and the same quantity of mucilage, which differs from that of gum arabic in containing one molecule less of water and in being precipitated by neutral acetate of lead. The marsh mallow is far more largely used on the Continent than in England.

The mallow of Scripture, Job xxx. 4, has been sometimes identified with Jew's mallow (*Corchorus olitorius*), but more plausibly (the word מַלּוּחַ implying a saline plant) with *Atriplex Halimus*, or sea orache. In Syria the *Halimus* was still known by the name *Mallûḥ* in the time of Ibn Beitar. See Bochart, *Hieroz.*, iii. 16.

MALLOW, a municipal and parliamentary borough, market-town, and watering-place in the county of Cork, Ireland, is situated on the Blackwater, 150 miles south-west from Dublin, and 20 north from Cork. The town owes its prosperity to its beautiful situation in a fine valley surrounded by mountains, and to its tepid mineral spring, which is very efficacious for general debility and for scorbutic and consumptive complaints. A spa-house with pump-room and baths was erected in 1828. Besides the parish church in the Later English style, erected in 1818, the principal buildings of the town are the court-house, the work-house and infirmary, and the bridewell. There are a manufactory of mineral water, a condensed-milk manufactory, corn-mills, and tanneries. Mallow received a charter of incorporation from James I. The population of the borough in 1871 was 4165, and in 1881 it was 4437.

MALMESBURY, a parliamentary borough and market-town of Wilts, England, is finely situated on an eminence almost surrounded by the Lower Avon, and on a branch of the Great Western Railway, 92 miles west of London. Of the Benedictine house which was founded in the 7th century, and in the reign of Edward III. rose to the dignity of a mitred abbey, little more than the nave and side aisles of the conventual church now remain; this at the dissolution was changed into a parish church, instead of the old church of St Paul's. There are a town-hall, national and endowed schools, and several almshouses. In the market-place there is a richly ornamented octagonal cross supposed to date from the reign of Henry VIII. The industries include the manufacture of ribbons and pillow lace, brewing, and tanning. The population of the town in 1871 was 3142, and of the parliamentary borough (which comprises an area of 21,772 acres, mostly rural) 6879. In 1881 the numbers were 3133 and 6866.

Malmesbury is supposed to have been a British town, and also a Roman settlement. A castle is known to have existed there as early as the 7th century, at which time the monastery was also founded. It received its first charter from Edward the Elder, which was confirmed by Athelstan. The charter granted to it by Charles I. has undergone various modifications, and at present it is governed by a high steward, an alderman, and twelve capital burgesses. From the reign of Edward I. the town sent two members to parliament; since the Reform Act of 1832 it has returned only one. During the civil war it was twice captured by the parliamentarians and once by the royalists. Malmesbury is the birthplace of the philosopher Hobbes. Athelstan was buried at Malmesbury, but the Gothic canopy in the church called his tomb dates from the 16th century.

MALMESBURY, JAMES HARRIS, EARL OF (1746–1820), the best-known English diplomatist of the latter half of the 18th century, was born at Salisbury on April 21, 1746. He was the son of JAMES HARRIS (*q.v.*), the author of *Hermes*, and, what was important for his son's future success, M.P. for Christchurch, a lord of the treasury under George Grenville (1763–65), and comptroller to the queen (1774–80). Educated at Winchester, Oxford, and Leyden, the younger Harris was intended for diplomacy. In 1768 he became secretary to the British embassy at Madrid, and in 1770 he was left as *chargé d'affaires* at that court on the departure of Sir James Gray until the arrival of George Pitt, afterwards Lord Rivers. This interval gave him his opportunity; he discovered the intention of Spain to attack the Falkland Islands, and was instrumental in thwarting it by putting on a bold countenance. As a reward he was appointed minister *ad interim* at Madrid, and in January 1772 minister plenipotentiary to the court of Prussia. His success was marked, and in 1776 he was transferred to the court of Russia. At St Petersburg he made his reputation, for he managed to get on with Catherine in spite of her predilections for France, and steered adroitly through the accumulated difficulties of the first Armed Neutrality. In 1782 Sir James Harris (he was now a Knight of the Bath) returned home from ill-health, and was appointed by his friend Fox minister at the Hague, an appointment confirmed after some delay by Pitt, which he took up in July 1784. He did very great service in furthering Pitt's policy of maintaining England's influence on the Continent by the arms of her allies, and held the threads of the diplomacy which ended in the king of Prussia's overthrowing the republican party in Holland, which was inclined to France, and re-establishing the prince of Orange. He was in recognition of his services created Lord Malmesbury of Malmesbury in the county of Wilts, and permitted by the king of Prussia to bear the Prussian eagle on his arms, and by the prince of Orange to use his motto "je maintiendrai." In 1789 he returned to England, and took an anxious interest in politics, which ended in his seceding from the Whig party with the duke of Portland in 1793, in which year he was sent, but in vain, to try to keep Prussia true to the first coalition against France. In 1794 he was sent to Brunswick to solicit the hand of the unfortunate Princess Caroline for the prince of Wales, to marry her as proxy, and conduct her to her husband in England. In 1796 and 1797 he was at Paris and Lille vainly negotiating with the French Directory. After 1797 he became partially deaf, and quitted diplomacy altogether; but for his long and eminent services he was in 1800 created earl of Malmesbury, and Viscount Fitzharris, of Heron Court in the county of Hants. He now became a sort of political Nestor, consulted on foreign policy by successive foreign ministers, trusted by men of the most different ideas in political crises, and above all was the confidant, and for a short time after Pitt's death almost the political director, of Canning. Younger men were also wont to go to him for advice, and Lord Palmerston particularly, who was his ward, was tenderly attached to him, and owed many of his ideas on foreign policy directly to his teaching. His later years were free from politics, and till his death in 1820 he lived very quietly and almost forgotten. As a statesman, Malmesbury had an influence among his contemporaries which is scarcely to be understood from his writings, but which must have owed much to personal charm of manner and persuasiveness of tongue; as a diplomatist, he seems to have deserved his reputation, and shares with Macartney, Auckland, and Whitworth the credit of raising diplomacy from a profession in which only great nobles won the prizes to a career opening the path of honour to ability.

Malmesbury did not publish anything himself, except an account of the Dutch revolution, and an edition of his father's works, but his grandson the third earl published four volumes of his diaries and correspondence from 1768–1807, and afterwards two volumes of letters to and from his family and friends.

MALMESBURY, WILLIAM OF, an historical writer of the 12th century, the date of whose birth is usually assigned to the year 1095, but may with more probability be placed some twenty years earlier. It may reasonably be conjectured from his own statement ("utriusque gentis sanguinem traho") that he was the son of a Norman father and an English mother; he undoubtedly represents the fusion of the two races, although his sympathies as a writer are unmistakably on the side of the conquerors. He received his early education at the ancient Benedictine abbey at Malmesbury, and he speaks of Aldhelm, bishop of Sherborne, the great benefactor and second founder of that house, who died in 709, as his "lord and patron," to whom he was indebted both for his life and his learning (*Gesta Pont.*, sec. 273). The earliest known incident in his personal history is the fact, which he himself records, that he assisted the abbot Godefrey in collecting books to form the first library of the abbey. William himself subsequently became the librarian, and was also precentor of the abbey; in 1140 he received the offer of the abbacy, an honour which he declined, probably from a desire to secure as much leisure as possible for study. In his later life he was honoured by the particular friendship of Robert, earl of Gloucester, a natural son of Henry I., and a distinguished patron of learned men and letters. In politics he was a warm partisan of the empress Matilda against Stephen, and he was present at the council of Winchester convened by her supporters in 1141. His death is supposed to have occurred in or after 1142.

Printed Works.—William's earliest important work was the *Gesta Regum Anglorum*, which he dedicated to his patron, the earl of Gloucester. It was originally completed in 1120, but subsequently brought down to 1128. It extends from 449 A.D. to the twenty-eighth year of the reign of Henry I., and is a record of the highest value, preserving from unknown sources numerous facts which would otherwise be lost to us. In 1125 William completed his *Gesta Pontificum Anglorum*. He himself tells us that the production of this work cost him especial pains, but that the material for its composition was neither so abundant nor so easily reducible to consistency as that for the *Gesta Regum.* The work may be regarded as the main source for our early ecclesiastical history, and constitutes the basis of later productions relating to the same subject at the same period. It is divided into five books, the bishops being grouped under their respective sees, and the chief monasteries under their jurisdiction being also noticed, sometimes at considerable length. The fifth book is mainly occupied by the life of St Aldhelm, and includes numerous details of interest not given in the earlier life by Faricius. The *Gesta Pontificum* is likewise brought by further additions down to the year 1140. William's last work was a continuation of the *Gesta Regum* under the title of *Historia Novella.* It concludes abruptly with the escape of Matilda from Oxford when besieged there by Stephen in 1142, and the manner of its termination suggests that the narrative was broken off by the death of the writer. Like the *Gesta Regum,* the *Historia* is dedicated to the duke of Gloucester, whose doings in behalf of his sister Matilda are described in such a way as to make him in a great measure the central figure of the narrative. Other printed writings of William are an account of the church of Glastonbury (included along with the life of St Aldhelm in Gale's *Scriptores XV.*), and a life of St Wulstan, of which a considerable portion is given in the second volume of Wharton's *Anglia Sacra.* The best text of the *Gesta Regum* and the *Historia Novella* is that given by Sir T. D. Hardy in the edition published by the English Historical Society in 1840; the text in Savile's *Scriptores* is faulty in the extreme. The *Gesta Pontificum* was edited for the Rolls Series, in 1870, by Mr N. E. S. A. Hamilton, from a manuscript which he was the first to identify as the autograph of William himself.

Extant Works Unprinted.—Among these are *Miracles of the Virgin Mary*; *Miracles of St Andrew*; *Life of St Dunstan*; a compend of the commentary on the book of Jeremiah attributed to Paschasius Radbertus; an abridgment of the treatise by Amalarius on *Sacred Offices*; *Lives of the English Saints*; and an epitome of the *History of Haymo of Fleury,* together with other abridgments or transcripts of historical and legal writers,—this last being an autograph preserved in the Bodleian, where, or at the British Museum, the other manuscripts are also to be found.

Lost Works.—Among these are a *Life of St Patrick*; a metrical *Life of St Ælfgiva*; the *Miracles of St Benignus*; and the *Little Chronicle,* in three books (of which a supposed fragment is preserved at the British Museum, Lansdowne MS. No. 436). The work which we have probably most cause to regret is the *Itinerarium Johannis Abbatis,* or account of the journey of John, abbot of Malmesbury, to Rome in 1140. This was written by William from the oral account which he received from Peter Baldwin, John's companion. A few extracts are given by Leland in his *Collectanea,* iii. 272.

Malmesbury's merits as an historian are of a very high order. He labours, it is true, under the defect of being but imperfectly acquainted with English institutions, and having but little sympathy with the English race, while he occasionally evinces a Norman contempt for the English language. His habitual carelessness in chronology is also at times extremely perplexing, and his narrative of facts is alloyed with romantic details which serve to excite distrust with respect to his general credibility. But, notwithstanding these faults, he is entitled to rank as an authority (in relation to the period of which he treats) with Bede and Matthew Paris. He is again the first of our historical writers in whom the critical faculty is to any extent discernible, and the comparisons which he occasionally institutes between two different and discrepant accounts of the same events form a noteworthy feature in his mode of treatment. The pains and judgment which he employs in the arrangement of his materials are also often no less conspicuous than his industry in collecting them.

MALMÖ, a seaport town of Sweden, inferior only to Stockholm and Gothenburg in importance, is the capital of the län or province of Malmöhus, and stands on the eastern shore of the Sound, opposite Copenhagen, from which it is 16 miles distant. The town, which is built on a level plain, formerly had strong fortifications, of which all that now remains is the citadel, where the earl of Bothwell was imprisoned for some time after 1573; it is at present used as a house of correction. In the large central square (Stortorg), which is planted with trees, stands the town-hall, a brick and sandstone structure in the Renaissance style; it contains the handsome Knutssal, or former council chamber of the guild of Canute. The principal ecclesiastical buildings are the church of St Peter (Petrikyrka), begun in 1319, and the German church (Tyskakyrka). The harbour in the north-west has recently been deepened, and admits vessels drawing 18 feet of water; there is daily communication by steamer with Copenhagen, and also at regular intervals with Stockholm, Gothenburg, Lübeck, &c. The trade of the port is considerable, the exports including timber, iron, tar, oil-cake, and bones, while the imports consist chiefly of wine, salt-fish, salt, and coal. There are a number of manufactures, that of gloves being the specialty. Malmö is connected with Stockholm by rail. Population in 1878, 35,626.

Malmö (Malmhauge, Malmey, Malmöye, Malmoughe), sometimes called "Ancona Scanorum" or "Ellenbogen," first appears in history about the middle of the 13th century. During the Hanseatic period it was the most important commercial town on the Sound, but in the 16th and 17th centuries greatly lost ground owing to the decay of its herring fisheries and the rise of its rival Copenhagen. Its modern prosperity is largely due to the enterprise of Frans Suell, one of its merchants, who first constructed the harbour, which has more than once been enlarged subsequently.

MALORY, Sir Thomas, the author or compiler of the *Morte Darthur,* was born most probably about the year 1430. From his own words he is known to have been a knight, and his description of himself as "a servant of Jesu both day and night" has led to the inference that he was also a priest. On the authority of Leland the antiquary he is believed to have been a Welshman. The name appears in a variety of forms, including those of Maillorie and Maleore. In the preface to the first edition of the *Morte Darthur* Caxton speaks of the work as printed by himself "after a copy unto me delivered, which copy Sir Thomas Malorye did take out of certain books of French, and reduced it into English." Malory himself tells us that he finished the book in the ninth year of Edward IV. (*c.* 1470). For the place of the *Morte Darthur* in the literary history of the Arthurian legend, see Arthur, Geoffrey of Monmouth, Grail (Holy), &c.

MALPIGHI, Marcello (1628–1694), of Bologna, was one of the first to apply the microscope to the study of animal and vegetable structure; his discoveries are so numerous and important that he may be considered to be the founder of microscopic anatomy. Shortly before his death, he drew up a long account of his academical and scientific labours, correspondence, and controversies, and committed it to the charge of the Royal Society of London, a body with which he had been in intimate relations for more than twenty years. The autobiography, along with some other posthumous writings, was published in London in 1696, at the cost of the Society. The personal details left by Malpighi are few and dry. His narrative is mainly occupied with a summary of his scientific contributions and an account of his relations to contemporary anatomists, and is entirely without graces of style or elements of ordinary human interest. He was born in the country, about 20 miles to the north of Bologna, on the 10th of March 1628. At the age of seventeen he began the study of the Aristotelian philosophy, and continued it for four years; it appears from another statement that he was in the habit of amusing himself with the microscope during this period. Owing to domestic circumstances, it became necessary for him, in 1649, to choose a profession, and he elected to study medicine; after four years study at Bologna he graduated there as doctor. He at once applied to be admitted to lecture in the university, but it was not till after three years (1656) that his request was granted. A few months later he was appointed to the chair of theoretical medicine at Pisa, where he enjoyed the friendship and countenance of Borelli. At the end of four years he left Pisa, on the ground of ill-health, and returned to Bologna. A call to be professor primarius at Messina (procured for him through Borelli, who had in the meantime become professor there) induced him to leave Bologna in 1662. His engagement at Messina was for a term of four years, at an annual stipend of 1000 scudi. An attempt was made to retain him at Messina beyond that period, but his services were secured for his native university, and he spent the next twenty-five years there. In 1691, being then in his sixty-fourth year, and in failing health, he removed to Rome to become private physician to Pope Innocent XII., and he died there of apoplexy three years later. In the portrait prefixed to his autobiography, the features are those of the phlegmatic type. His addiction to the microscope brought him into conflict with the respectabilities of the medical profession, including two of his colleagues at Bologna, whose names have been preserved from oblivion; it was felt by those who affected to watch over the future welfare of medicine that the study of microscopic anatomy was adverse to the true interests of medical practice, and that feeling is said to have found expression in a duel that was fought between the brother of Malpighi and a near relative of one of his conservative colleagues, in which the latter combatant was killed. Amid such incidents was the fruitful microscopic era of medical and biological science ushered in.

The compound microscope (invented in the Netherlands) had been used in Italy (Rome) to study the parts and organs of the bee as early as 1625, and it was employed by Malpighi and by his contemporaries Hooke (botanist) and Leeuwenhoek; the illumination of the objects was always direct, the mirror being a much later addition, and the tube was of unwieldy length. Owing to the inability to overcome spherical and chromatic aberration in compound lenses, the simple microscope came again into common use, and continued to be the chief instrument in the study of minute anatomy until the introduction of flint-and-crown glass lenses by English opticians about a century later. It was Malpighi's practice to open animals alive, and some of his most striking discoveries were made under those circumstances. Although Harvey had correctly inferred the existence of the capillary circulation, he had never seen it; it was reserved for Malpighi in 1661 (four years after Harvey's death) to see for the first time the marvellous spectacle of the blood coursing through a network of small tubes on the surface of the lung and of the distended urinary bladder of the frog. We are enabled to measure the difficulties of microscopic observation at the time by the fact that it took Malpighi four years longer to reach a clear understanding of the corpuscles in the frog's blood, although they are the parts of the blood by which its movement in the capillaries is made visible. His discovery of the capillary circulation was given to the world in the form of two letters *De Pulmonibus*, addressed to Borelli, published at Bologna in 1661 and reprinted at Leyden and other places in the years following; the letters to Borelli contained also the first account of the vesicular structure of the human lung, and they made a theory of respiration for the first time possible. The achievement that comes next both in importance and in order of time was a demonstration of the plan of structure of secreting glands; against the current opinion (revived by Ruysch forty years later) that the glandular structure was essentially that of a closed vascular coil from which the secretion exuded, he maintained that the secretion was formed in terminal acini standing in open communication with the ducts. The name of Malpighi is still associated with his discovery of the soft or mucous character of the lower stratum of the epidermis, of the vascular coils in the cortex of the kidney, and of the follicular bodies in the spleen. He was the first to attempt the finer anatomy of the brain, and his descriptions of the distribution of grey matter and of the fibre-tracts in the cord, with their extensions to the cerebrum and cerebellum, are distinguished by accuracy; but his microscopic study of the grey matter conducted him to the opinion that it was of glandular structure and that it secreted the "vital spirits." At an early period he applied himself to vegetable histology as an introduction to the more difficult study of the animal tissues, and he was acquainted with the spiral vessels of plants in 1662. It was not till 1671 that he wrote his *Anatome Plantarum* and sent it to the Royal Society, who published it in the following year. An English work under a similar title (*Anatomy of Vegetables*) had been published in London a few months earlier, by Nehemiah Grew; so that Malpighi's priority as a vegetable histologist is not so incontestable as it is in animal histology. The *Anatome Plantarum* contained an appendix, *Observationes de ovo incubato*, which gave an account (with good plates) of the development of the chick (especially of the later stages) in many points more complete than that of Harvey, although the observations were needlessly lessened in value by being joined to the metaphysical notion of "prædelineation" in the undeveloped ovum. His works are—*De pulmonibus: Epistolæ duæ ad Borellium*, Bologna, 1661 (went through several editions); *Epistolæ anatomicæ Marc. Malpighii et Car. Fracassati*, Amsterdam, 1662 (on the tongue, brain, skin, omentum, &c.); *De Viscerum Structura: exercitatio anatomica*, London, 1669; *Anatome Plantarum, cum appendice observationes de ovo incubato continente*, London, 1672 (other editions in 1675 and 1679); *De Structura Glandularum conglobatarum*, London, 1689; *Opera posthuma, et vita a seipso scripta*, London, 1697 (another edition, with preface and additions, was published at Amsterdam in 1700). An edition containing all his works except the last two was published in London in 1687, in 2 vols. folio, with portrait and plates.

MALSTATT-BURBACH, a town in the district of Treves, Prussia, is situated on the right bank of the Saar (Sarre), almost contiguous with the town of St Johann, and separated from Saarbrücken by the river. It lies in the midst of an important coal-mining and industrial district, and is itself little more than a long and narrow row of manufactories and workmen's houses. The largest factories are engaged in the production of iron, steel, and cement, one iron-work employing nearly 2000 men, and producing 285,000 tons of raw and manufactured metal annually. There is a large wharf on the river for the export of coal. At the census of 1880 Malstatt-Burbach contained 13,158 inhabitants.

Malstatt is of very ancient origin, and received municipal rights in 1321. These, however, were afterwards resigned to the newer town of Saarbrücken, and in 1818 Malstatt and Burbach were two small villages with a joint population of only 822. About the middle of the century the population began to increase rapidly, in consequence of the development of the mining industry of the district and the extension of the railway system, and in 1875 the two villages were united to form a town. In 1870 Malstatt-Burbach was cannonaded by French troops under the command of Napoleon III.

MALT is the grain of any cereal artificially germinated so as to induce certain changes in the constitution of the seed, specially a conversion of a portion of the starch into sugar. The varieties of grain usually employed for malting are barley and bere or bigg, and the processes of preparing the substance are fully explained under BREWING (vol. iv. p. 266).

The specific effect of the malting of grain is to transform by the process of germination a proportion of the starch into soluble sugar and dextrin. These changes are effected by the agency of a peculiar nitrogenous ferment, diastase, which exists in the grain, but which is increased in amount during the germination. The precise sequence of changes, and the exact nature of the new chemical compounds evolved, are still matters of some doubt. It is clearly established that the ferment of barley is incapable of transforming the starch on which it operates entirely into sugar, the ultimate products of the action being partly dextrin and partly sugar. The relative proportions of these bodies evolved by fermentation from starch have been matter of dispute, some holding that from three molecules of starch there are evolved two molecules of dextrin and one of sugar, while others affirm that the yield is two of sugar and one of dextrin, and a third party hold that for each molecule of sugar there is one of dextrin produced, thus :—

$$\underset{\text{Starch.}}{2C_6H_{10}O_5} + H_2O = \underset{\text{Sugar.}}{C_6H_{12}O_6} + \underset{\text{Dextrin.}}{C_6H_{10}O_5}.$$

These statements, however, are based on the assumption that the sugar which results from the fermentation of germinating barley is ordinary grape sugar or dextrose, $C_6H_{12}O_6$; but it has been demonstrated, first by O'Sullivan, that it is a form of sugar possessed of peculiar properties to which the name maltose has been given. Maltose, according to O'Sullivan, is isomeric with cane sugar, $C_{12}H_{22}O_{11}$, but Märcker considers that its constitution should be represented by $C_{18}H_{34}O_{17}$, and that the equation is as follows :—

$$\underset{\text{Starch.}}{4C_6H_{10}O_5} + 2H_2O = \underset{\text{Maltose.}}{C_{18}H_{34}O_{17}} + \underset{\text{Dextrin.}}{C_6H_{10}O_5}.$$

Maltose possesses the power of reducing Fehling's solution (cupric oxide) only to the extent of 63 per cent. as compared with dextrose, but its power of right-handed polarization is three times as great = +154°. According to Dubrunfaut the efficient ferment in barley is maltin, a much more richly nitrogenous and active body than diastase, which he considers to be only a product of the decomposition of maltin.

By the processes of malting 100 parts by weight of barley yield about 80 of kiln-dried malt and 2 to 3 of dried radicle and plumule called "malt dust." The progressive modification in composition is shown in the accompanying table of analyses extracted from the report presented by Mr (now Sir) J. B. Lawes to the Board of Trade "On the Relative Value of Unmalted and Malted Barley as Food for Stock, 1866,"—an inquiry which resulted in showing that the advantages claimed for malt as a feeding material were largely illusory:—

	Barley.	Barley after Steeping.	4¼ Days on the Floor.	8 Days on the Floor.	12¼ Days on the Floor.	14¼ Days on the Floor.	Screened Malt.	Malt Dust.
Sugar	2·56	1·56	8·16	10·19	11·67	12·14	11·01	11·35
Starch, dextrin, and fat	80·42	81·12	74·72	72·16	70·73	70·09	72·03	43·68
Albumenoids	9·83	9·83	9·89	10·14	10·27	10·39	9·95	26·90
Fibre	4·69	5·22	4·96	5·18	4·98	5·03	4·84	9·67
Ash	2·50	2·27	2·27	2·23	2·35	2·35	2·17	8·40
Water in Fresh	17·64	42·70	41·87	41·65	40·71	40·44	6·66	11·73

Since the article BREWING was written the malt tax then in force in the United Kingdom has been repealed, and in its place, under the provisions of the Inland Revenue Act 1880 (43 & 44 Vict. cap. 20), an equivalent duty on beer has been substituted. By that enactment numerous modifications have been made practicable in the use of malt for feeding and other industrial purposes, and much greater latitude has been given to brewers in the selection and use of raw materials for the manufacture of the beverages hitherto known as malt liquors. Taking as the unit of measurement the bushel of malt, which is defined by statute as equivalent to 42 lb of malt or corn of any description, or to 28 lb of sugar, the malt duty, which under the provisions of the repealed statutes amounted to 2s. 7d., with 5 per cent. additional, has been transformed into a beer duty of 6s. 3d. charged upon every 36 gallons of wort of a specific gravity of 1057; and every brewer is deemed to have brewed 36 gallons of worts of that gravity who has used 2 bushels of malt in brewing. In the case of brewers for sale, should the quantity of worts produced and the specific gravity of such worts exceed by more than 4 per cent. the quantity and gravity above specified, the duty is charged for the excess over and above such 4 per cent. Brewers for domestic use and for the use of their own farm labourers are exempt from duty when the annual value of the house occupied by the brewer is not more than £10, and all brewers for domestic use who occupy houses exceeding in value that amount, and who consequently are subject to the beer tax, must brew their beer on their own premises only.

The malt tax, which in reality was a duty on raw grain, had long been regarded as a grievous impost, and its repeal was systematically agitated for by the agricultural interest. The tax, it was alleged, operated injuriously on the cultivators of barley, and prevented stockholders from freely using malt for the feeding of cattle and of ewes at the lambing season, &c. On the part of brewers it was maintained that the operation of the tax restricted them to the use of the heaviest and most expensive classes of barley alone; and that they were consequently precluded from using many varieties of grain and saccharine materials which under other conditions they might employ with advantage both to themselves and to the consumers of beer. No sooner, however, was it proposed by the Government to effect the change so long clamoured for—not indeed the entire abolition of taxation on malt liquors, but the freeing of a raw material from fiscal impost—than the agricultural community discovered they had made a mistake, and that, while it was really the beer drinker who paid the malt tax, its operation had rather tended to give the British barley-grower a monopoly of the trade in that raw material, and to artificially enhance the value of the heavier qualities of the grain. Further it was found that the idea of using malt for feeding purposes to any considerable extent, a right which stockholders already possessed under the provisions of the "Gladstone Act" (27 & 28 Vict. cap. 9) was entirely illusory; and as a matter of fact no demand has arisen for malt for such purposes. On the other hand, the freedom of choice as to raw materials which the Inland Revenue Act 1880 has given to brewers has not been without influence on the industry, although the modifications have up to this time been by no means so numerous and important as had been anticipated. Barley continues to be the principal, and, supplemented by sugar, almost the only, raw material of wort; but brewers no longer have any interest in confining themselves to the heaviest and plumpest growths, and consequently much light foreign-grown barley is now used. It was also expected that raw grain, and particularly maize, would be largely used with malt in the mashings, especially as a method had been devised and patented by Mr R. Blair Robertson of Glasgow for removing the germ of that grain, which contains a peculiar acrid oil, and which communicates a bitter unpleasant flavour to the wort in which it may be infused. To a limited extent a "maize beer," in which one-third part of Robertson's patent prepared maize is mashed with two-thirds of malt, is being brewed with quite satisfactory results, but the mixture does not appear to have commended itself generally to the trade either on the score of quality or of cheapness.

Malt is also the raw material from which the whisky of Scotland and Ireland is principally distilled, and it is the source of the greater part of the best qualities of table and pickling vinegar. Chiefly on account of the great solvent power over starch possessed by the diastase or maltin it contains, malt is extensively used as a combination in prepared farinaceous food for infants, and in the form of a malt extract it possesses considerable reputation in pharmacy.

MALTA is the chief island of the Maltese group, consisting of Malta, 35° 50′ N. lat. and 14° 30′ E. long., Gozo, 36° 5′ N. lat. and 14° 10′ E. long., Comino, which lies between them, and the two islets Cominotto and Filfla, a crown colony, and one of the Mediterranean possessions of Great Britain. Malta is 17¼ miles long by 9¼ broad, containing an area of about 95 square miles (about two-thirds the size of the Isle of Wight), and Gozo is 9 miles long by 5 wide, with an area of 20 square miles. The islands lie directly south of Sicily, distant from 55 to 60 miles, near the centre of the Mediterranean basin, where they appear as the remains of an ancient chain of islands, much worn and still wearing away by the sea. Gozo, which has the same general character as Malta, possesses more moisture and richer soil, and therefore more verdure. A cluster of single hills, remarkable for their steeply conical shape, on one of which stands Rabato, the principal village, is near the middle of the island. Along the northern and eastern shores of Malta the coast-line is frequently broken by deep indentations and bays (St Paul's, St George's, and St Julian's Bays); on the peninsulas in and round the most remarkable of these Valetta and its fortifications are built. The geological formation is late Eocene, the prevailing rocks being white, grey, reddish, or yellow sandstone, with

Plate III.

some beds of marl and coral limestone, in many parts abounding in fossils. The surface of the country is diversified by valleys and steep hills; there is little water, and no river, brook, or lake exists on any of the islands. The highest point of Malta is near Casal Dingli, about 750 feet above the sea to the south; a little farther north lies the ancient capital, Citta Vecchia, upon another steep height; west of these lies the range of Bingemma Hills running north-east to south-west; from this higher ground the island slopes somewhat towards the north-west. On the west and south the cliffs rise sheer from the sea to a height of 300 or 400 feet; on the north the rock in many places shelves to the water's edge, though the harbours of Valetta and the rocks where the apostle Paul was wrecked are an exception to this. At the east end is the large harbour Marsa Scirocco, into which the south-east sirocco blows with full force. The general appearance of the land is bare, owing to the want of woodland, and also to the use of stone walls as enclosures for the fields, which in the east of the island are smaller than in the west. The dark foliage of the carob and the singular masses of the prickly pear are, however, very marked in the landscape, which with its contrasts of blue sea running into the brown and yellow land, heightened by whatever of green may be, is of fascinating beauty under the effects of morning light and setting sun. The land is closely cultivated; often the soil is terraced on the sides of the hills as a safeguard against the winter rains. The soil is in many places extremely thin; it is, however, so fertile that it produces two and sometimes three crops in a year. Large quantities of early potatoes grown for the English market, corn sufficient to supply the island for four months of the year, cotton, principally for home use, and a fine red-flowering clover, called *sulla*, are the chief crops; excellent honey is obtained from Gozo; oranges and figs come to great perfection. Goats abound, but few cows are kept; the mules and asses are fine; cattle and sheep for butcher meat are imported from Barbary. Fish is good and abundant. The flowers of Malta are famous; Cicero mentions the cushions stuffed with roses used by Verres, and many a lovely garden is hidden behind the high stone walls. The interesting flora of the islands approaches that of Africa (to which continent the old geographers considered them to belong, as the French do still), including the palm, cactus, and other sub-tropical plants. The scanty fauna is for the most part European; the Maltese dog is mentioned by Strabo and other old writers; a few still remain, though not wild. Of birds there are about ten or twelve indigenous species, but a large number of migratory birds pass or rest here. The marine plants and animals also offer a rich fund of material to the student.

The winter climate is temperate and healthy, the thermometer ranging from 51° to 71° Fahr. between October and May. In the summer months the heat is almost tropical; from July to the end of October it ranges between 80° and 90°. Snow is unknown, but hail occurs in winter, and much rain usually falls between December and February. The northerly winds are bracing, but the south-east wind, called the sirocco, which brings the warm air from the African deserts, and then takes up the salt sea mists, is very deleterious; it occurs suddenly, chiefly in August and September, occasionally in the spring, and fortunately lasts usually but a few hours. The "gregale" ("eurokylon" of Acts xxvii. 14) is a strong north-east wind which occasionally blows in the winter months with great fury and force for two or three days together, especially in November and February, rendering it dangerous to cross the harbour, sometimes tearing up stone walls and landing-steps, and otherwise doing much damage.

The Maltese are a strong well-formed race, the men dark, handsome, and lithe, the women with black eyes and fine hair and an easy carriage; as in other Eastern nations, the working classes grow old at a comparatively early age. They are a cheerful, good-humoured, and industrious people, sober and abstemious, though quick-tempered and addicted to the use of the knife. Bread or pasta, with a few olives, a little oil, or milk cheese, forms the chief support of the poor, who seldom or never eat meat, and drink but little of the light wine of the country. The gentry have a large admixture of Spanish, Italian, and French, but among the people in general the Arab race and character predominate, influenced by contact with Sicily. Of the native language 70 per cent. consists of Arabic words, the rest being chiefly a corrupt Italian; that spoken in Gozo is the purest Maltese. The festivals and ceremonials of the Roman Church are kept up to an extraordinary degree, together with a few that seem to be derived from the Greek Church. The perpetual ringing of monotonous church bells, and the peculiar method of striking time, are relics of South Italian customs.

Malta is divided into twenty-six casals or village districts, Gozo into nine; some of the villages are large and populous, each having its church, often large and handsome. Near the middle of the island, on sharply rising ground, stands the ancient capital, called Civitas Melita by the Romans and oldest writers, Medina (*i.e.*, the city) by the Saracens, Notabile ("jocale notabile, et insigne coronæ regiæ," as it is called in a charter by Alphonso, 1428) under the Sicilian rule, and Citta Vecchia (old city) by the knights. The cathedral, overthrown by an earthquake in 1693, but rebuilt, stands on the reputed site of the house of Publius, Paul's friend; many Maltese gentry live in this town, and the English utilize some of the buildings. The Roman remains and catacombs of Citta Vecchia must not be forgotten. Since 1570 the chief town has been Valetta,—a city built on a ridge of rock (Mount Sceberras) which runs like a tongue into the middle of a bay, which it thus divides into two great harbours, subdivided again by three other peninsulas into creeks. On two of these peninsulas, and at their base, are built the aggregate of towns called the Three Cities, part of which (grown up under the old Fort St Angelo) is much older than the coming of the knights, and is called Vittoriosa in commemoration of the siege of 1565. Valetta, including the suburb Florian, is about 2 miles long and $\frac{3}{4}$ mile wide; Fort St Elmo, with a lighthouse, stands on the point; the summer suburb Sliema lies on the point which encloses the west or Marsamusceit harbour; Fort Ricasoli on the opposite point enclosing the east or grand harbour. The streets of Valetta, paved with stone, run along and across the ridge, and end on each side towards the water in steep flights of steps. Many of the houses, which are of stone throughout, with flat roofs, are large and luxuriously built; wooden covered balconies project from the windows and give a peculiar aspect to the streets. There are several fine public buildings, as the governor's palace, the new opera-house, the public library, the *auberges* or lodges of the knights, especially the Auberge de Castile, the English church built by Queen Adelaide and others. Roman Catholic churches in Valetta are very numerous: the cathedral of St John is famous for its rich inlaid marbles, its Brussels tapestries, its roof painted by Matteo Preti (1661–99), and the picture by Caravaggio, the Decollation of John the Baptist. The hospital of the knights contains one of the longest rooms in Europe, 503 feet in length, without a central support. The extensive bagnios under the rock, formerly occupied by the slaves of the knights, are now used for naval stores. The knights strengthened Valetta and its harbours by bastions, curtain-walls, lines, and forts, towards the sea, towards the land, and on every available point, taking advantage in every particular of the natural rock and of the marvellous advantages of situation, rendering it then almost impregnable. The work of fortifying the place with modern armament is carried on by the British Government, which possesses there the finest naval hospital in Europe, a military prison, and other necessary institutions, including immense subterranean stores of grain. New sanitary and water works and dwellings for the over-crowded poor have lately been undertaken by the local authorities. The city is clean and well-regulated, gay with the motley throng of all nations that continually come and go, and presenting many features common to the East; the influx of winter visitors attracted by the mild climate and social gaieties has of late years proved a source of wealth to the inhabitants. A railroad from Valetta to Citta Vecchia, the first in the island, is now nearly completed.

The importance of Malta lies, as of old, in its harbours, which render it a splendid port of call, repair, or refuge, as well as a fine naval station, in its capabilities as a depôt for coals and stores, in its hospitals, and in its strength as a military station. Its position in the Mediterranean is of the utmost value towards keeping a clear highway to the East and to India. During the eighty-two years of British occupation the population, trade, and produce have largely increased. The government, created by royal letters patent of 11th May 1849, consists of a council of eighteen members, eight elected by the Maltese (about two thousand three hundred electors), nine chosen by the crown, and the governor, with a salary of £5000, who is usually a military officer. To these were added by letters patent of May 1881 an executive council of three members to advise and assist the governor. The council have powers to make laws and to vote money; this last was restricted by the British Government in 1875, leading to a protest in the following year by the elected eight. The government of the islands presents peculiarities owing to the combination of military and civil duties. Several recent inquiries on taxation, education, &c., have led to important changes during the last two years. The consolidated revenue is at the disposal of the crown through the governor and council; Malta is self-supporting, costing the imperial exchequer little beyond the military and naval establishments, and even contributing £5000 annually towards the former. The revenue arises chiefly from import duties (of which a large proportion accrues from a tax of 10s. a quarter upon grain) and tonnage dues.

	Revenue.	Expenditure.
1879	£183,794	£185,946
1880	190,661	169,318

The tonnage of vessels entering and clearing equals that at Gibraltar; in 1878 it amounted to 6,503,859 (5,669,046 of which was for British vessels), and in 1880 it was 6,147,234. In 1879 the value of imports actually landed was £794,565, and of exports £216,050,—a value of about £18,700,000 merely touching at the port. The figures fluctuate; in the following year they fell considerably. In 1837 the revenue was but £95,600, while but one steamship, of 137 tons, entered the harbour; in 1879 2894 steamers, with a tonnage of 2,781,806 entered. In the naval yard numerous vessels are repaired yearly; in 1876–77 these amounted to 39 ironclad and other ships and 43 smaller vessels. One arm of the harbour is devoted to a coaling station, where enormous quantities of coal are annually imported and sold (384,272 tons in 1880). The British Mediterranean fleet is stationed there for six months of the year, the strength of the naval forces being usually about 5000 men. The strength of the military in the island is usually about 6500, the largest garrison in any British colony.

The population, which in 1837 was 115,570, was 154,892 in 1880, exclusive of British troops and their families, about 24,000 being English and foreigners; it is rapidly increasing, and is unequally distributed, the greater part being settled in the large casals or villages on the eastern half of Malta, including the densely populated Valetta; large tracts to the west are bare and but sparsely inhabited; about one-third of the island is rocky and uncultivated. Malta has now 1510 inhabitants to the square mile, Gozo 962. In 1879 there were 9868 children (about two-fifths of these at school age) attending elementary schools, including 768 students at the university and two lyceums; in 1880 the total was 9595. All the casals of Malta and Gozo (with but one or two exceptions), besides Valetta and the Cities, have schools, which are now placed on the same system as the board schools in England; great efforts are being made to extend the acquisition of the English language, which till recently was neglected in favour of Italian. The director of public education, besides the elementary, has under his care several secondary schools, two lyceums in Vittoriosa and in Valetta, and the university (founded by the knights in 1768), with faculties of philosophy and arts, law, medicine, and theology. In Valetta is a large public library founded by the knights in 1760, containing 48,000 volumes, open free daily; in Gozo is a smaller one.

History and Antiquities.—Malta (*Melita*), with its sister Gozo (*Gaulus* or *Gaudus*), has from time immemorial been a place of importance to whatever race wished to hold the highway of the Mediterranean, whether Phœnician, Punic, Roman, or Arab. Thus even the stories of Homer have a semblance of truth, for the Ogygian isle where Ulysses took refuge has been supposed to be Malta or Gozo, in both of which tradition (born of the poem) yet points out the grottoes of Calypso. The earliest inhabitants of whose presence we have any actual trace are the Phœnicians, from whom we have several important inscriptions which tell of them and their temples, several curious images believed to belong to their worship, and many specimens of their pottery and glass, chiefly found in tombs, some bearing Phœnician characters and potters' marks. Sepulchral caves and clusters of rock-hewn tombs, especially those in the hills of Bingemma, in several of which terra cotta sarcophagi have been found, are referred with reason to a Phœnician or a Punic origin; Caruana's *Report* gives a list of these in eight places, distinguishing them from numerous Greek and Christian catacombs which also exist in the islands. The most remarkable remains are three rough stone erections, one in Gozo (Torre dei Giganti), and two in Malta, about a mile apart (Hagiar Kim and Mnaidra), which mainly consist of several apsidal chambers side by side, the walls of which are built of enormous horizontal and upright stones. In Malta the ruins show evidence of much skill in stone-cutting; the entrances to the chambers consist of three large slabs of stone in place of doorpost, each smaller than and at a little distance from the one outside it; several have well-shaped holes for ropes or other fastening; other slabs have sharply-squared holes and shelves cut in the solid stone; others again are ornamented with "pit-markings" or little depressions cut evenly all over the surface of the stone. A table or altar is also found in some of the rooms, a massive slab of stone supported on an upright formed like the trunk of a tree; in one case the two ends of the slab are carefully mortised into the walls at each side, the chamber being very small, and apparently intended specially for its reception. Hagiar Kim was excavated by the Government in 1840, when considerable traces of the action of fire were found on some of the walls, as well as buried ashes. In other rooms were found quantities of bones, many fragments of pottery, lamps, bowls, &c., nine images, and a small ornamented altar (*Archæol.*, vol. xxix. p. 227). The ruins in Gozo were excavated about 1827 (*Archæol.*, vol. xxii. p. 294). All these buildings stand on commanding positions, high on the side or the shoulder of steep hills. They have been usually considered Phœnician temples; and, on comparison of them with what is known of the great temple of Melkart at the south-east corner of Malta, the presumption is strong that these too were built by the same race, at some very early period. The bilingual inscription found there belongs to a later age, the Græco-Punic time, to which Greek coins found in both islands and a few other remains bear evidence. It is probable that the islands shared in some degree the varying fortunes that followed on the wars in Sicily, which took place as Greek drove out Phœnician, as Carthaginian drove out Greek and tried to regain the ancient possession of the mother-land, as finally Rome conquered all. During the First Punic War (264–241 B.C.) Malta seems to have been conquered and reconquered more than once (Orosius, iv. c. 8). In the Second Punic War the Carthaginians, under Hamilcar, son of Gisco, gave it up to Titus Sempronius, 218 B.C. (Livy, xxi. 51).

In the pursuit of manufactures and commerce Malta had attained a high degree of prosperity under the Phœnicians, which still existed under the Romans of the Augustan age. It was especially famous for its textile fabrics (probably of cotton, which is grown and spun there to this day); the Sicilian prætor Verres sent there for women's woven garments. The inhabitants were rich, and there were many artificers of all kinds. Ovid speaks of it as a fertile island (*Fast.*, iii. 567). The remains formerly existed (unfortunately now for the most part dispersed or destroyed) of several fine Græco-Roman temples, such as the temple of Juno spoken of by Cicero and Valerius Maximus, whose ornaments and fine ivories and carved figures of Victory tempted more than one sacrilegious robber; the temple of Proserpine, which we learn from an inscription was repaired by Chrestion, a freedman of Augustus, procurator of Malta; and the temple of Apollo at the chief town Melita, which with a theatre shared the munificence of a wealthy Maltese under the Antonine rule; these and the ruins of a princely Roman dwelling with mosaics, system of water supply, &c., at the same place, are but a few signs of the luxury enjoyed in the islands. Diodorus noticed the beauty and adornment of the houses in Malta in his time, a few years after the shipwreck of St Paul. One of the islanders was a friend of Cicero, who had thoughts of retiring there himself. A mole and important harbour works, discovered a few years ago, show that the Romans were not behind in strengthening the natural advantages of the islands for shelter. Inscriptions recording municipal institutions there date from the time of Hadrian; how much earlier they possessed them is unknown. Before then we hear of Chrestion the procurator mentioned above, and a Roman governor under Augustus, Lucius Castricius, styled *πρῶτος Μελιταίων*, "chief man of the Maltese" (Caruana, 1882, p. 134; 1881, pp. 20, 21), just as, half a century later, Publius was *πρῶτος τῆς νήσου*, "chief man of the island" (Acts xxviii. 7); all these were probably concerned in the local government. The Romans retained the Maltese group for many centuries. At the division of the empire in 337 A.D. it passed with Italy, Illyria, and Africa to Constans; after the reunion, and the final division after the death of Theodosius in 395, Malta, as one of the isles of the Mediterranean, remained with the empire of the East. History has but little to mention regarding it during those early times, except that event of ever-living interest, the shipwreck of St Paul, 58 A.D., which it is now well-ascertained took place in a bay on the north side of Malta. The alleged conversion of the Maltese to Christianity following the three months' stay of the apostle and his companions may be a fact; Chrysostom refers to it (*Hom.* 54 on Acts). Many Christian monograms and inscriptions have been found, ranging from the 2d to the 9th century; and the tombs and subterranean cemeteries near Citta Vecchia are said to be arranged like the Christian cemeteries of subterranean Rome (Caruana, 1881, p. 18). Tradition says these were used as hiding-places in times of persecution; it is certain that Ptolemy at the end of the 2d century notes the famous temples of Hercules and Juno as still in existence; the old religion and the new must have gone on side by side for a long time. After a time Malta was made a bishopric; according to R. Pirrus (*Sicilia Sacra*, Melitensis Eccl. Not. vii., *s.v.* "Lucillo") it was, though considered part of Africa, subject to the bishop of Palermo (in 6th century primate of Africa); we find Gregory the Great dealing with a contumacious bishop of Malta and directing the bishop of Syracuse and others to depose him, and to aid the successor appointed in his place (Greg., *Epist.*, ii. 44; ix. 63; x. 1).

The Saracens did not gain possession of Malta without a struggle of many years; they invaded it three times, in 828, 836 (when it appears to have been chiefly Gozo that suffered), and finally in 870, when the inhabitants of Melita, having massacred the Greek (Byzantine) garrison of 3000, opened their gates to the invaders. The Arabs are said to have destroyed part of the city so as to bring the fortifications within smaller compass, rendering it more easy to defend, and to have changed its name to Medina (great or chief city). In a suburb just outside the present walls there was discovered in 1881 a burial-place containing numerous Arab coffins, overlying the remains of the Roman palace mentioned above, which was thus finally ruined and concealed by the conquerors. It is known that they built a fortress in 973, at the point of Mount Sceberras where Fort St Elmo now stands. A few coins are preserved, but otherwise very little record remains of the Arab dominion, which lasted about two hundred and twenty years; no more Christian bishops are known until after that time, but tradition asserts, not without probability, that some of the original natives remained in certain villages and some Greeks in the capital, among whom were Christians.

The Norman knights, who brought their conquering arms into Apulia, Calabria, and Sicily, and even sent ships to Byzantium, were probably the first to bring a Teutonic race and influence into Malta. Through somewhat uncertain dates it appears that Roger I. (youngest son of Tancred, and brother of Guiscard) about 1090 landed in the island and levied tribute, and that about 1127 Roger II., this not being paid, set sail with a fleet, took Medina, then governed by a *gaito*, Maimono, and after setting free all the Christians and exacting a large sum in money, mules, and horses, completed the conquest of Malta and Gozo. Walter, bishop of Malta, whose name is found as witness to a document of 1090, is believed to have been now appointed by Roger I., and consecrated by the pope. A succession of Christian bishops, endowments and buildings made, tithes granted, &c., testify to the restoration of the church in the islands, while they shared with Sicily the feudal laws and administration newly established under the Norman rule. In 1193 Malta as a county gave a title to Margarito Brundusio, grand-admiral of Sicily, and three successive counts of Malta followed. After the Norman princes had possessed the islands about a century, the kingdom of the Two Sicilies, and the Maltese islands with it, passed in 1194 to the emperor Henry VI., in professed right of his wife Constance, daughter and heiress of Roger II. In 1223 a Maltese named Henry or Arrigo is stated to have been grand-admiral of Sicily (Pirrus, p. 906; Miège, ii. 38). He is probably the same as the distinguished Henry, count of Malta, who with three hundred Maltese youths in 1205 earned the favours of the Genoese by brilliantly taking two forts in Tripoli (Caffarus, *Ann. Genuenses*, in Muratori, t. vi.), and who took part also in the fourth crusade. No traces of the crusades, however, have been found in these islands, although it is probable that their leaders would not neglect the advantages of Maltese ports and sailors.

Henceforward Malta, as a fief of Sicily, followed the fortunes of that country. The Maltese seem to have taken no part in the Sicilian Vespers (1282), but to have held out for Charles of Anjou until Peter of Aragon, crowned king of Sicily, August 1282, won a battle at sea against the French, attacked Notabile and the forts, and thus obtained possession of the islands. For nearly two hundred and fifty years the Spanish house, through fourteen kings of Aragon, bore rule over Sicily and Malta. In 1391 the countship was erected into a marquisate, which lasted two years only. In 1427 a swarm of Moors (18,000) ravaged Malta and Gozo, but were not able to take the city Notabile; yet the people, though afflicted by the plague in 1431—as not unfrequently at other times—were able to sally forth to conquer Gerbi on the coast of Africa in the following year. The king at this time (1432) authorized the demolition of the old castle at Notabile, built three hundred and fifty years before, and gave the ground on which it stood to the town; but the fortifications of the island were strengthened (1466), the chief stronghold in the 15th century being the fortress of St Angelo. The inhabitants, addicted to fighting at sea, were forbidden from 1448 to 1494 to send out armed corsair ships, in order it is said to retain those capable of defence in the islands, the population of which was at the beginning of that period very scant. The Jews were expelled from Malta by the same edict of Ferdinand, in 1492, which turned them out of Spain. By 1514 the population of Malta had doubled; the two islands together contained 22,000 inhabitants (Miège, ii. 81). They frequently attacked the Moors on the mainland, and suffered reprisals themselves as late as 1526. Their last king of the Spanish house, the emperor Charles V., in 1530 granted Malta and Gozo (with the city of Tripoli) as a noble and free fief to the knights of St John of Jerusalem, still retaining, however, the suzerainty, by the homage of a falcon annually to be given by the knights.

Malta thus during many centuries occupied the position of a feudal fief of Sicily; her laws and her church date from the times of the Normans, and both developed as in other feudal governments. The progress of her political independence in the 15th century, especially under Alphonso I. and John I., has been shown by the historian Miège; the history of the relations between Malta and the monarchs of Sicily affords an interesting example of feudal obligations with their attendant difficulties. That these fostered a spirit of liberty and independence in the people, and must have tended largely to the prosperity of the islands, is shown by numerous diplomas of the Aragonese suzerains preserved in the archives at Malta (Eton's *Authentic Materials*, 1803, p. 108 *sq.*), where it is seen that the inhabitants acquired many privileges and were also able to pay on emergency considerable sums of money to increase and preserve their privileges. Thus in 1428, only a century before the knights came, they paid 30,000 florins of gold to King Alphonso in order to secure their tenure by the crown of Sicily without any middle-lords, being the second time they thus bought back their island rights (Eton, p. 84). These things are to be noticed, because, as has been complained, the knights unjustly depreciated the value and advantages of the islands, in order the more readily to obtain the grant from Charles V. Under the kings of Sicily, Notabile was a *università* or commune, with its popular council and jurats, a captain-justiciar representing the rights of the crown; in other words, Malta was a republic governed by its own laws; the principal magistrate was named by the king out of three persons proposed by the *consilio popolare*, and was liable to dismissal on complaint by the people. The king protected the island, and in return the Maltese took a share in his wars. When the knights took possession the Maltese stipulated that each grand master on entering office should take oath to maintain their ancient rights and liberties (Eton, pp. 38, 85, 101). The knights began by deceiving the Maltese candidates for admission into their ranks. Their rule, at first conciliatory, soon became despotic; in time the overshadowing power of a rich military organization encroached upon the constitutional government, corruption brought the officials under the control of the knights, and the people lost their liberties, though the material prosperity of the islands was in many ways heightened.

For the history of the order of St John see St John (Knights of). Twenty-eight successive grand masters, from Lisle d'Adam to Hompesch (1530 to 1798), held the islands. Lisle d'Adam established his convent and hospital in the Borgo, a city that had grown up on the coast near the castle St Angelo, opposite the ancient fort St Elmo. In 1541 was made the first survey for the fortification of Valetta. Ten years later the Turks, led by their famous naval commander Dragut, ravaged Gozo, and made an attempt upon Malta which failed. The knights, already famous for their power at sea, were soon engaged in much skirmishing warfare against the pirates and Turks, winning success and riches, and the gratitude of Christian nations. In 1565, after eight years of threatening preparations, during which the knights had been strengthening and fortifying their island, the Turks besieged them with an immense force; they defended themselves with such valour that it took a month to reduce Fort St Elmo, and in rather over two months more the Turks, whose further advance was successfully resisted, were forced to retire, leaving the knights free to build their new city Valetta and its fortifications. The admiration and gratitude of Catholic countries for this service to Christendom showed itself in liberal donations towards these works; large sums were also raised from the possessions of the order; and Valetta, the first stone of which was laid on 26th March 1566, in four years rose upon the ridge of rock, "a city built by gentlemen for gentlemen," as it has been well described,—the original design of which, the cutting down the rock to a level platform, had only suffered from the continual fear of molestation by the Turks while building.

The order, now firmly established in their island, continued to carry out their mission, that of keeping the Mediterranean clear from Turkish and Moorish pirates, and of protecting Christendom against the infidels. Numerous sea-fights took place during the 16th and 17th centuries, many of them undertaken more to make up for the neglect of some of the grand masters to supply the islands with corn, by seizing upon Turkish stores, than for any better reason. Valetta became in consequence "a vast slave mart." In 1614, under G. M. Vignacourt, an aqueduct was constructed at a cost of £13,000 to bring water to Valetta from springs near Citta Vecchia, a work of immense value, and still in use. But the work of fortifying Malta occupied a large share of money and attention, and was carried on without relaxation by many of the grand masters, down as late as the building of Fort Tigné in 1793. Besides the great lines and forts in and round Valetta, the knights have left their mark all over the islands: they made good roads, improved Citta Vecchia, built watch-towers round the coasts, and erected towers, country palaces, and gardens. They also established and continually carried on, at Notabile and Valetta, their hospitals for the sick and wounded. In 1768 the Jesuits, having given much trouble, were expelled and their property confiscated. Danger from rebellion twice threatened the knights—in 1722, when the slaves were believed to be in communication with the Turks, and from 1773 to 1775, when both people and priests were wrought upon by oppression and misgovernment, which, only mitigated for a time by the better measures of G. M. Rohan, led to the weak and disorganized condition of the order that ended in its overthrow. In June 1798, the possessions of the order in France having already been seized by the republicans, Bonaparte on his way to Egypt landed with a large force in a bay behind Valetta; no resistance was made, and in a few hours the French were in possession of the whole of Gozo and Malta except the town of Valetta and one little fort. In four days more, without bombardment, the order had surrendered Valetta and practically ceased to exist. Bonaparte stayed six days, laying down laws and regulations with a high hand, and collecting plunder from churches, &c. He left Vaubois in charge, but in less than three months the Maltese had revolted from the tyranny of their new masters, and Vaubois inside Valetta with 6000 men sustained a siege and blockade lasting two years, during which time Portuguese, Neapolitans, and a small force of English assisted the Maltese. Sir Alexander Ball commanded in the name of the Sicilian king, and was put at the head of their National Council by the Maltese. On 4th September 1800 Vaubois surrendered, and the Maltese (who lost 20,000 men) put themselves and their islands under the protection of the English,—reunion to the crown of Sicily, which they had sought, being no longer thought of. The treaty of Amiens (1802) provided that the islands should be restored to the order of St John, obviously to the advantage of France, but repugnant to the Maltese. War breaking out again, the islands remained in the hands of England till in 1814 they were secured to her by the treaty of Paris (Art. 7), under which she still holds them.

See Kenrick's *Phœnicia*, 1855; A. A. Caruana's *Reports on Phœnician and Roman Antiquities in Malta*, 1881 and 1882; James Smith, *Voyage and Shipwreck of St Paul*, 1866; R. Pirrus, *Sicilia Sacra*; T. Fazello, *Storia di Sicilia*, 1833; C. de Bazancourt, *Histoire de la Sicile*, 1846; G. F. Abela, *Malta Illustrata*, 1772; J. Quintin, *Insulæ Melitæ descriptio*, 1536; G. W. von Streitburg, *Reyse nach der Insel Malta*, 1632; R. Gregorio, *Considerazioni sopra la Storia di Sicilia*, 1839; F. A. C. Davalos, *Tableau historique de Malte*, 1816; W. Eton, *Authentic Materials for History of Malta*, 1802; Houel, *Voyage Pittoresque*, vol. iv., 1787; G. P. Badger, *Description of Malta and Gozo*, 1858; G. N. Godwin, *Guide to and Natural History of Maltese Islands*, 1880; Whitworth Porter, *History of Knights of Malta*, 1858; A. Bigelow, *Travels in Malta and Sicily*, 1831; M. Miège, *Histoire de Malte*, 1840; *Parliamentary Papers*—reports by Mr Rowsell on "Taxation and Expenditure of Malta," 1878, by Sir P. Julyan on "Civil Establishments," 1880, and Mr Keenan on the "Educational System," 1880 (the last two deal with the question of language); F. Vella, *Maltese Grammar for the use of the English*, 1831; *Malta Penny Magazine*, 1839–41; J. T. Mifsud, *Biblioteca Maltese*, 1764. Brydone, Teonge, John Dryden, jun., W. Tallack, Rev. H. Seddall, Boisgelin, Rev. W. K. R. Bedford, W. H. Bartlett, St Priest, Msgr. Bres, and F. Lacroix have also written on Malta. For natural science, see the works of Dr A. L. Adams, Professor E. Forbes, Captain Spratt, Dr G. Gulia, C. A. Wright, and Wood's *Tourist's Flora*. (L. T. S.)

MALTE-BRUN, Conrad, a distinguished geographer, was born August 12, 1755, at Thysted in Denmark, and died at Paris, December 14, 1826. His real name was Malte Conrad Bruun, and it was not till he settled in France that he became known by the more familiar form. While a student at Copenhagen, he made himself famous partly by his verses, but much more by the violence of his political pamphleteering; and at length, in 1800, the legal actions which the Government authorities had from time to time instituted against him culminated in a sentence of perpetual banishment. The principles which he had advocated were those of the French Revolution, and, though he at first sought asylum in Sweden, before long he found his way to Paris. There he looked forward to a political career; but, when Napoleon's personal ambition began to unfold itself, Malte Brun was bold enough to protest, and to turn elsewhere for employment and advancement. He was associated with Mentelle and Herbin in the compilation of their *Géographie mathématique . . de toutes les parties du Monde* (Paris, 1803–7, 16 vols.), and before many years he was recognized as one of the best geographers of France. He is remembered, not only as the author of six volumes of the learned *Précis de géographie universelle*, continued after his death by other hands, but also as the originator of the *Annales des Voyages* (1808), and the principal founder of the Geographical Society of Paris.

MALTHUS, Thomas Robert (1766–1834), the scientific expounder of the principle of population, was born in 1766 at the Rookery, a small estate owned by his father in the county of Surrey. His father was a gentleman of good family and independent fortune,—a man of considerable culture both in literature and philosophy, the friend and correspondent of Rousseau, and one of his executors, one, too, who showed no little interest in those social problems in which his son was to be an original inquirer. Young Malthus was never sent to a public school, but received his education from private tutors, who were themselves men of some distinction. In 1784 he was sent to Cambridge, where he was ninth wrangler, and became fellow of his own college (Jesus) in 1797. The same year he received orders, and undertook the charge of a small parish in Surrey, still, however, retaining his fellowship. In the following year he published the first edition of his great work, *An Essay on the Principle of Population as it affects the Future Improvement of Society, with remarks on the speculations of Mr Godwin, M. Condorcet, and other writers.* The work excited a good deal of surprise as well as attention; and with characteristic thoroughness and love of truth the author went abroad to collect materials for the verification and more exhaustive treatment of his views. As Britain was then at war with France, only the northern countries of Europe were quite open to his research at that time; but during the brief peace of Amiens Malthus continued his investigations in France and Switzerland. The result of these praiseworthy labours appeared in the greatly enlarged and more mature edition of his work, which was published in 1803. In 1805 Malthus married happily, and not long after was appointed professor of modern history and political economy in the East India Company's College at Haileybury. This situation he retained till his death in 1834. Malthus was one of the most amiable, candid, and cultured of men. In all his private relations he was not only without reproach, but distinguished for the beauty of his character. He bore the popular abuse and misrepresentation without the slightest murmur or sourness of temper. The aim of his inquiries was to promote the happiness of mankind, which could be better accomplished by pointing out the real possibilities of progress than by indulging in vague dreams of perfectibility apart from the actual facts which condition human life.

Malthus's *Essay on Population* grew out of some discussions which he had with his father respecting the perfectibility of society. His father shared the theories on that subject of Condorcet and Godwin; and his son combated them on the ground that the realization of a happy society will always be hindered by the miseries consequent on the tendency of population to increase faster than the means of subsistence. His father was struck by the weight and originality of his views, asked him to put them in writing, and then recommended the publication of the manuscript. It was in this way the *Essay* saw the light. Thus it will be seen that both historically and philosophically the doctrine of Malthus was a corrective reaction against the superficial optimism diffused by the school of Rousseau. It was the same optimism, with its easy methods of regenerating society and its fatal blindness to the real conditions that circumscribe human life, that was responsible for the wild theories of the French Revolution and many of its consequent excesses.

The *Essay on the Principle of Population* will best be considered under two heads :—(1) the principle itself, with the arguments and illustrations by which it is supported; and (2) remarks on its origin and its applications.

I. The principle itself. The idea with which Malthus starts is the improvement of society. In an inquiry concerning the improvement of society there are two things to be done,—(1) to investigate the causes that have hitherto impeded the progress of mankind to happiness, and (2) to examine the probability of the total or partial removal of these causes in future. Waiving the consideration of such an immense field of thought, Malthus restricts himself to the examination of one great cause intimately connected with human nature and its effects on society, which, though operating since the commencement of society, has been little noticed by writers. This cause is the constant tendency in all animated life to increase beyond the nourishment prepared for it. Throughout both the animal and vegetable kingdoms, nature has scattered the seeds of life abroad with the most profuse and liberal hand. Life on this planet is so prolific that, if allowed free room to develop itself, it would fill millions of worlds in the course of a few thousand years. There is only one limit to the indefinite increase, and that is necessity. In plants and irrational animals, which are impelled by blind instinct untroubled by doubts about providing for their offspring, the problem is simple; in their case increase is checked only by want of room and nourishment. As regards man, whose equally powerful instinct is controlled by reason, the question is more complicated. In his case, increase must either be checked by preventive restraint, which too frequently produces vice ; or a constant check, from the difficulty of acquiring food, must be in operation.

That population tends to increase beyond the means of subsistence is obvious in two ways,—(1) from a comparison of the natural increase of population, if left to exert itself with perfect freedom, with the available increase of subsistence under the most favourable conditions, and (2) from a review of the different states of society in which man has existed. Under the first head, Malthus considers it a safe calculation that population, when unchecked, goes on doubling itself every twenty-five years. It has even been calculated that it may double itself in about thirteen years ; that proportion has actually occurred for short periods in more countries than one. Malthus, however, contents himself with the more moderate rate, namely, that population, when unchecked, doubles itself every twenty-five years, or increases in a geometrical ratio. If so, how is the rate of increase of the means of subsistence to be estimated ? If we take a limited area, no improvement in developing the resources of the soil will keep pace with the unchecked increase of population. We may allow that, through the great improvements of agriculture in Great Britain, the average produce of the island could be doubled in the first twenty-five years ; but in the next twenty-five it is impossible to suppose that the produce could be quadrupled. The utmost we can allow is that the produce might be increased every twenty-five years by a quantity equal to what it at present yields. If we apply this supposition to the whole earth, we shall assume an increase much greater than any possible exertions of mankind could effect. On the whole, then, in the present average state of the earth, the means of subsistence could not be made to increase faster than in an arithmetical ratio. With such a disproportion between the ratio of increase of population and of the means of subsistence, population can be kept down to the level of the means of subsistence only by the strong law of necessity operating as a check on the greater power. In fact, the ultimate check to population is the want of food ; but this ultimate check is never the immediate check, except in cases of actual famine. The immediate check consists of all those customs and all those diseases which are generated by a scarcity of food, and all the causes independent of the scarcity which tend to weaken and destroy the human frame. These checks are either preventive or positive ; and the former consist either of moral restraint or of vice, always so pernicious to society. The positive checks are extremely various, including everything that contributes to shorten the natural duration of human life. "Under this head may be enumerated all unwholesome occupations, severe labour and exposure to the seasons, extreme poverty, bad nursing of children, large towns, excesses of all kinds, the whole train of common diseases and epidemics, wars, plague, and famine." The checks of all kinds may be reduced to three heads—moral restraint, vice, and misery. This theoretical exposition of the checks to population Malthus supports and illustrates by an exhaustive examination of the checks which have operated or still operate in the various countries and states of society from the brutal and revolting practices prevalent among the savages of Tierra del Fuego and Australia to the moral self-control of the highest nations. It is not a pleasant picture, but it is merely a presentation of historical and statistical facts for which Malthus is in no way responsible. Throughout his entire exposition he does not theorize, but seeks only to systematize and elucidate facts which cannot be controverted, belonging as they do to the history of the world. The only notable exception is his attempt to express in mathematical language the possible increase of the means of subsistence. The conditions determining such increase are too vague and various to be calculated in such a way. On this point Malthus is not followed by subsequent economists, and it is not essential to his principle. At the same time, in spite of its unsoundness, it does help us to realize the disproportion between the possible increase of population and the means of subsistence.

II. What remains to be said of the *Essay on the Principle of Population* may be embraced in the following notes. (1) Origin of the principle. The population question has always had a great influence on the development of mankind. In the most barbarous nations the problem of preserving the balance between food and population must always have been a pressing one, and has led to some of their cruellest and most immoral customs. The more theoretic consideration of the question has a large place in the political treatises of Plato and Aristotle. Just before Malthus's time it had been touched by such writers as Benjamin Franklin (*Observations concerning the Increase of Mankind*), Hume (*Populousness of the Ancient Nations*), Wallace (*On the Numbers of Mankind in Ancient and Modern Times*), Townshend (*Travels in Spain*), not to mention many other modern writers of less recent date. (2) The remedy for over-population usually proposed is emigration. No doubt there are immense fertile areas yet unpeopled. But the difficulty of transferring the surplus population, and especially of conveying surplus capital to these regions, and of co-ordinating the two, is a point that must not be overlooked. In spite of the great development of steam as a means of emigration, it remains a fact that population tends to excess in many of the most important centres of the world. Besides, emigration is only a postponing of the difficulty. In another century even the Mississippi valley will be well stocked. (3) Relation of Malthus to Darwin. In his book *Animals and Plants under Domestication*, vol. i. p. 10, Darwin expressly acknowledges his indebtedness to Malthus in thinking out his cardinal principle of natural selection. After the study of domestic productions had given him a just idea of the power of selection, he saw, "on reading Malthus *On Population*, that natural selection was the inevitable result of the rapid increase of all organic beings." (4) Poor-law reform. The reformed poor law of 1834 was a real triumph of Malthus's teaching. The effect of the old poor law was to encourage population by relieving the labouring classes of the due responsibility of supporting themselves and their families. By discouraging foresight, self-control, and the spirit of self-reliant independence, it demoralized the working man. The great aim of the new poor law was to emphasize the duty of self-support and the responsibilities of parentage. (5) Relation to modern politics. Some of the greatest difficulties in contemporary politics can be correctly understood only in the light of the principle of population. The most striking example of this is India, where, under the good government of England, the old and unhappy checks to population, such as war, famine, pestilence, and religious self-immolation, have been removed. As there has been no proportionate improvement in agriculture, and in the ethical development of the people, population has increased beyond the means of subsistence, and there prevails a tendency to chronic poverty, a very low standard of living, a general misery, and an unsatisfactory social *morale*, which correspond badly with the high European civilization under which such a state of things is maintained. (6) It is only due to the memory of a good man, who was a sincere lover of truth and of the progress of humanity, that we should emphasize the fact that Malthus is in no way responsible for the immoral theories popularly connected with his name. Apart from such increase in the means of subsistence as may be attained by emigration and improved agriculture, Malthus approved of only one method of solving the population question, namely, moral self-restraint. His single precept is "Do not marry till you have a fair prospect of supporting a family." The greatest and highest moral result of his principle is that it clearly and emphatically teaches the responsibility of parentage, and declares the sin of those who bring human beings into the world for whose physical, intellectual, and moral wellbeing no satisfactory provision is made.

Besides his great work, Malthus wrote *Observations on the Effect of the Corn Laws*; *An Inquiry into the Nature and Progress of Rent*; *Principles of Political Economy*; and *Definitions in Political Economy*. His views on rent were of real importance. For his life see *Memoir* by his friend Dr Otter, bishop of Chichester (prefixed to 2d edition, 1836, of the *Principles of Political Economy*). (T. K.)

MALTON, a parliamentary borough of Yorkshire, England, which includes Old Malton and New Malton in the North Riding, and the parish of Norton in the East Riding. New Malton is situated on an eminence on the right bank of the Derwent, 22 miles north-east of York and 213 north of London. Old Malton lies about a mile to the north-east, and a bridge across the river connects New Malton with Norton. New Malton, which is a market-town, consists of several well-built streets radiating from the market-place. The church of St Michael is a fine building in the Late Norman style; the church of St Leonard, of mixed architecture, with square tower and spire, has three Norman arches and a Norman font; the west doorway of the church of St Mary at Old Malton is one of the finest specimens of Norman in England. In Old Malton there is a grammar school founded in 1547, and also the remains of a priory of Gilbertine canons, founded in 1150. New Malton possesses a town-hall and a corn exchange. The town has some shipping trade, and also iron and brass foundries, agricultural implement works, corn mills, tanneries, and breweries. In the neighbourhood there are lime and whinstone quarries. The population of the parliamentary borough (area 6855 acres) in 1871 was 8168, and in 1881 it was 8750.

Malton was a Roman station, and various Roman remains have been found in the neighbourhood. The old castle, built by the De Vescis in the time of the Normans, was demolished by Henry II. In the reign of Stephen the town, while occupied by the Scots, was burned down by Thurston, archbishop of York, and on being rebuilt it was named New Malton. The borough sent members to parliament as early as the reign of Edward I., but for some years previous to 1640 the privilege was in abeyance. Since 1868 only one member has been returned.

MALTZAN, Heinrich K. E. H. Freiherr [Baron] von (1826–1874), African and Oriental traveller, was born in the vicinity of Dresden, and studied law at Jena, but on account of ill-health spent much of his time from 1850 in travel. Succeeding to his father's property in 1852, he extended the range of his journeys to Morocco and other parts of the Maghrib, and before his return home in 1854 had also visited Egypt, Palestine, and other countries of the Levant. In 1856–57 he was again in Algeria; in 1858 he reached the city of Morocco; and in 1860 he succeeded in performing the pilgrimage to Mecca, which he afterwards described in his book *Meine Wallfahrt nach Mecca*, but had to flee for his life to Jeddah without visiting Medina. He then visited Aden and Bombay, and after some two years of study in Europe again began to wander through the coasts and islands of the Mediterranean, repeatedly visiting Algeria. His first book of travel, *Three Years in the North-West of Africa*, appeared in 1863, and was followed by a variety of works and essays, popular and scientific, till a little before his death at Pisa in 1874, when he put an end with his own hand to neuralgic pains which had tortured him for years.

Maltzan's last book, *Reise in Arabien* (1873), is one of his most useful contributions. It contains, like his other works, some lively description, but is chiefly valuable as a digest of much information about little-known parts of South Arabia collected from natives during a residence at Aden in 1870–71. Among his other services to science must be noticed his collection of Punic inscriptions (*Reise in Tunis und Tripolis*, 3 vols., Leipsic, 1870), various collections on Arabic dialects (*Z. D. M. G.*, various dates), and the editing of Von Wrede's remarkable journey in Ḥadramaut (1873).

MALUS, Étienne Louis (1775–1812), the discoverer of the laws of the polarization of light by reflexion, born at Paris on the 23d of June 1775, was the son of Anne Louis Malus du Mitry, and of Louisa Charlotte Desboves, his wife. His father, who had a place in the treasury of France, gave him at home an excellent education in mathematics and in the fine arts, as well as in classical literature, and he then studied with distinction in the school of military engineers; but, being regarded as a suspected person, probably on account of the situation held by his father, he was dismissed from the school without receiving a commission, and obliged to enter the army as a private soldier. Being employed upon the fortifications of Dunkirk, he was soon distinguished by M. Lepère, the director of the works, as superior to his accidental situation, and was selected as a member of the École Polytechnique then to be established under Monge, who immediately chose him as one of the twenty who were to be instructors of the rest. In this institution, which at that moment was the only refuge of the sciences in France, he passed three years, giving special attention to the mathematical theory of optics. From the École he was admitted into the corps of engineers, and served in the army of the Sambre and Meuse; he was present at the passage of the Rhine in 1797, and at the affairs of Ukratz and Altenkirch. In Germany he fell in love with the daughter of Koch, the chancellor of the university of Giessen; and he was on the point of marrying her when he was obliged to join the Egyptian expedition. He remained in the East, and saw much service till the capitulation with the English, when he returned to France (October 1801), and hastened to Germany to fulfil his engagement. His fidelity was rewarded, during the eleven years that he survived, by the most constant and affectionate attention on the part of his wife.

Though his health was much broken by the eastern campaign, Malus was still able to combine the pursuit of his favourite sciences with his official duties in superintending the construction of works at Antwerp and at Strasburg; and upon occasion of a prize question proposed by the Institute he undertook the investigation of the extraordinary refraction of Iceland crystal, which the experiments of Dr Wollaston had previously shown to agree very accurately with the laws laid down by Huygens; and, besides completely confirming all Wollaston's results, he had the good fortune greatly to extend the Huygenian discovery of the peculiar modification of light produced by the action of such crystals, which Newton had distinguished by the name "polarity," and which Malus now found to be produced in a variety of circumstances, independently of the action of crystallized bodies. It seems natural to suppose that the investigation of the laws of the internal reflexion of light at the second surface of the crystals must have led him to the discovery of the effects of oblique reflexion in other circumstances; but, according to Biot, Malus's first observation of polarization by reflexion was due to the accident that he chanced to look through a quartz crystal at the image of the sun reflected from the windows of the Luxembourg. The value of his discovery was acknowledged by his election as a member of the Institute, by the award of the Rumford medal of the Royal Society of London, and by military promotion. Malus died on the 24th of February 1812, universally regretted by the lovers of science in all countries, and deeply lamented by his colleagues, who said of him, as Newton did of Cotes, that if his life had been prolonged we should at last "have known something" of the laws of nature.

Malus's first publication appears to have been a paper "On an unknown Branch of the Nile," in the first volume of the *Décade Égyptienne*. A mathematical "Traité d'Optique," presented to the Institute before the completion of his experiments on double refraction, was published in the *Mémoires pr. à l'Institut*, vol. ii., Paris, 1810. His more important discoveries were first made known in the second volume of the *Mémoires d'Arcueil*, Paris, 1809, 8vo; and again, in the "Theory of Double Refraction," *Mém. pr. à l'Inst.*, vol. ii., a paper which obtained a prize on the 2d of January 1810. See Delambre, *M. Inst.*, 1816, p. xxvii.; Biot, in *Biographie Universelle*, xxvi., Paris 1820.

MALVASIA (from the Greek *Monembasia*, *i.e.*, the city of the single approach or entrance; the Italian *Napoli di Malvasia*, the Turkish *Mengeshe* or *Beneshe*), one of the principal fortresses and commercial centres of the Levant during the Middle Ages, still represented by a considerable mass of ruins and a town of about 1000 inhabitants, stood on the east coast of the Morea, contiguous to the site of the ancient Epidaurus Limera, of which it took the place. So extensive was its trade in wine that the name of the place became familiar throughout Europe as the distinctive appellation of a special kind—the Italian *Malvasia*, Spanish *Malvagia*, French *Malvoisie*, English *Malvesie* or *Malmsey*. The wine was not of local growth, but came for the most part from Tenos and others of the Cyclades.

As a fortress Malvasia played an important part in the struggles between Byzantium, Venice, and Turkey. The Byzantine emperors considered it one of their most valuable posts in the Morea, and rewarded its inhabitants for their fidelity by unusual privileges. Phrantzes (lib. iv. cap. xvi.) tells how Mauricius Tiberius made the city (previously dependent in ecclesiastical matters on Corinth) a metropolis or archbishop's see, and how Alexius Comnenus, and more especially Andronicus Palæologus, gave the Monembasiotes freedom from all sorts of exactions throughout the empire. In 1147 Malvasia bade defiance to the Normans, and in 1205 obliged Villehardouin, after a four years' siege, to swear to preserve its liberties and privileges (Fallmerayer, i. pp. 408-409). It was defended against the Turks by Manuel Palæologus in 1460. In 1689 it was the only town of the Morea which held out against Morosini, and Cornaro his successor only succeeded in reducing it by famine. In 1715 it capitulated to the Turks, and on the failure of the insurrection of 1770 the leading families were scattered abroad. As the first fortress which fell into the hands of the Greeks in 1821, it became in the following year the seat of the first national assembly.

See Curtius, *Peloponnesos*, ii. pp 293 and 328; Castellan, *Lettres sur la Morée* (1808) for a plan; and Valiero, *Hist. della guerra di Candia* (Venice, 1679) for details as to the fortress.

MALVERN, GREAT, a watering-place of Worcestershire, England, beautifully situated on the eastern slope of the Malvern hills, 8 miles south-west by south of Worcester, and 120 north-west by west of London. The town is irregularly built, but there are many villas, and on account of its fine situation in the centre of the Chase of Malvern, its pure air, and its chalybeate and bituminous springs, it is much frequented by summer visitors. At Malvern a hermitage was endowed by Edward the Confessor, which after the Conquest was changed into a Benedictine priory. Of the buildings, which date from 1083, there still remain the abbey gate, and also the church (partly rebuilt in the reign of Henry VII., and restored since 1861), a very fine structure, Norman and Perpendicular, with square embattled tower. There is a proprietary college, founded in 1863. At Little Malvern, about 3 miles south of Great Malvern, there was a Benedictine priory, founded in 1171, upon the site of which the dwelling-house of Malvern Court has been erected, preserving the tower and chancel of the old priory church. At Malvern Wells, 2 miles south of Malvern, is the celebrated "Holy Well," the water of which is of perfect purity. The population of Malvern in 1871 was 5693, and in 1881 it was 5847.

MÁLWÁ, an historical province of Central India, roughly coextensive with the western portion of the Central India agency, is bounded on the N. by Hindustan Proper, on the E. by Bundelkhand, on the S. by the Deccan, and on the W. by Rájputána. It consists of an upland region, with many fertile valleys, included within the main rivers of the Ganges, the Són, the Chambal, and the Nerbudda. In prehistoric times the capital was the ancient city of Ujain (Oojein), associated in Hindu legend with the great king Vikramáditya, the date of whose accession (57 B.C.) has given the "Samvat" era to all India. The Mohammedan chronicler Ferishta describes Málwá as the kingdom of an independent rájá, when Mahmúd of Ghazní invaded India in the beginning of the 11th century. It appears to have first fallen into the hands of the Moslems about 1309, during the reign of the Delhi emperor Alá-ud-dín. When the Tughlak dynasty was weakened by the repeated attacks of the Mughals, their viceroy in Málwá succeeded in establishing his independence. The first Moslem king of Málwá was Diláwar Khán Ghori, of Afghán origin, who ruled from 1387 to 1405, and placed his capital at Mandu. He was succeeded by his son Hoshang Ghori, to whom are attributed most of the magnificent ruins still to be seen at Mandu. In 1526 the Ghori dynasty came to an end, being overthrown by Bahádur Sháh of Guzerát; and in 1570 Málwá was, on the conquest of Guzerát by the emperor Akbar, incorporated in the Mughal dominions. On the decay of the Delhi empire in the 18th century, Málwá was one of the first provinces to be overrun by the Mahrattas. In 1737 the peshwá exacted *chauth* or one-fourth of the revenue, and at a later date the two great military chiefs Sindhia and Holkar carved out for themselves kingdoms, which their descendants still retain. But the Mahrattas set up no organized government, so that Málwá, besides its native population of predatory Bhíls, became the refuge of all the mercenary bandits of the peninsula. In the beginning of the present century, the depredations of these bandits or Pindárís led to what is sometimes known as the fourth Mahratta war of 1817, under the governor-generalship of Lord Hastings. As the result, the Pindárís were extirpated; and under the rule of Sir John Malcolm the Bhíls were tamed, and the jungles were cleared of wild beasts. Many of the Bhíls have been enlisted as British soldiers; and the headquarters of the Málwá Bhíl corps is at Sardárpur. At the present day Málwá is best known as giving its name to the opium which is annually exported from Bombay to the amount of about 37,000 chests.

MAMELUKE, a corruption of the Arabic *Mamlûk* (*Memlook*), a slave. The name of Mamelukes has passed into history from the body-guard of Turkish slaves first formed in Egypt under the successors of Saladin, who ultimately usurped the supreme power. For the history of the Mameluke sultans and Mameluke beys, see EGYPT, vol. vii. p. 755 *sq.*

MAMMALIA

MAMMALIA (French, *Mammifères*; German, *Säugethiere*) is the name invented by Linnæus (from the Latin, *mamma*), and now commonly used by zoologists, for one of the classes of vertebrated animals, which, though the best known and undoubtedly the most important group of the animal kingdom, has never received any generally accepted vernacular designation in our language. The unity of structure of the animals composing this class, and their definite demarcation from other vertebrates, were not recognized until comparatively modern times, and hence no word was thought of to designate what zoologists now term a mammal. The nearest equivalents in common use are "beast" and "quadruped," both of which, however, cover a different ground, as they are often used to include the larger four-footed reptiles, and to exclude certain undoubted mammals, as Man, Bats, and Whales.

The limits of the class as now understood by zoologists are perfectly well defined, and, although certain forms still existing on the earth (though not those mentioned above as excluded by the popular idea) are of exceedingly aberrant structure, exhibiting several well-marked characters which connect them with the lower vertebrated groups, common consent retains them in the class with which the great proportion of their characters ally them, and hitherto no traces of any species showing still more divergent or transitional characters have been discovered. There is thus a great interval, not bridged over by any known forms, recent or extinct, between mammals and other vertebrates.

In the gradual order of evolution of living beings, mammals taken altogether are certainly the highest in organization, as they were probably the last to appear on the earth's surface, though this must be said with some reservation, pending further knowledge of the early history of the class of birds. But, as in speaking of all other large and greatly differentiated groups, this expression must not be understood in too limited a sense. The tendency to gradual perfection for their particular station in life, which all groups manifest, leads to various lines of specialization, or divergence from the common or general type, which may or may not take the direction of elevation. A too complex and sensitive condition of organization may in some circumstances of life be disadvantageous, and modification may then take place in a retrograde direction. In mammals, as in other classes, there are low forms as well as high forms, but by any tests that can be applied, especially those based on the state of development of the central nervous system, it will be seen that the average exceeds the average of any other class, that many species of this class far excel those of any other in perfection of structure, and that it contains one form which is unquestionably the culminating point yet arrived at amongst organized beings.

With regard to the time of the first appearance of mammals upon the earth, the geological record is provokingly imperfect. At the commencement of the Tertiary period they were abundant, and already modified into most of the leading types at present existing. It was at one time thought that they first came into being at this date, but the discovery of fragments of numerous small species has revealed the existence of some forms of the class at various periods throughout almost the whole of the age of the deposition of the Secondary rocks. This subject will be reverted to later on.

It hardly need be said that mammals are vertebrated animals, and possess all the characteristics common to the members of that division of the animal kingdom. They are separated from the *Ichthyopsida* (fishes and amphibia) and agree with the *Sauropsida* (reptiles and birds) in the possession during their development of an amnion and allantois, and in never having external branchiæ or gills. They differ from reptiles and resemble birds in being warm-blooded, and having a heart with four cavities and a complete double circulation. They differ from both birds and reptiles in the red corpuscles of the blood being nucleated and, with very few exceptions, circular in outline; in the lungs being freely suspended in a thoracic cavity, separated from the abdomen by a complete muscular partition, the diaphragm, which is the principal agent in inflating the lungs in respiration; in having but one aortic arch, which curves over the left bronchus; in the skin being more or less clothed with hair, and never with feathers; in the greater perfection of the commissural system of the cerebral hemispheres, which has either a complete corpus callosum, or an incomplete one associated with a very large anterior commissure; in having no syrinx or inferior vocal organ, but a complete larynx at the upper end of the trachea; in having a mandible of which each ramus (except in very early developmental conditions) consists of a single bone on each side, articulating to the squamosal, without the intervention of a quadrate bone; in having a pair of laterally placed occipital condyles instead of one median one; and in the very obvious character of the female being provided with mammary glands, by the secretion of which the young (produced alive and not by means of externally hatched eggs) are nourished for some time after birth.

In common with all vertebrated animals, mammals have never more than two pairs of limbs. In the great majority of the class both are well-developed and functional, and adapted for terrestrial progression, as the larger number of mammals live ordinarily on the surface of the earth. They are, however, by no means limited to this situation. Some species spend the greater part of their lives beneath the surface, their fore limbs being specially modified for burrowing; others are habitually arboreal, their limbs being fitted for climbing or hanging to boughs of trees; some are as aerial as birds, the fore limbs being developed into wings of a special character; others are as aquatic as fishes, the limbs assuming the form of fins or paddles. In many of the latter the hinder extremities are either completely suppressed, or present only in a rudimentary state. In no known mammal are the fore limbs absent.

The hinder extremity of the axis of the body is usually prolonged into a tail, which may be a mere pendent appendage, or modified to perform various functions, as grasping boughs in climbing, or even gathering food, in the case of the prehensile-tailed Monkeys and Opossums, swimming in the *Cetacea*, and acting as a flap to drive away troublesome insects from the skin in the *Ungulata*.

GENERAL ANATOMICAL CHARACTERS OF THE MAMMALIA.

Tegumentary Structures.

The external surface of the greater number of members of the class is thickly clothed with a peculiarly modified form of epidermis, commonly called hair. This consists of hard, elongated, slender, cylindrical or tapering, filiform, unbranched masses of epidermic material, growing from a short papilla sunk at the bottom of a follicle in the derm or true skin. Such hairs upon different parts of the same Hair.

animal, or upon different animals, assume various forms, and are of various sizes and degrees of rigidity,—as seen in the delicate soft velvety fur of the Mole, the stiff bristles of the Pig, and the spines of the Hedgehog and Porcupine, all modifications of the same structures. These differences arise mainly from the different arrangement of the constituent elements into which the epithelial cells are modified. Each hair is composed usually of a cellular pithy internal portion, containing much air, and a denser or more horny cortical part. In some animals, as Deer, the substance of the hair is almost entirely composed of the medullary or cellular substance, and it is consequently very easily broken; in others the horny part prevails almost exclusively, as in the bristles of the Wild Boar. In the Three-toed Sloth (*Bradypus*) the hairs have a central horny axis and a pithy exterior. Though generally nearly smooth, or but slightly scaly, the surface of some hairs is strongly imbricated, notably so in some Bats, while in the Two-toed Sloth (*Cholœpus*) they are longitudinally grooved or fluted. Though usually more or less cylindrical or circular in section, they are often elliptical or flattened, as in the curly-haired races of men, the terminal portion of the hair of Moles and Shrews, and conspicuously in the spines of the Rodents *Xerus* and *Platacanthomys*. Hair having a property of mutual cohesion or "felting," which depends upon a roughened scaly surface and a tendency to curl, as in domestic Sheep (in which animals this property has been especially cultivated by selective breeding), is called "wool."

In a large number of mammals hairs of one kind only are scattered pretty evenly over the surface, but in many there are two kinds, one longer, stiffer, and alone appearing on the surface, and the other shorter, finer, and softer, constituting the under fur, analogous to the down of birds. In most cases hairs of a different character from those of the general surface grow in special regions, forming ridges or tufts on the median dorsal or ventral surface or elsewhere. The tail is very often completed in this way by variously disposed elongated hairs. The margins of the eyelids are almost always furnished with a special row of stiffish hairs, called *ciliæ* or eyelashes, and in most mammals specially modified hairs, constituting the *vibrissæ* or whiskers, endowed, through the abundant nerve supply of their basal papillæ, with special tactile powers, grow from the lips and cheeks. In some mammals the hairy covering is partial and limited to particular regions; in others, as the Hippopotamus and the *Sirenia*, though scattered over the whole surface, it is extremely short and scanty; but in none is it reduced to so great an extent as in the *Cetacea*, in which it is limited to a few small bristles confined to the neighbourhood of the lips and nostrils, and often only present in the young or even fœtal condition.

Some kinds of hairs, as those of the mane and tail of the Horse, appear to persist throughout the life-time of the animal; but more generally, as in the case of the body hair of the same animal, they are shed and renewed periodically, generally annually. Many mammals have a longer hairy coat in winter, which is shed as summer comes on; and some few, which inhabit countries covered in winter with snow, as the Arctic Fox, Variable Hare, and Ermine, undergo a complete change of colour in the two seasons, being white in winter, and grey or brown in summer. The several species of Cape Mole (*Chrysochloris*), the Desmans or Water Moles (*Myogale*), and *Potamogale velox* are remarkable as being the only mammals whose hair reflects those iridescent tints so common in the feathers of tropical birds.

The principal and most obvious purpose of the hairy covering is to protect the skin against external influences, especially cold and damp. Its function in the hairless *Cetacea* is supplied by the specially modified and thickened layer of adipose tissue beneath the skin called "blubber."

Scales, &c.

True scales, or flat imbricated plates of horny material, covering the greater part of the body, so frequently occurring in reptiles, are found in one family only of mammals, the *Manidæ* or Pangolins; but these are also associated with hairs growing from the intervals between the scales or on the parts of the skin not covered by them. Similarly imbricated epidermic productions form the covering of the under surface of the tail of the flying Rodents of the genus *Anomalurus*; and flat scutes, with the edges in apposition, and not overlaid, clothe both surfaces of the tail of the Beaver, Rats, and others of the same order, and also of some Insectivores and Marsupials. The Armadillos alone have an ossified exoskeleton, composed of plates of true bony tissue, developed in the derm or corium, and covered with scutes of horny epidermis. Other epidermic appendages are the horns of Ruminants and Rhinoceroses,—the former being elongated, tapering, hollow caps of hardened epidermis of fibrillated structure, fitting on and growing from conical projections of the frontal bone, and always arranged in pairs, while the latter are of similar structure, but without any internal bony support, and situated in the median line. Callosities, or bare patches covered with hardened and thickened epidermis, are found over the ischial tuberosities of many apes, the sternum of camels, on the inner side of the limbs of the *Equidæ*, the grasping under surface of the tail of prehensile-tailed monkeys, &c. The greater part of the skin of both species of one-horned Asiatic Rhinoceros is immensely thickened and stiffened by increase of the tissue both of the derm and epiderm, constituting the well known jointed "armour-plated" hide of those animals.

Nails, claws, hoofs.

With very few exceptions, the terminal extremities of the digits of both limbs are more or less protected or armed by epidermic plates or sheaths, constituting the various forms of nails, claws, or hoofs. These are wanting in the *Cetacea* alone. A perforated spur, with a special secreting gland in connexion with it, is found attached to the hind leg of the males of the two species of *Monotremata*, the *Ornithorhynchus* and *Echidna*.

Odour-secreting glands.

Besides the universally distributed sebaceous glands connected with the pilose system, most mammals have special glands situated in modified portions of the integument, often involuted to form a shallow recess or a deep sac with a narrow opening, situated in various parts of the surface of the body, and which secrete odorous substances, by the aid of which individuals appear to recognize one another, and which probably afford the principal means by which wild animals are able to become aware of the presence of other members of the species, even at great distances. Although the commencement of the modifications of portions of the external covering for the formation of special secretions may be at present difficult to understand, the principle of natural selection will readily explain how such organs can become fixed and gradually increase in development in any species, especially as there would probably be a corresponding modification and increased sensibility of the olfactory organs. Such individuals as by the intensity and peculiarity of their scent had greater power of attracting the opposite sex would certainly be those most likely to leave descendants to inherit and in their turn propagate the modification.

To this group of structures belong the suborbital gland or "crumen" of Antelopes and Deer, the frontal gland of the Muntjak and of Bats of the genus *Phyllorhina*, the submental gland of the Chevrotains and of *Taphozous* and some other Bats, the post-auditory follicle of the Chamois, the temporal gland of the Elephant, the lateral glands of the Musk-Shrew, the lumbar gland of the Peccary, the inguinal glands of Antelopes, the preputial glands of the Musk Deer and Beaver (both so well known for the use made of their powerfully odorous secretion in medicine and perfumery) and also of the Swine and Hare, the anal glands of *Carnivora*, the perineal gland of the Civet (also of commercial value), the caudal glands of the Fox and Goat, the gland on the humeral membrane of Bats of the genus *Saccopteryx*, the post-digital gland of the Rhinoceros, the inter-digital glands of the Sheep and many Ruminants, and numerous others. In some of these cases the glands are peculiar to, or more largely developed in, the male; in others they are found equally developed in both sexes.

Dental System.

The dental system of mammals may be considered rather more in detail than space permits for some other portions of their structure, both on account of the important part it plays in the economy of the animals of this class, and of its interest to zoologists as an aid in classification and identification of species. Owing to the imperishable nature of their tissues, teeth are preserved for an indefinite time, and in the case of extinct species often offer the only indications available from which to derive an idea of the characters, affinities, and habits of the animal to which they have belonged. Hence even their smallest modifications have received great attention from comparative anatomists, and they have formed the subject of many special monographs.[1]

Teeth are present in nearly all mammals, and are applied to various purposes. They are, however, mainly subservient to the function of alimentation, being used either in procuring food by seizing and killing living prey or gathering and biting off portions of vegetable material, and more indirectly in tearing or cutting through the hard protective coverings of food substances, as the husks and shells of nuts, or in pounding, crushing, or otherwise mechanically dividing the solid materials before swallowing, so as to prepare them for digestion in the stomach. Certain teeth are also in many animals most efficient weapons of offence and defence, and for this purpose alone, quite irrespective of subserviency to the digestive process, are they developed in the male sex of many herbivorous animals, in the females of which they are absent or rudimentary.

Teeth belong essentially to the tegumentary or dermal system of organs, and, as is well seen in the lower vertebrates, pass by almost insensible gradations into the hardened spines and scutes formed upon the integument covering the outer surface of the body, but in mammals they are more specialized in structure and limited in locality. In this class they are developed only in the gums or fibro-mucous membrane covering the alveolar borders of the upper and lower jaw or the premaxillary and maxillary bones and the mandible. In the process of development, for the purpose of giving them that support which is needful for the performance of their functions, they almost always become implanted in the bone,—the osseous tissue growing up and moulding itself around the lengthening root of the tooth, so that ultimately they become apparently parts of the skeleton. In no mammal, however, does ankylosis or bony union between the tooth and jaw normally take place, as in many fishes and reptiles,—a vascular layer of connective tissue, the alveolo-dental membrane, always intervening.[2]

[1] L. F. E. Rousseau, *Anatomie comparée du Système Dentaire chez l'Homme et chez les principaux Animaux*, 2d ed. 1839; F. Cuvier, *Des Dents des Mammifères considérées comme caractères zoologiques*, 1822–25; R. Owen, *Odontography*, 1840–45; C. G. Giebel, *Odontographie*, 1855; C. S. Tomes, *Manual of Dental Anatomy, Human and Comparative*, 2d ed., 1882.

[2] The lower incisors of some species of Shrews are, however, said to become ankylosed to the jaw in adult age.

The presence of two or more roots, frequently met with in mammals, implanted into corresponding distinct sockets of the jaw, is peculiar to animals of this class.

Structure of teeth. The greater number of mammalian teeth when fully formed are not simple and homogeneous in structure, but are composed of several distinct tissues.

Pulp. 1. The *pulp*, a soft substance, consisting of a very delicate gelatinous connective tissue, in which numerous cells are imbedded, and abundantly supplied with blood-vessels and nerves, constitutes the central axis of all the basal part of the tooth, and affords the means by which the vitality of the whole is preserved. The nerves which pass into the pulp and endow the tooth with sensibility are branches of the fifth pair of cranial nerves. The pulp occupies a larger relative space, and performs a more important purpose in the young growing tooth than afterwards, as by the calcification and conversion of its outer layers the principal hard constituent of the tooth, the dentine, is formed. In teeth which have ceased to grow the pulp occupies a comparatively small space, which in the dried tooth is called the pulp cavity. This communicates with the external surface of the tooth by a small aperture at the apex of the root, through which the branches of blood-vessels and nerves, by which the tooth receives its nutrition and sensitiveness, pass in to be distributed in the pulp. In growing teeth the pulp cavity is widely open below, while in advanced age it often becomes obliterated, and the pulp itself entirely converted into bone-like material.

Dentine. 2. The *dentine* or *ivory* forms the principal constituent of the greater number of teeth. When developed in its most characteristic form, it is a very hard but elastic substance, white, with a yellowish tinge, and slightly translucent. It consists of an organic matrix, something like but not identical with that of bone, richly impregnated with calcareous salts (chiefly phosphate of lime), these constituting in a fresh human tooth 72 per cent. of its weight. When subjected to microscopical examination it is seen to be everywhere permeated by nearly parallel branching tubes which run, in a slightly curving or wavy manner, in a general direction from the centre towards the free surface of the tooth. These tubes communicate by open mouths with the pulp cavity, and terminate usually near the periphery of the dentine, by closed ends or loops, though in Marsupials and certain other mammals they penetrate into the enamel. They are occupied in the living tooth by soft gelatinous fibrils connected with the cells of the pulp. A variety of dentine, permeated by canals containing blood-vessels, met with commonly in fishes and in some few mammals, as the Megatherium, is called vaso-dentine. Other modifications of this tissue occasionally met with are called osteo-dentine and secondary dentine,—the latter being a dentine of irregular structure which often fills up the pulp cavity of old animals.

Enamel. 3. The *enamel* constitutes a thin investing layer, complete or partial, of the outer or exposed and working surface of the dentine of the crown of the teeth of most mammals. This is the hardest tissue met with in the animal body, containing from 95 to 97 per cent. of mineral substances (chiefly phosphate and some carbonate of lime, with traces of fluoride of calcium). Its ultimate structure consists of prismatic fibres, placed generally with their long axes at right angles to the free surface of the tooth. Enamel is easily distinguished from dentine with the naked eye, by its clear, bluish-white, translucent appearance.

Cementum. 4. The *cementum* or *crusta petrosa* is always the most externally placed of the hard tissues of which teeth are composed, as will be understood when the mode of development of these organs is considered. It is often only found as a thin layer upon the surface of the root, but sometimes, as in the complex-crowned molar teeth of the Horse and

Elephant, it is a structure which plays a very important part, covering and filling in the interstices between the folds of the enamel. In appearance, histological structure, and chemical composition it is closely allied to osseous tissue, containing lacunæ and canaliculi, though only when it is of considerable thickness are Haversian canals present in it.

Development.

Development of the Teeth.—The two principal constituents of the teeth, the dentine and the enamel, are developed from the two layers of the buccal mucous membrane, the dentine from the submucous, the enamel from the epithelial layer. The latter dips down into the substance of the gum, and forms the enamel organ or germ, the first rudiment of the future tooth, which is constantly present even in those animals in which the enamel is not found as a constituent of the perfectly-formed tooth. Below the mass of epithelial cells thus embedded in the substance of the gum, and remaining connected by a narrow neck of similar structure with the epithelium of the surface, a portion of the vascular submucous areolar tissue becomes gradually separated and defined from that which surrounds it, and assumes a distinct form, which is that of the crown of the future tooth,—a single cone in the case of simple teeth, or with two or more eminences in the complex forms. This is called the dental papilla or dentine germ, and by the gradual conversion of its tissue into dentine the bulk of the future tooth is formed, the uncalcified central portion remaining as the pulp. The conversion of the papilla into hard tissue commences at the outer surface of the apex, and gradually proceeds downwards and inwards, so that the form of the papilla exactly determines the form of the future dentine, and no alteration either in shape or size of this portion of the tooth, when once calcified, can take place by addition to its outer surface. In the meanwhile calcification of portion of the cells of the enamel organ, which adapts itself like a cap round the top of the dentinal papilla, and has assumed a somewhat complex structure, results in the formation of the enamel coating of the crown of the tooth. While these changes are taking place the tissues immediately surrounding the tooth germ become condensed and differentiated into a capsule, which appears to grow up from the base of the dental papilla, and encloses both this and the enamel germ, constituting the follicle or tooth sac. By the ossification of the inner layer of this follicle, the cementum is formed. This substance therefore, unlike the dentine, increases from within outwards, and its growth may therefore be the cause of considerable modification of form and enlargement, especially of the roots, of certain teeth, as those of Seals and some *Cetacea*. The delicate homogeneous layer which coats the enamel surface of newly-formed teeth, in which cementum is not found in the adult state, and known as Nasmyth's membrane, is considered by Tomes as probably a film of this substance, too thin to exhibit its characteristic structure, though by others it is believed to be derived from the external layer of the enamel organ. The homology of the teeth with the dermal appendages, hairs, scales, and claws has already been alluded to, and it will now be seen that in both cases two of the primary embryonic layers are concerned in their development, the mesoblast and epiblast, although in very different proportions. In the hair or nail the part derived from the epiblast forms the principal bulk of the organ, the mesoblast only constituting the papilla or matrix. In the tooth the epiblastic portion is limited to the enamel, always of relatively small bulk and often absent, while the dentine (the principal constituent of the tooth) and the cementum are formed from the mesoblast.

When more than one set of teeth occur in mammals, those of the second set are developed in a precisely similar manner to the first, but the enamel germ, instead of being derived directly from an independent part of the oral epithelium, is formed from a budding out of the neck of the germ of the tooth succeeded. In the case of the true molars which have no predecessors, the germ of the first has an independent origin, but that of the others is derived from the neck of the germ of the tooth preceding it in the series. The foundations of the permanent teeth are thus laid as it were almost simultaneously with those of their predecessors, although they remain in many cases for years before they are developed into functional activity.

Although the commencement of the formation of teeth takes place at an early period of embryonic life, they are in nearly all mammals still concealed beneath the gum at the time of birth. The period of eruption, or "cutting" of the teeth as it is called, that is, their piercing through and rising above the surface of the mucous membrane, varies much in different species. In some, as Seals, the whole series of teeth appear almost simultaneously; but more often there are considerable intervals between their appearance, the front teeth usually coming into place first, and those at the back of the mouth at a later period.[1]

Forms of teeth.

General Characters.—The simplest form of tooth may be exemplified on a large scale by the tusk of the Elephant (fig. 1, I.). It is a hard mass almost entirely composed of dentine, of a conical shape at first, but during growth becoming more and more cylindrical or uniform in width. The enamel covering, present on the apex in its earliest condition, soon disappears, but a thin layer of cementum covers the circumference of the tooth throughout life. On section it will be seen that the basal portion is hollow, and contains a large conical pulp, as broad at the base as the tooth itself, and deeply imbedded in the bottom of a recess or socket in the upper maxillary bone. This pulp continues to grow during the lifetime of the animal, and to be converted at its surface into dentine. The tooth therefore continually elongates, but the use to which the animal subjects it in its natural state causes the apex to wear away, at a rate generally proportionate to the growth at the base, otherwise it would become of inconvenient length and weight. Such teeth of indefinite growth are said to be "rootless," or to have "persistent pulps."

One of the corresponding front teeth of man (fig. 1, II. and III.) may be taken as an example of a very different condition. After its crown is fully formed by calcification of the germ, the pulp, though continuing to elongate, begins to contract in diameter; a neck or slight constriction is formed; and the remainder of the pulp is converted into the root (or fang), a tapering conical process which is imbedded in the alveolar cavity of the bone, and has at its extremity a minute perforation, through which the vessels and nerves required to maintain the vitality of the tooth enter the pulp cavity, very different from the widely open cavity at the base of the growing tooth. When the crown of the tooth is broad and complex in character, instead of having a single root, it may be supported by two or more roots, each of which is implanted in a distinct alveolar recess or socket, and to the apex of which a branch of the common pulp cavity is continued (fig. 1, IV.). Such teeth are called "rooted teeth." When they have once attained their position in the jaw, with the neck a little way above the level of the upper margin of the alveolus, and embraced by the gum or tough fibro-vascular membrane which covers the alveolar border, and having the root fully formed, they can never increase in length or alter their position. If they appear to do so in old age it is only in consequence of absorption and retrocession of the surrounding alveolar margins. If, as

[1] See the conclusion of the article DIGESTIVE ORGANS, vol. vii. p. 233 *sq.*, for a more detailed and illustrated account of the structure and development, especially of the human teeth.

often happens, their surface wears away in mastication, it is never renewed. The open cavity at the base of the imperfectly developed rooted tooth (fig. 1, II.) causes it to resemble the persistent condition of the rootless tooth. The latter is therefore a more primitive condition, the formation of the root being a completion of the process of tooth development. Functionally it is, however, difficult to say that the one is a higher form than the other, as they both serve important and different purposes in the animal economy.

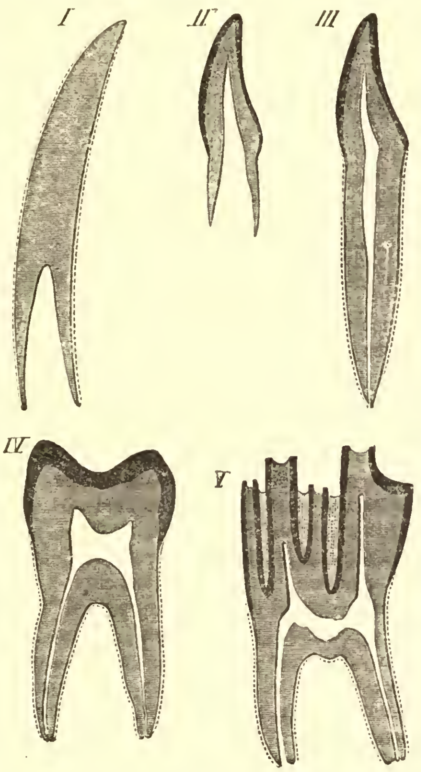


FIG. 1.—Diagrammatic Sections of various forms of Teeth. I. Incisor of Elephant, with pulp cavity persistently open at base. II. Human incisor during development, with root imperfectly formed, and pulp cavity widely open at base. III. Completely formed human incisor, with pulp cavity contracted to a small aperture at the end of the root. IV. Human molar, with broad crown and two roots. V. Molar of Ox, with enamel covering the crown deeply folded and with the depressions filled up with cementum. The surface is worn by use; otherwise the enamel coating would be continuous at the top of the ridges. In all the figures the enamel is black, the pulp white, the dentine represented by horizontal lines, and the cementum by dots.

As is almost always the case in nature, intermediate conditions between these two forms of teeth are met with. Some, as the molars of the Horse, and of many Rodents, are for a time rootless, and have growing pulps producing a very long crown with parallel sides, the summit of which may be in use and beginning to wear away while the base is still growing, but ultimately the pulp contracts, forms a neck and distinct roots, and ceases to grow. The canine tusks of the Musk Deer and of the Walrus have persistent pulps, and are open at their base until the animal is of advanced age, when they close, and the pulp ceases to be renewed.

The simplest form of the crown of a tooth is that of a cone; but this may be variously modified. It may be flattened, with its edges sharp and cutting, and pointed at the apex, as in the laterally compressed premolars of most *Carnivora*, or it may be chisel- or awl-shaped, with a straight truncated edge, as in the human incisors; or it may be broad, with a flat or rounded upper surface. Very often there is a more or less prominent ridge encircling the whole or part of the base of the crown just above the neck, called the cingulum, which serves as a protection to the edge of the gum in masticating, and is best developed in flesh-eating and insectivorous animals, in which the gums are liable to be injured by splinters of bone or other hard fragments of their food. The form of the crown is frequently rendered complex by the development upon its surface of elevations or tubercles called cusps, or by ridges usually transverse, but sometimes variously curved or folded. When the crown is broad and the ridges greatly developed, as in the molars of the Elephant, Horse, and Ox (fig. 1, V.), the interspaces between them are filled with cementum, which supports them and makes a solid compact mass of the whole tooth. When such a tooth wears away at the surface by friction against the opposed tooth of the other jaw, the different density of the layers of the substances of which it is composed—enamel, dentine, and cementum—arranged in characteristic patterns, causes them to wear unequally, the hard enamel ridges projecting beyond the others, thus giving rise to a grinding surface of great mechanical advantage.

Succession of teeth.

Succession of Teeth.—The dentition of all mammals consists of a definite set of teeth almost always of constant and determinate number, form, and situation, and, with few exceptions, persisting in a functional condition throughout the natural term of the animal's life. In many species these are the only teeth which the animal ever possesses. —the set which is first formed being permanent, or, if accidentally lost, or decaying in extreme old age, not being replaced by others. These animals are called Monophyodont. But, in the larger number of mammals, certain of the teeth are preceded by others, which may be only of a very transient, rudimentary, and functionless character (being in the Seals, for example, shed either before or within a few days after birth), or may be considerably developed, and functionally occupy the place of the permanent teeth for a somewhat lengthened period, during the growth and development of the latter and of the jaws. In all cases these teeth disappear (by the absorption of their roots and shedding of the crowns) before the frame of the animal has acquired complete maturity as evidenced by the coalescence of the epiphyses of the osseous system. As these teeth are, as a general rule, present during the period in which the animal is nourished by the milk of the mother, the name of "milk teeth" (French *dents de lait*, German *Milchzähne*) has been commonly accorded to them, although it must be understood that the epoch of their presence is by no means necessarily synchronous with that of lactation. Animals which possess such teeth are called Diphyodont. No mammal is known to have more than two sets of teeth; and the definite and orderly replacement of certain members of the series is a process of quite a different nature from the indefinite succession which takes place in all the teeth continuously throughout the lifetime of the lower vertebrates.

When the milk teeth are well developed, and continue in place during the greater part of the animal's growth, as is especially the case with the *Ungulata*, and, though to a less degree, with the *Primates* and *Carnivora*, their use is obvious, as taken all together they form structurally a complete epitome on a small scale of the more numerous and larger permanent set (see fig. 3), and, consequently, are able to perform the same functions, while time is allowed for the gradual maturation of the latter, and especially while the jaws of the growing animal are acquiring the size and strength sufficient to support the permanent teeth. Those animals, therefore, that have a well-developed and tolerably persistent set of milk teeth may be considered to be in a higher state of development, *quoad* dentition, than those that have the milk teeth absent or rudimentary.

It is a very general rule that individual teeth of the milk and permanent set have a close relationship to one another, being originally formed, as mentioned above, in exceedingly near proximity, and with, at all events as far as the enamel germ is concerned, a direct connexion. Moreover, as the latter ultimately come to occupy the position in the alveolar border temporarily held by the former, they are spoken of respectively as the predecessors or successors of each other. But it must be understood that milk teeth may be present which have no successors in the permanent series, and, what is far more general, permanent teeth may have no predecessors in the milk series.

The complete series of permanent teeth of most mammals forms a complex machine, with its several parts adapted for different functions,—the most obvious structural modification for this purpose being an increased complexity of the individual components of the series from the anterior towards the posterior extremity of such series. Since, as has just been said, the complete series of the milk teeth often presents structurally and functionally a similar machine, but composed of fewer individual members, and the anterior of which are as simple, and the posterior as complex, as those occupying corresponding positions in the permanent series,—and since the milk teeth are only developed in relation to the anterior or lateral, never to the most posterior of the permanent series,—it follows that the hinder milk teeth are usually more complex than the teeth of which they are the predecessors in the permanent series, and represent functionally, not their immediate successors, but those more posterior permanent teeth which have no direct predecessors. This character is clearly seen in those animals in which the various members of the molar series are well differentiated from each other in form, as the *Carnivora*, and also in Man.

In animals which have two sets of teeth the number of the teeth of the permanent series which are preceded by milk teeth varies greatly, being sometimes, as in Marsupials and some Rodents, as few as one on each side of each jaw, and sometimes including the larger portion of the series.

Although there are difficulties in some cases in arriving at a satisfactory solution of the question, it is, on the whole, safest to assume that when only one set of teeth is present, these correspond to the permanent teeth of the Diphyodonts. When this one set is completely developed, and remains in use throughout the animal's life, there can be no question on this subject. When, on the other hand, the teeth are rudimentary and transient, as in the Whalebone Whales, it is possible to consider them as representing the milk series; but there are weighty reasons in favour of the opposite conclusion.[1]

Arrangement and classification of teeth.

General Arrangement, Homologies, and Notation of Teeth of Mammals.—The teeth of the two sides of the jaws are always alike in number and character, except in cases of accidental or abnormal variation, and in the one remarkable instance of constant deviation from bilateral symmetry among mammals, the tusks of the Narwhal (see fig. 49, p. 398), in which the left is of immense size, and the right rudimentary. In those animals also, as the Dolphins and some Armadillos, which have a very large series of similar teeth, not always constant in number in different individuals, there may be differences in the two sides; but, apart from these, in describing the dentition of any mammal, it is quite sufficient to give the number and characters of the teeth of one side only. As the teeth of the upper and the lower jaws work against each other in masticating, there is a general correspondence or harmony between them, the projections of one series, when the mouth is closed, fitting into corresponding depressions of the other. There is also a general resemblance in the number, characters, and mode of succession of both series, so that, although individual teeth of the upper and lower jaws may not be in any strict sense of the term homologous parts, there is a great convenience in applying the same descriptive terms to the one which are used for the other.

The simplest dentition as a whole is that of many species of Dolphin (fig. 2), in which the crowns are single-pointed, slightly curved cones, and the roots also single and tapering, and all alike in form from the anterior to the posterior end of the series, though it may be with some slight difference in size, those at the two extremities of the series being rather smaller than the others. Such a dentition is called Homodont, and in the case cited, as the teeth are never changed, it is also Monophyodont. Such teeth are adapted only for catching slippery living prey, as fish.

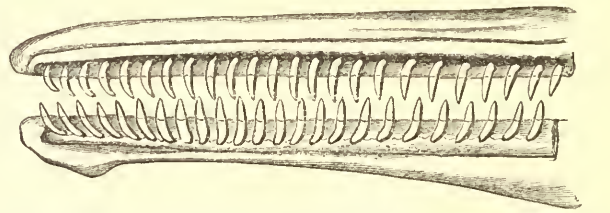


FIG. 2.—Upper and Lower Teeth of one side of the Mouth of a Dolphin (*Lagenorhynchus*), as an example of the homodont type of dentition. The bone covering the outer side of the roots of the teeth has been removed to show their simple character.

In a very large number of mammals the teeth of different parts of the series are more or less differentiated in character, and have different functions to perform. The front teeth are simple and one-rooted, and are adapted for cutting and seizing. They are called "incisors." The back teeth have broader and more complex crowns, tuberculated or ridged, and they are supported on two or more roots. They crush or grind the food, and are hence called "molars." Many animals have, between these two sets, a tooth at each corner of the mouth, longer and more pointed than the others, adapted for tearing or stabbing, or for fixing struggling prey. From the conspicuous development of such teeth in the *Carnivora*, especially the Dogs, they have received the name of "canines." A dentition with its component parts so differently formed that these distinctive terms are applicable to them is called Heterodont. In most cases, though by no means invariably, animals with Heterodont dentition are also Diphyodont.

This general arrangement is extremely obvious in a considerable number of mammals; and closer examination shows that, under very great modifications in detail, there is a remarkable uniformity of essential characters in the dentition of a large number of members of the class belonging to different orders and not otherwise closely allied, so much that it has been possible (chiefly through the researches of Professor Owen) to formulate a common plan of dentition from which the others have been derived by the alteration of some and suppression of other members of the series, and occasionally, but very rarely, by addition. The records of palæontology fully confirm this view, as by tracing back many groups now widely separated in dental characters we find a gradual approximation to a common type. In this generalized form of mammalian dentition (which is best exemplified in the genera *Anoplotherium* and *Homalodontotherium*) the entire number of teeth present is 44, or 11 above and 11 below on each side. Those of each jaw are placed in continuous series without intervals between them; and, although the anterior teeth are simple and single-rooted, and the posterior teeth complex and with several roots, the transition between the two kinds is gradual.

In dividing and grouping such teeth for the purpose of description and comparison, more definite characters are required than those derived merely from form or function. The first step towards a classification has been made by the observation that the upper jaw is composed of two bones, the premaxilla and the maxilla, and that the suture between these bones separates the

[1] This and other questions concerning the homologies, notation, and succession of the teeth of mammals are more fully developed in two memoirs by the present writer:—"Remarks on the Homologies and Notation of the Teeth of the Mammalia," in the *Journal of Anatomy and Physiology*, vol. iii. p. 262, 1869; and "Notes on the First or Milk Dentition of the Mammalia," in the *Trans. Odontological Society of Great Britain*, 1871.

three anterior teeth from the others. These three teeth then, which are implanted by their roots in the premaxilla, form a distinct group, to which the name of "incisor" is applied. This distinction is, however, not so important as it appears at first sight, for, as mentioned when speaking of the development of the teeth, their connexion with the bone is only of a secondary nature, and, although it happens conveniently for our purpose that in the great majority of cases the segmentation of the bone coincides with the interspace between the third and fourth tooth of the series, still, when it does not happen to do so, as in the case of the Mole, we must not give too much weight to this fact, if it contravenes other reasons for determining the homologies of the teeth. The eight remaining teeth of the upper jaw offer a natural division, inasmuch as the posterior three never have milk predecessors, and, although some of the anterior teeth may be in the same case, the particular one preceding these three always has such a predecessor. These three then are grouped apart as the "molars," or "true molars," as some of the teeth in front of them often have a molariform character. Of the five teeth between the incisors and molars the most anterior, or that which is usually situated close behind the premaxillary suture, almost always, as soon as any departure takes place from the simplest and most homogeneous type, assumes a lengthened and pointed form, and is the tooth so developed as to constitute the "canine" or "laniary" tooth of the *Carnivora*, the tusk of the Boar, &c. It is customary therefore to call this tooth, whatever its size or form, the "canine." The remaining four are the "premolars" or "false molars." This system of nomenclature has been objected to as being artificial, and in many cases not descriptive, the distinction between premolars and canine especially being sometimes not obvious, but the terms are now in such general use, and are so practically convenient—especially if, as it is best to do in all such cases, we forget their original signification, and treat them as arbitrary signs—that it is not likely they will be superseded by any that have been proposed as substitutes for them.

With regard to the lower teeth the difficulties are greater, owing to the absence of any suture corresponding to that which defines the incisors above; but, as the number of the teeth is the same, as the corresponding teeth are preceded by milk teeth, and as in the large majority of cases it is the fourth tooth of the series which is modified in the same way as the canine (or fourth tooth) of the upper jaw, it is quite reasonable to adopt the same divisions as with the upper series, and to call the first three, which are implanted in the part of the mandible opposite to the premaxilla, the incisors, the next the canine, the next four the premolars, and the last three the molars. It may be observed that when the mouth is closed, especially when the opposed surfaces of the teeth present an irregular outline, the corresponding upper and lower teeth are not exactly opposite, otherwise the two series could not fit into one another, but as a rule the points of the lower teeth shut into the interspaces in front of the corresponding teeth of the upper jaw. This is seen very distinctly in the canine teeth of the *Carnivora*, and is a useful guide in determining the homologies of the teeth of the two jaws. Objections have certainly been made to this view, because, in certain rare cases, the tooth which, according to it, would be called the lower canine has the form and function of an incisor (as in Ruminants and Lemurs), and on the other hand (as in *Oreodon*, an extinct Ungulate from North America) the tooth that would thus be determined as the first premolar has the form of a canine; but it should not be forgotten that, as in all such cases, definitions derived from form and function alone are quite as open to objection as those derived from position and relation to surrounding parts, or still more so.

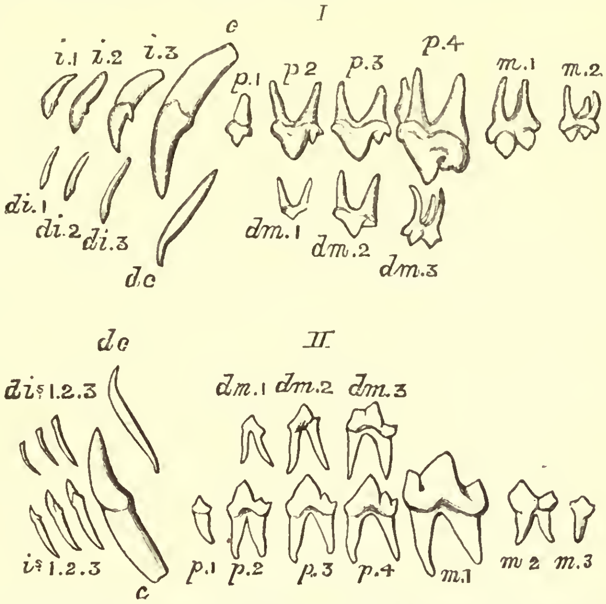


FIG. 3.—Milk and Permanent Dentition of Upper (I.) and Lower (II.) Jaw of the Dog (*Canis familiaris*), with the symbols by which the different teeth are commonly designated. The third upper molar (*m* 3) is the only tooth wanting in this animal to complete the typical heterodont mammalian dentition.

Dental formulæ. For the sake of brevity the complete dentition, arranged according to these principles, is often described by the following formula, the numbers above the line representing the teeth of the upper, those below the line those of the lower jaw:—incisors $\frac{3-3}{3-3}$, canines $\frac{1-1}{1-1}$, premolars $\frac{4-4}{4-4}$, molars $\frac{3-3}{3-3}=\frac{11-11}{11-11}$; total 44. As, however, initial letters may be substituted for the names of each group, and it is quite unnecessary to give more than the numbers of the teeth on one side of the mouth, the formula may be conveniently abbreviated into—

$$i\,\tfrac{3}{3},\ c\,\tfrac{1}{1},\ p\,\tfrac{4}{4},\ m\,\tfrac{3}{3}=\tfrac{11}{11}\text{; total 44.}$$

The individual teeth of each group are always enumerated from before backwards, and by such a formula as the following—

$$\frac{i\,1,\ i\,2,\ i\,3,\ c,\ p\,1,\ p\,2,\ p\,3,\ p\,4,\ m\,1,\ m\,2,\ m\,3}{i\,1,\ i\,2,\ i\,3,\ c,\ p\,1,\ p\,2,\ p\,3,\ p\,4,\ m\,1,\ m\,2,\ m\,3}$$

a special numerical designation is given by which each one can be indicated. In mentioning any single tooth, such a sign as $\underline{m\,1}$ will mean the first upper molar, $\overline{m\,1}$ the first lower molar, and so on. The use of such signs saves much time and space in description.

It was part of the view of the founder of this system of dental notation that, at least throughout the group of mammals whose dentition is derived from this general type, each tooth has its strict homologue in all species, and that in those cases in which fewer than the typical number are present (as in all existing mammals except the genera *Sus*, *Gymnura*, *Talpa*, and *Myogale*) the teeth that are missing can be accurately defined. According to this view, when the number of incisors falls short of three it is assumed that the absent ones are missing from the outer and posterior end of the series. Thus when there is but one incisor present, it is *i* 1; when two, they are *i* 1 and *i* 2. Furthermore, when the premolars and the molars are below their typical number, the absent teeth are missing from the fore part of the premolar series, and from the back part of the molar series. If this were invariably so, the labours of those who describe teeth would be greatly simplified; but there are unfortunately so many exceptions that a close scrutiny into the situation, relations, and development of a tooth may be required before its nature can be determined, and in some cases the evidence at our disposal is scarcely sufficient for the purpose.

The milk dentition is expressed by a similar formula, *d* for deciduous being commonly added before the letter expressive of the nature of the tooth. As the three molars and (almost invariably[1]) the first premolar of the permanent series have no predecessors, the typical milk dentition would be expressed as follows—$di\ \frac{3}{3}$, $dc\ \frac{1}{1}$, $dm\ \frac{3}{3} = \frac{7}{7} = 28$. The teeth which precede the premolars of the permanent series are all called molars in the milk dentition, although, as a general rule, in form and function they represent in a condensed form the whole premolar and molar series of the adult. When there is a marked difference between the premolars and molars of the permanent dentition, the first milk molar resembles a premolar, and the last has the characters of the posterior true molar.

Exceptions from generalized type.

The dentition of all the animals of the orders *Primates*, *Carnivora*, *Insectivora*, *Chiroptera*, and *Ungulata* can clearly be derived from the above-described generalized type. The same may be said of the Rodents, and even the *Proboscidea*, though with greater modification, at least in the existing members of the order. It is also apparent in certain extinct Cetaceans, as *Zeuglodon* and *Squalodon*, but it is difficult to find any traces of it in existing *Cetacea*, *Sirenia*, or any of the so-called *Edentata*. All the Marsupials, different as they are in their general structure and mode of life, and variously modified as is their dentition, present in this system of organs some deep-lying common characters which show their unity of origin. The generalized type to which their dentition can be reduced presents considerable resemblance to that of the placental mammals, yet differing in details. It is markedly heterodont, and susceptible of division into incisors, canines, premolars, and molars upon the same principles. The whole number is, however, not limited to forty-four. The incisors may be as numerous as five on each side, and are almost always different in number in the upper and the lower jaw. The premolars and molars are commonly seven, as in the placental mammals, but their arrangement is reversed, as there are four true molars and three premolars; and finally the milk dentition of all known Marsupials, existing or extinct, is (if not entirely absent) limited to a single tooth on each side of each jaw, this being the predecessor of the last permanent premolar.

In very few mammals are teeth entirely absent. Even in the Whalebone Whales their germs are formed in the same manner and at the same period of life as in other mammals, and even become partially calcified, but they never rise above the gums, and completely disappear before the birth of the animal. In some species of the order *Edentata*, the true Anteaters and the Pangolins, no traces of teeth have been found at any age. The *Monotremata* are in like case, although the *Ornithorhynchus* has flattened, ridged, horny plates at the back of both jaws, which answer the purpose of molar teeth.

Modifications of the Teeth in Relation to their Functions.—The principal functional modifications noticed in the dentition of *Mammalia* may be roughly grouped as (1) piscivorous, (2) carnivorous, (3) insectivorous, (4) omnivorous, and (5) herbivorous, each having, of course, numerous variations and transitional conditions.

Piscivorous dentition.

1. The essential characters of a piscivorous dentition are best exemplified in the Dolphins, and also (as modifications of the carnivorous type) in the Seals. It consists of an elongated, rather narrow mouth, wide gape, with numerous subequal, conical, sharp-pointed, recurved teeth adapted simply to rapidly seize, but not to divide or masticate, active, slippery, but not powerful prey. All animals which feed on fish as a rule swallow and digest them entire, a process which the structure of prey of this nature, especially the intimate interblending of delicate, sharp-pointed bones with the muscles, renders very advantageous, and for which the above-described type of dentition is best adapted.

Carn voro

2. The carnivorous type of dentition is shown in its most perfect development among existing mammals in the *Felidæ*. The function being here to seize and kill struggling animals, often of large size and great muscular power, the canines are immensely developed, trenchant, and piercing, and are situated wide apart so as to give the firmest hold when fixed in the victim's body. The jaws are as short as is consistent with the free action of the canines, so that no power may be lost. The incisors are very small, so as not to interfere with the penetrating action of the canines, and the crowns of the molar series are reduced to scissor-like blades, with which to pare off the soft tissues from the large bones, or to divide into small pieces the less dense portions of the bone for the sake of nutriment afforded by the blood and marrow it contains. The gradual modification between this and the two following types will be noticed in their appropriate places.

Inse voro

3. In the most typical insectivorous animals, as the Hedgehogs and Shrews, the central incisors are elongated, pointed, and project forwards, those of the upper and lower jaw meeting like the blades of a pair of forceps, so as readily to secure small active prey, quick to elude capture, but powerless to resist when once seized. The crowns of the molars are covered with numerous sharp edges and points, which working against each other, rapidly cut up the hard cased insects into little pieces, fit for swallowing and digestion.

Omn voro

4. The omnivorous type, especially that adapted for the consumption of soft vegetable substances, such as fruits of various kinds, may be exemplified in the dentition of Man, of most Monkeys, and of the less modified Pigs. The incisors are moderate, subequal, and cutting. If the canines are enlarged, it is usually for other purposes than those connected with food, and only in the male sex. The molars have their crowns broad, flattened, and elevated into rounded tubercles.

Herb voro

5. In the most typically herbivorous forms of dentition, as seen in the Horse and Kangaroo, the incisors are well developed and trenchant, adapted for cutting off the herbage on which the animals feed; the canines are rudimentary or suppressed; the molars are large, with broad crowns, which in the simplest forms have strong transverse ridges, but may become variously complicated in the higher degrees of modification which this type of tooth assumes.

The natural groups of mammals, or those which in our present state of knowledge we have reason to believe are truly related to each other, may each contain examples of more than one of these modifications. Thus the *Primates* have both omnivorous and insectivorous forms. The *Carnivora* show piscivorous, carnivorous, insectivorous, and omnivorous modifications of their common type of dentition. The *Ungulata* and the *Rodentia* have among them the omnivorous and various modifications, both simple and complex, of the herbivorous type. The *Marsupialia* exhibit examples of all forms, except the purely piscivorous. Other orders, more restricted in number or in habits, as the *Proboscidea* and *Cetacea*, naturally do not show so great a variety in the dental structure of their members.

In considering the taxonomic value to be assigned to

[1] *Hyrax* alone among existing mammals which have four premolars has also four milk molars.

ıxo- omy.

the modifications of teeth of mammals, two principles, often opposed to each other, which have been at work in producing these modifications, must be held in view:—(1) the type, or ancestral form, as we generally now call it, characteristic of each group, which in most mammals is itself derived from the still more generalized type described above; and (2) variations which have taken place from this type, generally in accordance with special functions which the teeth are called upon to fulfil in particular cases. These variations are sometimes so great as completely to mask the primitive type, and in this way the dentition of many animals of widely different origin has come to present a remarkable superficial resemblance, as in the case of the Wombat (a Marsupial), the Aye-Aye (a Lemur), and the Rodents, or as in the case of the Thylacine and the Dog. In all these examples indications may generally be found of the true nature of the case by examining the earlier conditions of dentition; for the characters of the milk teeth or the presence of rudimentary or deciduous members of the permanent set will generally indicate the route by which the specialized dentition of the adult has been derived. It is perhaps owing to the importance of the dental armature to the well-being of the animal in procuring its sustenance, and preserving its life from the attacks of enemies, that great changes appear to have taken place so readily, and with such comparative rapidity, in the form of these organs, changes often accompanied with but little modification in the general structure of the animal. Of this proposition the Aye-Aye (*Chiromys*) among Lemurs, the Walrus among Seals, and the Narwhal among Dolphins form striking examples; as, in all, the superficial characters of their dentition would entirely separate them from the animals with which all other evidence (even including the mode of development of their teeth) proves their close affinity.

The Skeleton.

The skeleton is a system of hard parts, forming a framework which supports and protects the softer organs and tissues of the body. It consists of dense fibrous and cartilaginous tissues, of which portions remain through life in this state, but the greater part is transformed during the growth of the animal into bone or osseous tissue. This is characterized by a peculiar histological structure and chemical composition, being formed mainly of a gelatinous basis, strongly impregnated with salts of lime, chiefly phosphate, and disposed in a definite manner, containing numerous minute nucleated spaces or cavities called lacunæ, connected together by delicate channels or canaliculi, which radiate in all directions from the sides of the lacunæ. Parts composed of bone are, next to the teeth, the most imperishable of all the organs of the body, often retaining their exact form and internal structure for ages after every trace of all other portions of the organization has completely disappeared, and thus, in the case of extinct animals, affording the only means of attaining a knowledge of their characters and affinities.[1]

In the Armadillos and their extinct allies alone is an ossified exoskeleton, or bony covering developed in the skin, present. In all other mammals the skeleton is completely internal. It may be described as consisting of an axial portion belonging to the head and trunk, and an appendicular portion belonging to the limbs. There are also certain bones called splanchnic, being developed within the substance of some of the viscera. Such are the *os cordis* and *os penis* found in some mammals.

It is characteristic of all the larger bones of the *Mammalia* that their ossification takes its origin from several distinct centres. One near the middle of the bone, and spreading throughout its greater portion, constitutes the *diaphysis*, or "shaft," in the case of the long bones. Others near the extremities, or in projecting parts, form the *epiphyses*, which remain distinct during growth, but ultimately coalesce with the rest of the bone.

Axial skeleton.

The axial skeleton consists of the skull, the vertebral column (prolonged at the posterior extremity into the tail), the sternum, and the ribs.

Skull.

In the *skull* of adult mammals, all the bones, except the lower jaw, the auditory ossicles, and the bones of the hyoid arch, are immovably articulated together, their edges being

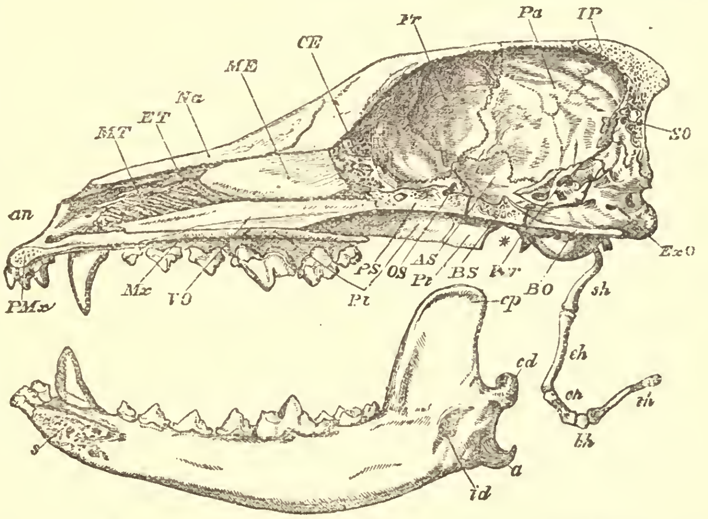


Fig. 4.—Longitudinal and Vertical Section of the Skull of a Dog (*Canis familiaris*), with mandible and hyoid arch. *an*, anterior narial aperture; *MT*, maxillo-turbinal bone; *ET*, ethmo-turbinal; *Na*, nasal; *ME*, ossified portion of the mesethmoid; *CE*, cribriform plate of the ethmo-turbinal; *Fr*, frontal; *Pa*, parietal; *IP*, interparietal; *SO*, supra-occipital; *ExO*, ex-occipital; *BO*, basi-occipital; *Per*, periotic; *BS*, basi-sphenoid; *Pt*, pterygoid; *AS*, ali-sphenoid; *OS*, orbito-sphenoid; *PS*, presphenoid; *Pl*, palatine; *Vo*, vomer; *Mx*, maxilla; *PMx*, premaxilla; *sh*, stylo-hyal; *eh*, epi-hyal; *ch*, cerato-hyal; *bh*, basihyal; *th*, thyro-hyal; *s*, symphysis of mandible; *cp*, coronoid process; *cd*, condyle; *a*, angle; *id*, inferior dental canal. The mandible is displaced downwards, to show its entire form; the * indicates the part of the cranium to which the condyle is articulated.[2]

in close contact, often interlocking by means of fine denticulations projecting from one bone and fitting into corresponding depressions of the other, and held together by the periosteum, or fibrous membrane investing the bones, passing directly from one to the other, permitting no motion, beyond perhaps a slight yielding to external pressure. In old animals there is a great tendency for the different bones to become actually united by the extension of ossification from one to the other, with consequent obliteration of the sutures. The cranium, thus formed of numerous originally independent ossifications, retaining through life more or less of their individuality, or all fused together, according to the species, the age, or even individual peculiarity, consists of a brain case, or bony capsule for enclosing and protecting the brain, and a face for the support of the organs of sight, smell, and taste and of those concerned in seizing and masticating the food. The brain case articulates directly with the anterior cervical vertebra, by means of a pair of oval eminences, called condyles, placed on each side of the large median foramen which transmits

[1] See for the principal modifications of the skeleton of this class, the large and beautifully illustrated *Ostéographie* of De Blainville, 1835–54; the section devoted to this subject in Bronn's *Klassen und Ordnungen des Thier-Reichs*, by Giebel, 1874–79; and *An Introduction to the Osteology of the Mammalia*, by W. H. Flower, 2d ed. 1876.

[2] This and many of the following figures are taken from Flower's *Osteology of the Mammalia*, Macmillan, 1876.

the spinal cord. It consists of a basal axis, continuous serially with the axes or centra of the vertebræ, and of an arch above, roofing over and enclosing the cavity which contains the cephalic portion of the central nervous system (see fig. 4). The base with its arch is composed of three segments placed one before the other, each of which is comparable to a vertebra with a greatly expanded neural arch. The hinder or occipital segment consists of the basi-occipital, ex-occipital, and supra-occipital bones; the middle segment of the basi-sphenoid, ali-sphenoid, and parietal bones; and the anterior segment of the pre-sphenoid, orbito-sphenoid, and frontal bones. The axis is continued forwards into the mesethmoid, or septum of the nose, around which the bones of the face are arranged in a manner so extremely modified for their special purposes that anatomists who have attempted to trace their serial homologies with the more simple portions of the axial skeleton have arrived at very diverse interpretations. The characteristic form and structure of the face of mammals is mainly dependent upon the size and shape of (1) the orbits, a pair of cup-shaped cavities for containing the eye-ball and its muscles, which may be directed forwards or laterally, placed near together or wide apart, and may be completely or only partially encircled by bone; (2) the nasal fossæ, cavities on each side of the median nasal septum, and forming the passage for the air to pass between the external and the internal nares, and containing in their upper part the organ of smell; (3) the zygomatic arch, a bridge of bone for the purpose of muscular attachment, which extends from the side of the face to the skull, overarching the temporal fossa; (4) the roof of the mouth, with its alveolar margin for the implantation of the upper teeth. The face is completed by the mandible, or lower jaw, consisting of two lateral rami, articulated by a hinge joint with the squamosal (a cranial bone interposed between the posterior and penultimate segment of the brain case, where also the bony capsule of the organ of hearing is placed), each being composed of a single solid piece of bone, and united together in the middle line in front, at the symphysis,—which union may be permanently ligamentous or become completely ossified. Into the upper border of the mandibular rami the lower teeth are implanted.

In only those species in which the brain holds a large relative proportion to the rest of the body, as in Man and the smaller species of the *Primates* and some other orders, does the external form of the skull receive much impress from the real shape of the cavity containing the brain. The size and form of the mouth, and the modifications of the jaws for the support of teeth of various shape and number, the ridges and crests on the cranium for the attachment of the muscles necessary to put this apparatus in motion, outgrowths of bone for the enlargement of the external surface required for the support of sense organs or of weapons, such as horns or antlers (which outgrowths, to prevent undue increase of weight, are filled with cells containing air), cause the principal variations in the general configuration of the skull. These variations are, however, only characteristically developed in perfectly adult animals, and are in many cases more strongly marked in the male than the female sex. Throughout all the later stages of growth up to maturity the size and form of the brain case remain comparatively stationary, while the accessory parts of the skull rapidly increase and take on their distinctive development characteristic of the species.

The hyoidean apparatus in mammals supports the tongue and larynx, and consists of a median portion below, the basi-hyal, from which two pairs of half arches, or cornua, extend upwards and outwards. The anterior is the most important, being connected with the periotic bone of the cranium. It may be almost entirely ligamentous, but more often has several ossifications, the largest of which is usually the stylo-hyal. The posterior cornu (thyro-hyal) is united at its extremity with the thyroid cartilage of the larynx, which it suspends in position. The median portion, or basi-hyal, is sometimes, as in the Howling Monkeys, enormously enlarged and hollowed, admitting into its cavity an air-sac connected with the organ of voice.

Ver- colu-

The *vertebral column* consists of a series of distinct bones called vertebræ, arranged in close connexion with each other along the dorsal side of the neck and trunk, and in the median line.[1] It is generally prolonged posteriorly beyond the trunk, to form the axial support of the appendage called the tail. Anteriorly it is articulated with the occipital region of the skull. The number of distinct bones of which the vertebral column is composed varies greatly among the *Mammalia*, the main variation being due to the elongation or otherwise of the tail. Apart from this, in most mammals the number is not far from thirty, though it may fall as low as twenty-six (as in some Bats), or rise as high as forty (*Hyrax* and *Cholœpus*). The different vertebræ, with some exceptions, remain through life quite distinct from each other, though closely connected by means of fibrous structures which allow of a certain, but limited, amount of motion between them. The exceptions are the following:—near the posterior part of the trunk, in nearly all mammals which possess completely developed hinder limbs, two or more vertebræ become ankylosed together to form the "sacrum," the portion of the vertebral column to which the pelvic girdle is attached; also, in certain species of Whales and of Armadillos, there are constant ossific unions of certain vertebræ of the cervical region.

Although the vertebræ of different regions of the column of the same animal or of different animals present great diversities of form, there is a certain general resemblance among them, or a common plan on which they are constructed, which is more or less modified by alteration of form or proportions, or by the addition or suppression of parts to fit them to fulfil their special purpose in the economy. An ordinary or typical vertebra consists in the first place of a solid piece of bone, the body or centrum (fig. 5, *c*), of the form of a disk or short cylinder. The bodies of contiguous vertebræ are connected together by a very dense, tough, and elastic material called the "intervertebral substance," of peculiar and complex arrangement. This substance forms the main, and in some cases the only, union between the vertebræ. Its elasticity provides for the vertebræ always returning to their normal relation to each other and to the column generally, when they have been disturbed therefrom by muscular action. A process (*p*) arises on each side from the dorsal surface of the body. These, meeting in the middle line above, form together an arch, surmounting a space or short canal (*nc*). As in this space lies the posterior prolongation of the great cerebro-spinal nervous axis, or spinal cord, it is called the neural canal, and the arch is called the neural arch, in contradistinction to another arch on the ventral surface of the

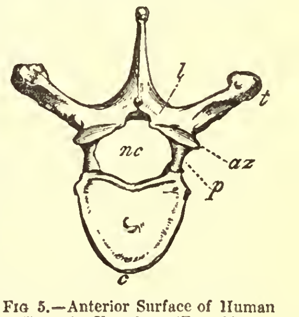


FIG 5.—Anterior Surface of Human Thoracic Vertebra (Fourth). *c*, body or centrum; *nc*, neural canal; *p*, pedicle, and *l*, lamina of the arch; *t*, transverse process; *az*, anterior zygapophysis.

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[1] For the sake of uniformity, in all the following descriptions of the vertebral column, the long axis of the body is supposed to be in the horizontal position.

body of the vertebra, called the hæmal arch. The last is, however, never formed in mammals by any part of the vertebra itself, but only by certain distinct bones placed more or less in apposition to it—the ribs in the thoracic, and the "chevron bones" in the caudal region. In most cases the arch of one vertebra is articulated with that of the next by distinct surfaces with synovial joints, placed one on each side, called "zygapophyses" (*z*), but these are often entirely wanting when flexibility is more needed than strength, as in the greater part of the caudal region of long-tailed animals. In addition to the body and the arch, there are certain projecting parts called processes, chiefly serving for the attachment of the numerous muscles which move the vertebral column. Of these two are single and median,—the spinous process or neural spine, or neurapophysis (*s*), arising from the middle of the upper part of the arch, and the hypapophysis from the under surface of the body. This, however, is as frequently absent as the former is constant. The other processes are paired and lateral. They are transverse processes (*t*), of which there may be two, an upper and a lower, in which case the former is called, in the language of Owen (to whom we are indebted for the terminology of the parts of vertebræ in common use), "diapophysis," and the latter "parapophysis." Other processes less constantly present are called respectively "metapophyses" (*m*) and "anapophyses" (*a*).

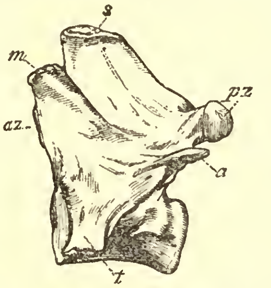

FIG. 6.—Side View of the First Lumbar Vertebra of a Dog (*Canis familiaris*). *s*, spinous process; *az*, anterior zygapophysis; *pz*, posterior zygapophysis; *m*, metapophysis; *a*, anapophysis; *t*, transverse process.

The vertebral column is divided for convenience of description into five regions, the cervical, thoracic or dorsal, lumbar, sacral, and caudal. This division is useful, especially as it is not entirely arbitrary, and in most cases is capable of ready definition; but at the contiguous extremities of the regions the characters of the vertebræ of one are apt to blend into those of the next region, either normally or as peculiarities of individual skeletons.

vical ebræ.

The *cervical* region constitutes the most anterior portion of the column, or that which joins the cranium. The vertebræ which belong to it are either entirely destitute of movable ribs, or if they have any these are small, and do not join the sternum. As a general rule they have a considerable perforation through the base of the transverse process (the vertebrarterial canal (fig. 7, *t*), or, as it is sometimes described, they have two transverse processes, superior and inferior, which, meeting at their extremities, enclose a canal. This, however, rarely applies to the last vertebra of the region, in which only the upper transverse process is usually developed. The transverse process, moreover, very often sends down near its extremity a more or less compressed plate (inferior lamella), which, being considered to be serially homologous with the ribs of the thoracic vertebræ (though not developed autogenously), is often called the "costal" or "pleurapophysial" plate. This is usually largest on the sixth, and altogether wanting on the seventh vertebra. The first and second cervical vertebræ, called respectively "atlas" and "axis," are specially modified for the function of supporting and permitting the free movements of the head. They are not united together by the intervertebral substance, but connected only by ordinary ligaments and synovial joints.

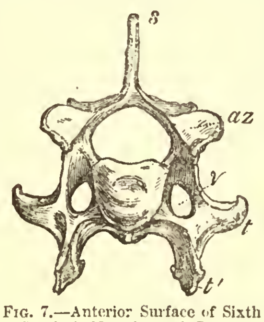

FIG. 7.—Anterior Surface of Sixth Cervical Vertebra of Dog. *s*, spinous process; *az*, anterior zygapophysis; *v*, vertebrarterial canal; *t*, transverse process; *t'*, its inferior lamella.

The cervical region in mammals presents the remarkable peculiarity that, whatever the length or flexibility of the neck, the number of vertebræ is the same, viz., seven, with only three known exceptions, the Manatee and Hoffman's Two-toed Sloth (*Cholœpus hoffmanni*), which both have but six, and the Three-toed Sloth (*Bradypus tridactylus*), which has nine, though in this case the last two usually support movable ribs, though not sufficiently developed to reach the sternum.

Dorsal vertebræ.

The *dorsal* (or *thoracic*, as it would be more correctly termed) region consists of the vertebræ which succeed those of the neck, having ribs movably articulated to them. These ribs arch round the thorax,—the anterior one, and most usually the greater number of those that follow, being attached below to the sternum.

Lumbar vertebræ.

The *lumbar* region consists of those vertebræ of the trunk in front of the sacrum which bear no movable ribs. It may happen that, as the ribs decrease in size posteriorly, the last being sometimes more or less rudimentary, the step from the thoracic to the lumbar region may be gradual and rather undetermined in a given species. But most commonly this is not the case, and the distinction is as well defined here as in any other region. As a general rule there is a certain relation between the number of the thoracic and lumbar vertebræ, the whole number being tolerably constant in a given group of animals, and any increase of the one being at the expense of the other. Thus in all known Artiodactyle *Ungulata* there are 19 dorso-lumbar vertebræ; but these may consist of 12 dorsal and 7 lumbar vertebræ, or 13 dorsal and 6 lumbar, or 14 dorsal and 5 lumbar. The smallest number of dorso-lumbar vertebræ in mammals occurs in some Armadillos, which have but 14. The number found in Man, the higher Apes, and most Bats, viz., 17, is exceptionally low 19 prevails in the Artiodactyles, nearly all Marsupials, and very many Rodents; 20 or 21 in *Carnivora* and most *Insectivora*; and 23 in *Perissodactyla*. The highest and quite exceptional numbers are in the Two-toed Sloth (*Cholœpus*) 27, and the Hyrax 30. The prevailing number of rib-bearing vertebræ is 12 or 13, any variation being generally in excess of these numbers.

Sacral vertebræ.

The *sacral* region offers more difficulties of definition. Taking the human "os sacrum" for a guide for comparison, it is generally defined as consisting of those vertebræ between the lumbar and caudal regions which are ankylosed together to form a single bone. It happens, however, that the number of such vertebræ varies in different individuals of the same or nearly allied species, especially as age advances, when a certain number of the tail vertebræ generally become incorporated with the true sacrum. Other suggested tests, as those vertebræ which have a distinct additional (pleurapophysial) centre of ossification between the body and the ilium, those to which the ilium is directly articulated, or those in front of the insertion of the ischio-sacral ligaments, being equally unsatisfactory or unpractical, the old one of ankylosis, as it is found to prevail in the average condition of adults in each species, is used in the enumeration of the vertebræ in the following pages. The *Cetacea*, having no iliac bones, have no part of the vertebral column modified into a sacrum.

Caudal vertebræ.

The *caudal* vertebræ are those placed behind the sacrum, and terminating the vertebral column. They vary in number greatly,—being reduced to 5, 4, or even 3, in a most rudimentary condition, in Man and in some Apes and Bats, and being numerous and powerfully developed, with strong and complex processes, in many mammals, especially among the *Edentata*, *Cetacea*, and *Marsupialia*. The highest known number, 46, is possessed by the African Long-tailed Manis. Connected with the under surface of the caudal vertebræ of many mammals which have the tail well developed are certain bones formed more or less like an inverted arch, called chevron bones, or by the French *os en V*. These are always situated nearly opposite to an intervertebral space, and are generally articulated both to the vertebra in front and the vertebra behind, but sometimes chiefly or entirely either to one or the other.

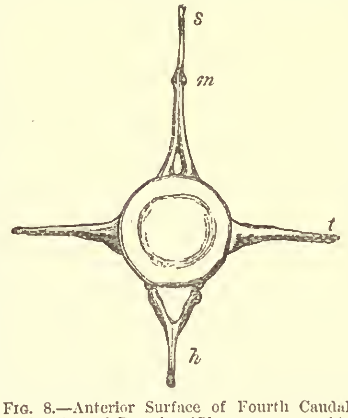

Fig. 8.—Anterior Surface of Fourth Caudal Vertebra of Porpoise (*Phocæna communis*). *s*, spinous process; *m*, metapophysis; *t*, transverse process; *h*, chevron bone.

Sternum. The *sternum* of mammals is a bone, or generally a series of bones, placed longitudinally in the mesial line, on the inferior or ventral aspect of the thorax, and connected on each side with the vertebral column by a series of more or less ossified bars called "ribs." It is present in all mammals, but varies much in character in the different groups. It usually consists of a series of distinct segments placed one before the other, the anterior being called the presternum or "manubrium sterni" of human anatomy, and the posterior the xiphisternum, or xiphoid or ensiform process, while the intermediate segments, whatever their number, constitute the mesosternum or "body." In the Whalebone Whales the presternum alone is developed, and but a single pair of ribs is attached to it.

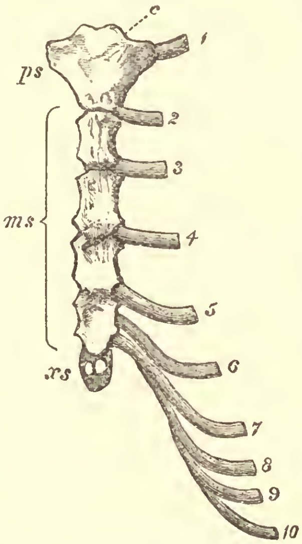

Fig. 9.—Human Sternum and Sternal Ribs. *ps*, presternum; *ms*, mesosternum; *xs*, xiphisternum; *c*, point of attachment of clavicle; 1 to 10, the cartilaginous sternal ribs.

Ribs. The *ribs* form a series of long, narrow, and more or less flattened bones, extending laterally from the sides of the vertebral column, curving downwards towards the median line of the body below, and mostly joining the sides of the sternum. The posterior ribs, however, do not directly articulate with that bone, but are either attached by their extremities to the edges of each rib in front of them, and thus only indirectly join the sternum, or else they are quite free below, meeting no part of the skeleton. These differences have given rise to the division into "true" and "false" ribs (by no means good expressions), signifying those that join the sternum directly and those that do not; and of the latter, those that are free below are called "floating" ribs. The portion of each rib nearest the vertebral column and that nearest the sternum differ in their characters, the latter being usually but imperfectly ossified, or remaining permanently cartilaginous. These are called "costal cartilages," or when ossified "sternal ribs."

In the anterior part of the thorax the vertebral extremity of each rib is divided into two parts, "head" and "tubercle"; the former is attached to the side of the body of the vertebra, the latter to its transverse process; the former attachment corresponds to the interspace between the vertebræ, the head of the rib commonly articulating partly with the hinder edge of the body of the vertebra antecedent to that which bears its tubercle. Hence the body of the last cervical vertebra usually supports part of the head of the first rib. In the posterior part of the series the capitular and tubercular attachments commonly coalesce, and the rib is attached solely to its corresponding vertebra. The number of pairs of ribs is of course the same as that of the thoracic vertebræ.

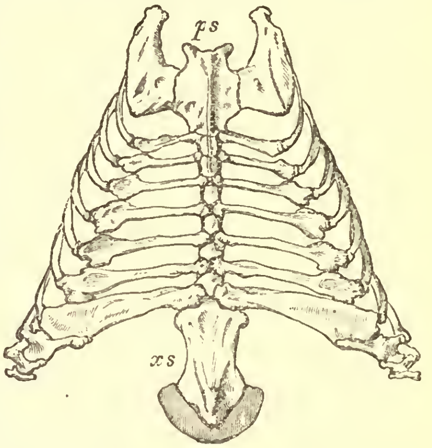

Fig. 10.—Sternum and strongly ossified Sternal Ribs of Great Armadillo (*Priodon gigas*). *ps*, presternum; *xs*, xiphisternum.

The appendicular portion of the framework consists, when completely developed, of two pairs of limbs, anterior and posterior. Ap[pen]dicu[lar] skel[eton].

The anterior limb is present and fully developed in all mammals, being composed of a shoulder girdle and three segments belonging to the limb proper, viz., the upper arm or brachium, the fore-arm or antibrachium, and the hand or manus. Ant[erior] limb.

The *shoulder girdle* in the large majority of mammals is in a rudimentary or rather modified condition, compared to that in which it exists in other vertebrates. In the *Monotremata* (*Ornithorhynchus* and *Echidna*) alone is the ventral portion, or coracoid, complete and articulates with the sternum below, as in the *Sauropsida*. In all other mammals this portion, though ossified from a distinct centre, forms only a process, sometimes a scarcely distinct tubercle, projecting from the anterior border of the glenoid cavity of the scapula. The last-named bone is always well developed, generally broad and flat (whence its vernacular name "blade bone"), with a ridge called the "spine" on its outer surface, generally ending in a free curved process, the "acromion." As the scapula affords attachment to many of the muscles which act upon the anterior limb, its form and the development of its processes are greatly modified according to the uses to which the member is put. It is most reduced and simple in character in those animals whose limbs are mere organs of support, as the Ungulates, and most complex when they are also used for grasping, climbing, or digging. The development or absence of the clavicle or "collar-bone," an accessory bar which connects the sternum with the scapula and steadies the shoulder-joint, has a somewhat similar relation, though its complete absence in the Bears shows that this is not an invariable rule. A complete clavicle is found in Man and all the *Primates*, in *Chiroptera*, all *Insectivora* (except *Potamogale*), in many Rodents, in most Edentates, and in all Marsupials, except *Perameles*. More or less rudimentary clavicles (generally suspended freely in the muscles) are found in the Cat, Dog, and most *Carnivora*, *Myrmecophaga*, and some Rodents. Clavicles are altogether absent in most of the *Ursidæ*, all the *Pinnipedia*, Manis among Edentates, the *Cetacea*, *Sirenia*, *Proboscidea*, all Ungulates, and some Rodents. Sho[ulder] gird[le].

The proximal segment of the limb proper contains a single bone, the humerus, and the second segment two rachi- n and itibra- iium.

bones, the radius and the ulna, placed side by side, articulating with the humerus at their proximal, and with the carpus at their distal extremity. In their primitive and unmodified condition these bones may be considered as placed one on each border of the limb, the radius being preaxial or anterior, and the ulna postaxial or posterior, when the distal or free end of the limb is directed outwards or away from the trunk. This is their position in the earliest embryonic condition, and is best illustrated in adult mammals in the *Cetacea*, where the two bones are fixed side by side and parallel to each other. In the greater number of mammals the bones assume a very modified and adaptive position, usually crossing each other in the forearm, the radius in front of the ulna, so that the preaxial bone (radius), though external (in the ordinary position of the limb) at the upper end, is internal at the lower end; and the hand, being mainly fixed to the radius, also has its preaxial border internal. In the large majority of mammals the bones are fixed in this position, but in some few, as in Man, a free movement of crossing and uncrossing—or pronation and supination, as it is termed—is allowed between them, so that they can be placed in their primitive parallel condition, when the hand (which moves with the radius) is said to be supine, or they may be crossed, when the hand is said to be prone.

In most mammals which walk on four limbs, and in which the hand is permanently prone, the ulna is much reduced in size, and the radius increased, especially at the upper end; and the articular surface of the latter, instead of being confined to the external side of the trochlea of the humerus, extends all across its anterior surface, and the two bones, instead of being external and internal, are anterior and posterior. In many hoofed or ungulated mammals, and in Bats, the ulna is reduced to little more than its upper articular extremity, and firmly ankylosed to the radius,—stability of these parts being more essential than mobility.

'anus. The terminal segment of the anterior limb is the hand or manus. Its skeleton consists of three divisions :—(1) the "carpus," a group of small, more or less rounded or angular bones with flattened surfaces applied to one another, and, though articulating by synovial joints, having scarcely any motion between them; (2) the "metacarpus," a series of elongated bones placed side by side, with their proximal ends articulating by almost immovable joints with the carpus; (3) the "phalanges" or bones of the digits, usually three in number to each, articulating to one another by freely movable hinge-joints, the first being connected in like manner to the distal end of the corresponding metacarpal bone.

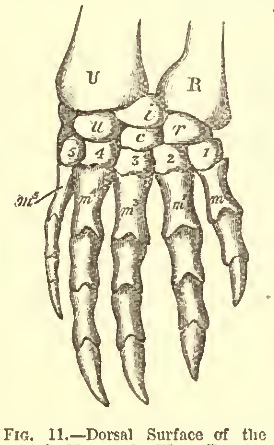

FIG. 11.—Dorsal Surface of the Right Manus of a Water Tortoise (*Chelydra serpentina*). After Gegenbaur. U, ulna; R, radius; *u*, ulnare; *i*, intermedium; *r*, radiale; *c*, centrale; 1–5, the five bones of the distal row of the carpus; m^1–m^5, the five metacarpals.

'arpus. To understand thoroughly the arrangement of the bones of the carpus in mammals, it is necessary to study their condition in some of the lower vertebrates. Fig. 11 represents the manus in one of its most complete and at the same time most generalized forms, as seen in one of the Water Tortoises (*Chelydra serpentina*). The carpus consists of two principal rows of bones. The upper or proximal row contains three bones, to which Gegenbaur has applied the terms *radiale* (*r*), *intermedium* (*i*), and *ulnare* (*u*), the first being on the radial or preaxial side of the limb. The lower or distal row contains five bones, called *carpale* 1, 2, 3, 4, and 5 respectively, commencing on the radial side. Between these two rows, in the middle of the carpus, is a single bone, the *centrale* (*c*). In this very symmetrical carpus it will be observed that the *radiale* supports on its distal side two bones, *carpale* 1 and 2; the *intermedium* is in a line with the *centrale* and *carpale* 3, which together form a median axis of the hand, while the *ulnare* has also two bones articulated with its distal end, viz., *carpale* 4 and 5. Each of the carpals of the distal row supports a metacarpal.

In the carpus of the *Mammalia* there are usually two additional bones developed in the tendons of the flexor muscles, one on each side of the carpus, which may be called the radial and ulnar sesamoid bones; the latter is most constant and generally largest, and is commonly known as the pisiform bone. The fourth and fifth carpals of the distal rows are always united into a single bone, and the centrale is very often absent. As a general rule all the other bones are present and distinct, though it not unfrequently happens that one or more may have coalesced to form a single bone, or may be altogether suppressed.

The following table shows the principal names in use for the various carpal bones,—those in the second column being the terms most generally employed by English anatomists :—

Radiale	= Scaphoid	= *Naviculare.*
Intermedium	= Lunar	= *Semilunare, Lunatum.*
Ulnare	= Cuneiform	= *Triquetrum, Pyramidale.*
Centrale	= Central	= *Intermedium* (Cuvier).
Carpale 1	= Trapezium	= *Multangulum majus.*
Carpale 2	= Trapezoid	= *Multangulum minus.*
Carpale 3	= Magnum	= *Capitatum.*
Carpale 4 } *Carpale* 5 }	= Unciform	= *Hamatum, Uncinatum.*

The metacarpal bones, with the digits which they support, are never more than five in number, and are described numerically—first, second, &c., counting from the radial towards the ulnar side. The digits are also sometimes named (1) the pollex, (2) index, (3) medius, (4) annularis, (5) minimus. One or more may be in a rudimentary condition, or altogether suppressed. If one is absent, it is most commonly the first. Excepting the *Cetacea*, no mammals have more than three phalanges to each digit, but they may occasionally have fewer by suppression or ankylosis. The first or radial digit is an exception to the usual rule, one of its parts being constantly absent, for, while each of the other digits has commonly a metacarpal and three phalanges, it has only three bones altogether; whether the missing one is a metacarpal or one of the phalanges is a subject which has occasioned much discussion, and has not yet been satisfactorily decided. The terminal phalanges of the digits are usually specially modified to support the nail, claw, or hoof, and are called "ungual phalanges." In walking, some mammals (as the Bears) apply the whole of the lower surface of the carpus, metacarpus, and phalanges to the ground; to these the term "plantigrade" is applied. Many others (as nearly all the *Ungulata*) only rest on the last one or two phalanges of the toes, the first phalanx and the metacarpals being vertical and in a line with the fore-arm. These are called "digitigrade." Intermediate conditions exist between these two forms, to which the terms "phalangigrade" (as the Camel) and "subplantigrade," (as in most *Carnivora*) are applied. When the weight is borne entirely on the distal surface of the ungual phalanx, and the horny structures growing around it, as in the Horse, the mode of progression is called "unguligrade." Metacarpus and phalanges.

In the *Chiroptera* the digits are enormously elongated, and support a cutaneous expansion constituting the organ of flight. In the *Cetacea* the manus is formed into a paddle, being covered by continuous integument, which conceals all trace of division into separate digits, and without sign of nails or claws. In the Sloths the manus is long and very narrow, habitually curved, and terminating in two or three pointed curved claws in close apposition with each other, incapable, in fact, of being divaricated, so that it is reduced to the condition of a hook, by which the animal suspends itself to the boughs of the trees among which it lives. These are only examples of the endless modifications to which the distal extremity of the limb is subjected in adaptation to the various purposes to which it is applied.

Posterior limb. The posterior limb is constructed upon a plan very similar to that of the anterior extremity. It consists of a pelvic girdle and three segments belonging to the limb proper, viz., the thigh, the leg, and the foot or pes.

Pelvic girdle. The pelvic girdle is present in some form in all mammals, though in the *Cetacea* and the *Sirenia* it is in an exceedingly rudimentary condition. In all mammals except those belonging to the two orders just named, each lateral half of the pelvic girdle consists essentially, like the corresponding part of the anterior limb, of a flattened rod of bone crossing the long axis of the trunk, having an upper or dorsal and a lower or ventral end. The upper end diverges from that of the opposite side, but the lower end approaches, and, in most cases, meets it, forming a symphysis, without the intervention of any bone corresponding to the sternum. The pelvic girdle differs from the shoulder girdle in being firmly articulated to the vertebral column, thus giving greater power to the hinder limb in its function of supporting and propelling the body. Like the shoulder girdle, it bears on its outer side, near the middle, a cup-shaped articular cavity ("acetabulum"), into which the proximal end of the first bone of the limb proper is received. Each lateral half of the girdle is called the "os innominatum," and consists originally of three bones which unite at the acetabulum. The "ilium" or upper bone is that which articulates with the sacral vertebræ. Of the two lower bones the anterior or "pubis" unites with its fellow of the other side at the symphysis; the posterior is the "ischium." These two form two bars of bone, united above and below, but leaving a space between them in the middle, filled only by membrane, and called the "thyroid" or "obturator" foramen. The whole circle of bone formed by the two innominate bones and the sacrum is called the pelvis. In the *Monotremata* and *Marsupialia*, a pair of thin, flat, elongated bones called epipubic or marsupial bones are attached to the fore part of the pubis, and project forward into the muscular wall of the abdomen.

Thigh and leg. The first segment of the limb proper has one bone, the femur, corresponding with the humerus of the upper limb. The second segment has two bones, the tibia and fibula, corresponding with the radius and ulna. These bones always lie in their primitive unmodified position, parallel to each other, the tibia on the preaxial and the fibula on the postaxial side, and are never either permanently crossed or capable of any considerable amount of rotation, as in the corresponding bones of the fore limb. In the ordinary walking position the tibia is internal, and the fibula external. In many mammals the fibula is in a more or less rudimentary condition, and it often ankyloses with the tibia at one or both extremities. The patella or "knee-cap" is found in an ossified condition in all mammals, with the exception of some of the *Marsupialia*. It is a large sesamoid bone developed in the tendon of the extensor muscles of the thigh, where the tendon passes over the front of the knee-joint, to which it serves as a protection. There are frequently smaller ossicles, one or two in number, situated behind the femoral condyles, called "fabellæ."

The terminal segment of the hind limb is the foot or pes. Foot. Its skeleton presents in many particulars a close resemblance to that of the manus, being divisible into three parts:—(1) a group of short, more or less rounded or square-shaped bones, constituting the tarsus; (2) a series of long bones placed side by side, forming the metatarsus; and (3) the phalanges of the digits or toes.

The bones of the tarsus of many of the lower *Vertebrata* closely resemble both in number and arrangement those of the carpus, as shown in fig. 11. They have been described in their most generalized condition by Gegenbaur under the names expressed in the first column of the following table. The names in the second column are those by which they are most generally known to English anatomists, while in the third column some synonyms occasionally employed are added

Tibiale } *Intermedium* }	= Astragalus	= *Talus.*
Fibulare	= Calcaneum	= *Os calcis.*
Centrale	= Navicular	= *Scaphoideum.*
Tarsale 1	= Internal cuneiform	= *Entocuneiforme.*
Tarsale 2	= Middle cuneiform	= *Mesocuneiforme.*
Tarsale 3	= External cuneiform	= *Ectocuneiforme.*
Tarsale 4 } *Tarsale* 5 }	= Cuboid.	

The bones of the tarsus of mammals present fewer diversities of number and arrangement than those of the carpus. The proximal row (see fig. 12) always consists of two bones, the astragalus (*a*, which probably represents the coalesced scaphoid and lunar of the hand) and the calcaneum (*c*). The former is placed more to the dorsal side of the foot than the latter, and almost exclusively furnishes the tarsal part of the tibio-tarsal or ankle-joint. The calcaneum, placed more to the ventral or "plantar" side of the foot, is elongated backwards to form a more or less prominent tuberosity, the "tuber calcis," to which the tendon of the great extensor muscles of the foot is attached. The navicular bone (*n*) is interposed between the proximal and distal row on the inner or tibial side of the foot, but on the outer side the bones of the two rows come into contact. The distal row, when complete, consists of four bones, which, beginning on the inner side, are the three cuneiform bones, internal (c^1), middle (c^2), and external (c^3), articulated to the distal surface of the navicular, and the cuboid (*cb*), articulated with the calcaneum. Of these the middle cuneiform is usually the smallest in animals in which all five digits are developed; but when the hallux is wanting the internal cuneiform may be rudimentary or altogether absent. The three cuneiform bones support respectively the first, second, and third metatarsals, and the cuboid supports the fourth and fifth; they thus exactly correspond with the four bones of the distal row of the carpus.

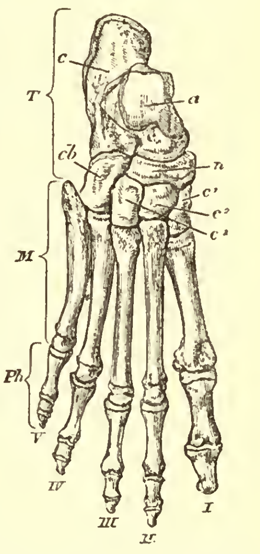

FIG. 12.—Bones of the Right Human Foot. *T*, tarsus; *M*, metatarsus; *Ph*, phalanges; *c*, calcaneum; *a*, astragalus; *cb*, cuboid; *n*, navicular; c^1, internal cuneiform; c^2, middle cuneiform; c^3, external cuneiform. The digits are indicated by Roman numerals, counting from the tibial to the fibular side.

In addition to these constant tarsal bones, there may be supplemental or sesamoid bones:—one situated near the middle of the tibial side of the tarsus, largely developed in many *Carnivora* and *Rodentia*; another, less frequent, on the fibular side; and a third, often developed in the tendons of the plantar surface of the tarsus, is especially large in Armadillos. There is also usually a pair of sesamoid bones on the plantar aspect of each metatarso-phalangeal articulation.

The metatarsal bones never exceed five in number, and the phalanges follow the same numerical rule as in the manus, never exceeding three in each digit. Moreover, the first digit, counting from the tibial side, or hallux, resembles the pollex of the hand in always having one segment less than the other digits. As the function of the hind foot is more restricted than that of the hand, the modifications of its structure are less striking. In the *Cetacea* and the *Sirenia* it is entirely wanting, though in some members of the first-named order rudiments of the bones of the first and second segment of the limb have been detected.

Digestive System.

The search after the purpose which every modification of structure subserves in the economy is always full of interest, and, if conducted with due caution and sufficient knowledge of all the attendant circumstances, may lead to important generalizations. It must always be borne in mind, however, that adaptation to its special function is not the only cause of the particular form or structure of an organ, but that this form, having in all probability been arrived at by the successive and gradual modification of some other different form from which it is now to a greater or less degree removed, has other factors besides use to be taken into account. In no case is this principle so well seen as in that of the organs of digestion. These may be considered as machines which have to operate upon alimentary substances in very different conditions of mechanical and chemical combination, and to reduce them in every case to the same or precisely similar materials; and we might well imagine that the apparatus required to produce flesh and blood out of coarse fibrous vegetable substances would be different from that which had to produce exactly the same results out of ready-made flesh or blood; and in a very broad sense we find that this is so. If we take a large number of carnivorous animals, belonging to different fundamental types, and a large number of herbivorous animals, and strike a kind of average of each, we shall find that there is, pervading the first group, a general style, if we may use the expression, of the alimentary organs, different from that of the others. There is a specially carnivorous and a specially herbivorous modification of these parts. But, if function were the only element which has guided such modification, it might be inferred that, as one form must be supposed to be best adapted and most perfect in its relation to a particular kind of diet, that form would be found in all the animals consuming that diet. But this is far from being the case. The Horse and the Ox, for instance,—two animals whose food in the natural state is precisely similar,—are yet most different as regards the structure of their alimentary canal, and the processes involved in the preparation of that food. Again, the Seal and the Porpoise, both purely fish-eaters, which seize and swallow and digest precisely the same kind of prey in precisely the same manner, have a totally different arrangement of the alimentary canal. If the Seal's stomach is adapted in the best conceivable manner for the purpose it has to fulfil, why is not the Porpoise's stomach an exact facsimile of it, and *vice versa*? We can only answer, the Seal and Porpoise belong to different natural groups of animals, formed on different primitive types, or descended from differently constructed ancestors. On this principle only can we account for the fact that, whereas, owing to the comparatively small variety of the different alimentary substances met with in nature, few modifications would appear necessary in the organs of digestion, there is really endless variety in the parts devoted to this purpose.

The digestive apparatus of mammals, as in other vertebrates, consists mainly of a tube with an aperture placed at or near either extremity of the body,—the oral and the anal orifice,—with muscular walls, the fibres of which are so arranged as by their regular alternate contraction and relaxation to drive onwards the contents of the tube from the first to the last of these apertures. The anterior or commencing portion of this tube and the parts around it are greatly and variously modified in relation to the functions assigned to them of selecting and seizing the food, and preparing it by various mechanical and chemical processes for the true digestion which it has afterwards to undergo before it can be assimilated into the system. For this end it is dilated into a chamber or cavity called the mouth, bordered externally by the lips, usually muscular and prehensile, and supported by a movable framework which carries the teeth,—organs the structure and modifications of which have been already described. The roof of the mouth is formed by the palate, terminating behind by a muscular, contractile arch, having in Man and some few other species a median projection called uvula, beneath which the mouth communicates with the pharynx. The anterior part of the palate is composed of mucous membrane tightly stretched over the flat or slightly concave bony lamina which separates the mouth from the nasal passages, and is generally raised into a series of transverse ridges, which sometimes, as in Ruminants, attain a considerable development. In the floor of the mouth, between the rami of the mandible, and supported behind by the hyoidean apparatus, lies the tongue, an organ the free surface of which, especially in its posterior part, is devoted to the sense of taste, but which also by its great mobility, being composed almost entirely of muscular fibres, performs important mechanical functions connected with masticating and procuring food. Its modifications of form in different mammals are very numerous. Between the long, extensile, vermiform tongue of the Anteaters, which is essential to the peculiar mode of feeding of those animals, and the short, sessile, and almost functionless tongue of the Porpoise, every intermediate condition is found. Whatever the form, the upper surface is always covered with numerous fine papillæ, in which the terminal filaments of the gustatory nerve are distributed.

The mouth.

Salivary glands.

In connexion with the buccal cavity is an extensive and complex glandular apparatus which pours its secretions into it—secretions which constitute the fluid commonly known as saliva. This apparatus consists of small glands embedded in the mucous membrane or submucous tissue lining the cavity of the mouth, and which are of two kinds (the follicular and the racemose), and of others in which the secreting structure is aggregated in distinct masses removed some distance from the cavity, other tissues besides the lining membrane being usually interposed, and pouring their secretion into the cavity by a distinct tube or duct, which traverses the mucous membrane. To the latter alone the name of "salivary glands" is ordinarily appropriated, although the distinction between them and the smaller racemose glands is only one of convenience for descriptive purposes, their structure being more or less identical; and, as the fluids secreted by all become mixed in the mouth, their functions are, at all events in great part, common. Under the name of salivary glands are commonly included —(1) the "parotid," situated very superficially on the side of the head, below or around the cartilaginous external auditory meatus, and the secretion of which enters the mouth by a duct (often called Steno's or Stenson's) which crosses the masseter muscle and opens into the upper and back part of the cheek; and (2) the "submaxillary," situated in the neck, near or below the angle of the mandible, and sending a long duct (Wharton's) forwards to open in the fore-part of the floor of the cavity of the mouth, below the apex of the tongue. These are the most largely developed and constant of the salivary glands, being met with in various degrees of development in almost all animals of the class. Next in constancy are (3) the "sublingual," closely associated with the last-named, at all events in the locality in which the secretion is poured out; and (4) the "zygomatic," found only in some animals in the cheek, just under cover of the anterior part of the zygomatic arch, its duct entering the buccal cavity near that of the parotid.

The most obvious function common to the secretion of these various glands, and to that of the smaller ones placed in the mucous membrane of the lips, the cheeks, the tongue, the palate and fauces, is the mechanical one of moistening and softening the food, to enable it the more readily to be tasted, masticated, and swallowed, though each kind of gland may contribute in different manner and different degree to perform this function. The saliva is, moreover, of the greatest importance in the first stage or introduction to the digestive process, as it dissolves or makes a watery extract of all soluble substances in the food, and so prepares them to be further acted on by the more potent digestive fluids met with subsequently in their progress through the alimentary canal. In addition to these functions it seems now well established by experiment that saliva serves in Man and many animals to aid directly in the digestive process, particularly by its power of inducing the saccharine transformation of amylaceous substances. As a general rule, in mammals the parotid saliva is more watery in its composition, while that of the submaxillaries, and still more the sublingual, contains more solid elements and is more viscid, so much so that some anatomists consider the latter, together with the small racemose glands of the cheeks, lips, and tongue, as mucous glands, retaining the name of salivary only for the parotid. These peculiar properties are sometimes illustrated in a remarkable degree, as, for example, the great secretion of excessively viscid saliva which lubricates the tongue of the Anteaters and Armadillos, associated with enormously developed submaxillary glands; while, on the other hand, the parotids are of great size in those animals which habitually masticate dry and fibrous food.

After the preparation which the aliment has undergone in the mouth,—the extent of which varies immensely in different forms, being reduced almost to nothing in such animals as the Seals and Cetaceans, which, to use the familiar expression, "bolt" their food entire,—it is swallowed, and is carried along the œsophagus by the Stomach. action of its muscular coats into the stomach. In the greater proportion of mammals this organ is a simple saccular dilatation of the alimentary canal, but in others it undergoes remarkable modifications and complexities. The lining of the stomach is thickly beset with tubular glands, which are generally considered to belong to two different forms, recognizable by their structure, and different in their function—the most numerous and important secreting the gastric juice (the active agent in stomachic digestion), and hence called "peptic" glands, the others concerned only in the elaboration of mucus. The relative distribution of these glands in different regions of the walls of the stomach varies greatly in different animals, and in many species there are large tracts of the mucous membrane which do not secrete a fluid having the properties of gastric juice, and often constitute more or less distinct cavities devoted to storing and perhaps softening or otherwise preparing the food for digestion. Sometimes there is a great aggregation of glands forming distinct thickened patches of the stomach wall, as in the Beaver and Koala, or even collected in pyriform pouches with a common narrow opening into the cavity, as in the Manatee and the curious African Rodent *Lophyomys*. The action of the gastric fluid is mainly exerted upon the nitrogenous elements of the food, which it dissolves and modifies so as to render them capable of undergoing absorption, which is partly effected by the blood-vessels of the stomach, though the greater part passes through the pylorus, an aperture surrounded by a circular muscular valve, into the intestinal canal. Here it comes in contact with the secretion of a vast number of small glands called the crypts of Lieberkuhn, somewhat similar to those of the stomach, and also of several special glands of a different character, namely, the small racemose, duodenal, or Brunner's glands, the pancreas, and the liver.

The intestinal canal varies greatly in relative length and capacity in different animals, and it also offers manifold peculiarities of form, being sometimes a simple cylindrical tube of nearly uniform calibre throughout, but more often subject to alterations of form and capacity in different portions of its course,—the most characteristic and constant being the division into an upper and narrower and a lower and wider portion, called respectively the small and the large intestine, the former being divided quite arbitrarily and artificially into duodenum, jejunum, and ileum, and the latter into colon and rectum. One of the most striking peculiarities of this part of the alimentary canal is the frequent presence of a diverticulum or blind pouch, the *caput cæcum coli*, as it was first called, a name generally abbreviated into "cæcum," situated at the junction of the large and the small intestine, a structure presenting an immense variety of development, from the smallest bulging of a portion of the side wall of the tube to a huge and complex sac, greatly exceeding in capacity the remainder of the alimentary canal. It is only in herbivorous animals that the cæcum is developed to this great extent, and among these there is a curious complementary relationship between the size and complexity of the organ and that of the stomach. Where the latter is simple the cæcum is generally the largest, and *vice versa*. Both cæcum and colon are often sacculated, a disposition caused by the arrangement of the longitudinal bands of muscular tissue in their walls; but the small intestine is always smooth and simple-walled externally, though its lining membrane often exhibits various contrivances for increasing the absorbing surface without adding to the general bulk of the organ, such as the numerous small villi by which it is everywhere beset, and the more obvious transverse, longitudinal, or reticulating folds projecting into the interior, met with in many animals, of which the "valvulæ conniventes" of Man form well-known examples. Besides the crypts of Lieberkuhn found throughout the intestinal canal, and the glands of Brunner confined to the duodenum, there are other structures in the mucous membrane, about the nature of which there is still much uncertainty, called "solitary" and "agminated" glands, the latter more commonly known by the name of "Peyer's patches." These were formerly supposed to be secretory organs, which discharged some kind of fluid into the intestine, but are now more generally considered to belong to the group of structures of somewhat mysterious function of which the lymphatic and lacteal

Intest canal.

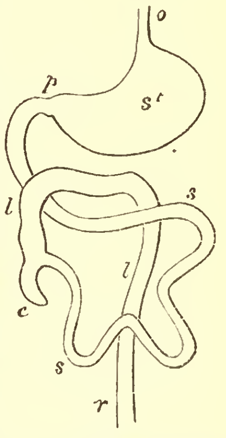

Fig. 13.—Diagrammatic Plan of the general arrangement of the Alimentary Canal in a typical Mammal. *o*, œsophagus; *st*, stomach; *p*, pylorus; *ss*, small intestine (abbreviated); *c*, cæcum; *ll*, large intestine or colon, ending in *r*, the rectum.

glands are members. The solitary glands are found scattered irregularly throughout the whole intestinal tract; the agminated, on the other hand, are always confined to the small intestine, and are most abundant in its lower part. They are subject to great variation in number and in size, and even in different individuals of the same species, and also differ in character at different periods of life, becoming atrophied in old age.

iver. The distinct glands situated outside of the walls of the intestinal canal, but which pour their secretion into it, are the pancreas and the liver. The latter is the most important on account of its size, if not on account of the direct action of its secretion in the digestive process. This large gland, so complex in structure and function, is well developed in all mammals, and its secreting duct, the bile duct, always opens into the duodenum or that portion of the canal which immediately succeeds the stomach. It is situated in the right side of the abdomen in contact with the diaphragm and the stomach, but varies greatly in relative size, and also in form, in different groups of mammals. In most mammals a gall-bladder, consisting of a pyriform diverticulum from the gall duct, is present, but in many it is wanting, and it is difficult to find the rationale of its presence or absence in relation to use or any other circumstance in the animal economy.

The descriptions of the livers of various animals to be met with in treatises or memoirs on comparative anatomy are very difficult to understand for want of a uniform system of nomenclature. The difficulty usually met with arises from the circumstance that this organ is divided sometimes, as in Man, Ruminants, and the *Cetacea*, into two main lobes, which have been always called respectively right and left, and in other cases, as in the lower Monkeys, *Carnivora*, *Insectivora*, and many other orders, into a larger number of lobes. Among the latter the primary division usually appears at first sight tripartite, the whole organ consisting of a middle, called "cystic" or "suspensory" lobe, and two lateral lobes, called respectively right and left lobes. This introduces confusion in describing livers by the same terms throughout the whole series of mammals, as the right and left lobes of the Monkey or Dog, for instance, do not correspond with parts designated by the same name in Man and the Sheep. There are, moreover, conditions in which neither the bipartite nor the tripartite system of nomenclature will answer, which we should have considerable difficulty in describing without some more general system. In order to arrive at such a system it appears desirable to consider the liver in all cases as primarily divided by the umbilical vein (see fig. 14, *u*) into two segments, right and left. This corresponds with its development and with the condition characteristic of the organ in the inferior classes of vertebrates. The situation of this division can almost always be recognized in adult animals by the persistence of some traces of the umbilical vein in the form of the round ligament, and by the position of the suspensory ligament.

When the two main parts into which the liver is thus divided are entire, as in Man, the Ruminants, and *Cetacea*, they may be spoken of as the right and left lobes; when fissured, as the right and left segments of the liver, reserving the term lobe for the subdivisions. This will involve no ambiguity, for the terms right and left lobe will no longer be used for divisions of the more complex form of liver. In the large majority of mammals each segment is further divided by a fissure, more or less deep, extending from the free towards the attached border, which are called right and left lateral fissures (fig. 14, *rlf* and *llf*). When these are more deeply cut than the umbilical fissure (*u*), the organ has that tripartite or trefoil-like form just spoken of, but it is easily seen that it is really divided into four regions or lobes, those included between the lateral fissures being the right and left central (*rc* and *lc*) separated by the umbilical fissure, and those beyond the lateral fissures on each side being the right and left lateral lobes (*rl* and *ll*). The essentially bipartite character of the organ and its uniformity of construction throughout the class are thus not lost sight of, even in the most complex forms. The left segment of the liver is rarely complicated to any further extent, except in some cases by minor or secondary fissures marking off small lobules, generally inconstant and irregular, and never worthy of any special designation. On the other hand, the right segment is usually more complex. The gall bladder, when present, is always attached to the under surface of the right central lobe, sometimes merely applied to it, in other cases deeply embedded in its substance. In many cases the fossa in which it is sunk is continued to the free margin of the liver as an indent, or even a tolerably deep fissure (*cf*). The portal fissure (*p*), through which the portal vein and

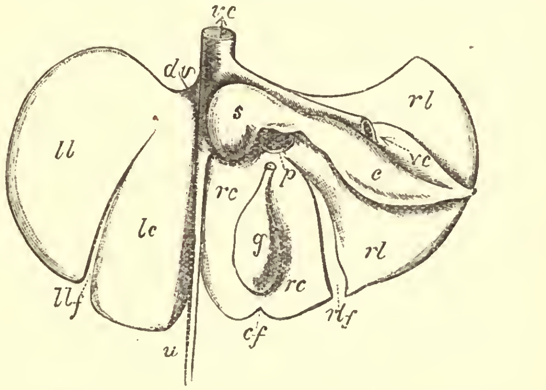

FIG. 14.—Diagrammatic Plan of the Inferior Surface of a Multilobed Liver of a Mammal. The posterior or attached border is uppermost. *u*, umbilical vein of the fœtus, represented by the round ligament in the adult, lying in the umbilical fissure; *dv*, the ductus venosus; *vc*, the inferior vena cava; *p*, the vena portæ entering the transverse fissure; *llf*, the left lateral fissure; *rlf*, the right lateral fissure; *cf*, the cystic fissure; *ll*, the left lateral lobe; *lc*, the left central lobe; *rc*, the right central lobe; *rl*, the right lateral lobe; *s*, the Spigelian lobe; *c*, the caudate lobe; *g*, the gall bladder.

hepatic artery enter and the gall duct emerges from the liver, crosses this lobe transversely, near the attached border of the liver. The right lateral lobe always has the great vena cava (*vc*) either grooving its surface or tunnelling through its substance near the inner or left end of its attached border; and a prolongation of the lobe to the left, between the vein and the portal fissure, sometimes a mere flat track of hepatic substance, but more often a prominent tongue-shaped process, is the so-called "Spigelian lobe" (*s*). From the under surface of the right lateral lobe a portion is generally partially detached by a fissure, and called the "caudate lobe" (*c*). In Man this is almost obsolete, but in most mammals it is of considerable magnitude, and has very constant and characteristic relations. It is connected by an isthmus at the left (narrowest or attached) end to the Spigelian lobe, behind which isthmus the vena cava is always in relation to it, channelling through or grooving its surface. It generally has a pointed apex, and is deeply hollowed to receive the right kidney, to the upper and inner side of which it is applied.

Considerations derived from the comparatively small and simple condition of the liver of the Ungulates, compared with its large size and complex form in the *Carnivora*, have led to the perhaps too hasty generalization that the first type is related to a herbivorous and the latter to a carnivorous diet. The exceptions to such a proposition are very numerous. The fact of the great difference between the liver of the *Cetacea* and that of the Seals cannot be accounted for by difference of habits of life, though it perhaps may be by difference of origin, upon the supposition that the former are modifications of the primary branch of mammals from which the Ungulates, and the latter of that from which the *Carnivora*, are derived.[1]

Circulatory, Absorbent, Respiratory, and Urinary Systems.

Blood. The blood of mammals is always red, and during the life of the animal hot, having a nearly uniform temperature, varying within a few degrees on each side of 100° Fahr. The corpuscles are, as usual in vertebrates, of two kinds:—(1) colourless, spheroidal, nucleated, and exhibiting amœboid movements; while (2) the more numerous, on which depends the characteristic hue of the fluid in which they are suspended, are coloured, non-nucleated, flattened, slightly biconcave disks, with circular outline in all known species except the Camels and Llamas, where they have the elliptical form characteristic of the red corpuscles of nearly all the other vertebrates, though adhering to the mammalian type in absence of nucleus and relatively small size. As a rule they are smaller as well as more numerous than in other classes, but vary considerably in size in different species, and not always in relation to the magnitude of the animal, a Mouse, for instance, having as large corpuscles as a Horse. Within the limits of any natural group there is, however, very often some such relation, the largest corpuscles being found among the large species and the smallest corpuscles among the small species of the group, but even to this generalization there are many exceptions. The transverse diameter of the red corpuscles in Man averages $\frac{1}{3200}$ of an inch, which is exceptionally large, and only exceeded by the Elephant ($\frac{1}{2745}$), and by some *Cetacea* and *Edentata*. They are also generally large in Apes, Rodents, and the *Monotremata*, and small in the Artiodactyles, least of all in the Chevrotains (*Tragulus*), being in *T. javanicus* and *meminna* not more than $\frac{1}{12325}$.[2]

Heart. The heart of mammals consists of four distinct cavities, two auricles and two ventricles. Usually the ventricular portion is externally of conical form, with a simple apex, but in the *Sirenia* it is broad and flattened, and a deep notch separates the apical portion of each ventricle. A tendency to this form is seen in the *Cetacea* and the Seals. It is characteristic of mammals alone among vertebrates that the right auriculo-ventricular valve is tendinous like the left, consisting of flaps held in their place by fibrous ends (*chordæ tendiniæ*) which arise from projections from the muscular walls of the ventricular cavity (*musculi papillares*). In the *Monotremata* a transition between this condition and the simple muscular flap of the *Sauropsida* is observed. In most of the larger Ungulates a distinct but rather irregular ossification is developed in the central tendinous portion of the base of the heart.

Blood-vessels. The orifices of the aorta and pulmonary artery are each guarded by three semilunar valves. The aorta is single, and arches over the left bronchial tube. After supplying the tissues of the heart itself with blood by means of the coronary arteries, it gives off large vessels ("carotid") to the head and ("brachial") to the anterior extremities. The mode in which these vessels arise from the aorta varies much in different mammals, and the study of their disposition affords some guide to classification. In nearly all cases the right brachial and carotid have a common origin (called "innominate artery" in anthropotomy). The other two vessels may come off from this, as is the rule in Ungulates, the common trunk constituting the "anterior aorta" of veterinary anatomy; or they may be detached in various degrees, both arising separately from the aorta, as in Man, or the left carotid from the innominate and the left brachial from the aorta, a very common arrangement, or the last two from a common second or left innominate as in some Bats and Insectivores. The aorta, after giving off the intercostal arteries, passes through the diaphragm into the abdomen, and, after supplying the viscera of that cavity by means of the gastric, hepatic, splenic, mesenteric, renal, and spermatic vessels, gives off in the lumbar region a large branch (iliac) to each of the hinder extremities, which also supplies the pelvic viscera, and is continued onwards in the middle line, greatly diminished in size, along the under surface of the tail. In certain mammals, arterial plexuses, called *retia mirabilia*, formed by the breaking up of the vessel into an immense number of small trunks, which may run in a straight course parallel to one another (as in the limbs of Sloths and Slow Lemurs), or form a closely packed network, as in the intracranial plexuses of Ruminants, or a sponge-like mass of convoluted vessels, as in the intercostals of Cetaceans, are peculiarities of the vascular system the meaning of which is not in all cases clearly understood. In the *Cetacea* they are obviously receptacles for containing a large quantity of oxygenated blood available during the prolonged immersion, with consequent absence of respiration, to which these animals are subject.

The vessels which return the blood to the heart from the head and upper extremities usually unite, as in Man, to form the single *vena cava superior* or precaval vein, but in some Insectivores, *Chiroptera*, and Rodents, and in the Elephant, and all Marsupials and Monotremes, the two superior caval veins enter the right auricle without uniting, as in birds. In Seals and some other diving mammals there is a large venous sinus or dilatation of the inferior cava immediately below the diaphragm. In the *Cetacea* the purpose of this is supplied by the immense abdominal venous plexuses. As a rule the veins of mammals are furnished with valves, but these are said to be altogether wanting in the *Cetacea*, and in the superior and inferior cava, subclavian and iliac veins, the veins of the liver (both portal and hepatic), heart, lungs, kidneys, brain, and spinal chord of other mammals. Many of the veins within the cranium are included in spaces formed by the separation of the laminæ of the dura mater, and do not admit of being dilated beyond a certain size; these are termed sinuses. The portal circulation in mammals is limited to the liver, the portal vein being formed by the superior and inferior mesenteric, the splenic, the gastro-epiploic, and the pancreatic veins. The kidney is supplied solely by arterial blood, and its veins empty their contents only into the inferior cava.

Lymphatic vessels. The *absorbent* or *lymphatic* system of vessels is very completely developed in the *Mammalia*. Its ramifications extend through all the soft tissues of the body, and convey a colourless fluid called lymph, containing nucleated corpuscles, and also, during the process of digestion, the chyle, a milky fluid taken up by the lymphatics (here called lacteals) of the small intestine, and pour them into the general vascular system, where they mix with the venous blood. The lymphatic vessels of the hinder extremities, as well as those from the intestinal canal, unite in the abdomen to form the "thoracic duct," the hinder end or commencement of which has a dilatation called the *receptaculum chyli*. The duct, which is of irregular size and sometimes double, often dividing and uniting again in its course, or even becoming plexiform, passes forwards close to the bodies of the thoracic vertebræ, and empties itself, by an orifice guarded by a valve, into the great left brachiocephalic vein, having previously received the lymphatics

[1] See "Lectures on the Comparative Anatomy of the Organs of Digestion of the Mammalia," *Medical Times and Gazette*, Feb.–Dec. 1872.

[2] G. Gulliver, *Proc. Zool. Soc.*, 1862, p. 91.

from the thorax and the left side of the head and left anterior extremity. Those from the right side of the head and right anterior limb usually enter by a small distinct trunk into the corresponding part of the right brachiocephalic vein. The duct, and also the principal lymphatic vessels, are provided with valves.

Lymphatic glands, rarely met with in the *Sauropsida*, are usually present in mammals, both in the general and in the lacteal system, the latter being called "mesenteric glands." They are round or oval masses, situated upon the course of the vessels, which break up in them and assume a plexiform arrangement, and then reunite as they emerge. No structures corresponding to the pulsating "lymphatic hearts" of the lower vertebrates have been met with in mammals.

Ductless glands. Associated with the vascular and lymphatic systems are certain bodies, the functions of which are not properly understood, and which are usually, on account of their general appearance, grouped together under the name of "ductless glands." Of these the "spleen" is the largest, and single, always placed in mammals in relation to the fundus or left end of the stomach, to which it is attached by a fold of peritoneum. It is dark-coloured and spongy in substance, and has a depression on one side or "hilus," into which the splenic artery, a branch of the cœliac axis of the abdominal aorta, enters, and from which the vein, which joins the portal system, emerges. It varies much in size and form in different mammals, being relatively very small in the *Cetacea*. It is sometimes almost spherical, but more often flattened, oval, triangular, or elongated, and occasionally, as in Monotremes and most Marsupials, triradiate. The "suprarenal bodies" or "adrenals" are two in number, each situated either in contact with or at a short distance in front of the anterior extremity of the kidney. They are abundantly supplied with nerves, and are much larger relatively in early than in adult life. The "thyroid body," or rather bodies, for there are generally two, though in Man and some other species connected by an isthmus passing across the middle line, are constant in mammals, though only met with in a rudimentary condition, if at all, in other vertebrates. They are situated in the neck, in contact with the sides of the anterior extremity of the trachea. The "thymus" lies in the anterior part of the thorax, between the sternum and the great vessels at the base of the heart, and differs from the thyroid in being median and single, and having a central cavity. It attains its greatest development during the period of lactation, and then diminishes and generally disappears before full growth is attained.

Nostrils. *Respiratory Organs.*—Mammals breathe occasionally through the mouth, but usually, and in many cases exclusively, through the nostrils or nares. These are apertures, always paired (except in the toothed *Cetacea*, where they unite to form a single external opening), and situated at the fore part of the face, generally at or beneath the end of the muzzle, a median prominence above the mouth. This is sometimes elongated to form a proboscis, to the extremity of which the nostrils are carried, and which attains its maximum of development in the Elephant. In the *Cetacea* the nostrils are situated at a considerable distance behind the anterior end of the face, upon the highest part of the head, and are called "blow-holes," from the peculiar mode of respiration of these animals. The nostrils are kept open by means of cartilages which surround their aperture, and which many animals have the power of moving so as to cause partial dilatation or contraction. In diving animals, as Seals and *Cetacea*, they can be completely closed at will so as to prevent the entrance of water when beneath the surface. The passage to which the nostrils lead is in most mammals filled by a more or less complex sieve-like apparatus, formed of the convoluted turbinal bones and cartilages, over which a moist, vascular, ciliated mucous membrane is spread, and which intercepts particles of dust, and also aids in warming the inspired air before it reaches the lungs. In the *Proboscidea*, in which these functions are performed by the walls of the long tubular proboscis, this apparatus is entirely wanting. The narial passages have the organ of smell situated in their upper part, and communicate posteriorly with the pharynx, and through the glottis with the "trachea" or windpipe, a tube by which the air is conveyed to and from the lungs. The permanent patency of the trachea during the varied movements of the neck is provided for by its walls being stiffened by a series of cartilaginous rings or hoops, which in most mammals are incomplete behind. Having entered the thorax, the trachea bifurcates into the two bronchi, one of which enters, and, dividing dichotomously, ramifies through, each lung. In some of the *Cetacea* and *Artiodactyla* a third bronchus is given off from the lower part of the trachea, above its bifurcation, and enters the right lung. Trachea.

Larynx. The upper end of the trachea is modified into the organ of voice or "larynx," the air passing through which to and from the lungs is made use of to set the edges of the "vocal cords," fibrous bands stretched one on each side of the tube, into vibration. The larynx is composed of several cartilages, of which the "thyroid," the "cricoid," and the "arytenoid" are the principal, moved upon one another by muscles, and suspended from the hyoidean arch. By alteration of the relative position of these cartilages the cords can be tightened or relaxed, approximated or divaricated, as required to modulate the tone and volume of the voice. A median tongue-shaped fibro-cartilage at the top of the larynx, the "epiglottis," protects the "glottis," or aperture by which the larynx communicates with the pharynx, from the entry of particles of food during deglutition. The form of the larynx and development of the vocal cords present many variations in different members of the class, the greatest modification from the ordinary type being met with in the *Cetacea*, where the arytenoid cartilages and epiglottis are united in a tubular manner, project into the nasal passage, and, being grasped by the muscular posterior margin of the palate, provide a direct channel of communication from the lungs to the external surface. An approach to this condition is met with in the Hippopotamus and some other Ungulates. Nearly all mammals have a voice, although sometimes it is only exercised at seasons of sexual excitement. Some Marsupials and Edentates appear to be quite mute. In no mammal is there an inferior larynx, or "syrinx, as in birds.

Diaphragm. The thoracic cavity of mammals differs from that of the *Sauropsida* in being completely separated from the abdomen by a muscular partition, the "diaphragm," attached to the vertebral column, the ribs, and the sternum. This is much arched, with the convexity towards the thorax, so that when its fibres contract it is flattened and the cavity of the thorax increased, and when they are relaxed the cavity is diminished.

Lungs. The lungs are suspended freely in the thorax, one on each side of the heart, being attached only by the root, which consists of the bronchus or air-tube, and pulmonary arteries and veins by which the blood is passed backwards and forwards between the heart and the lungs. The remaining part of the surface of each lung is covered by serous membrane, the "pleura," and, whatever the state of distension or contraction of the chest-wall, is accurately in contact with it. Inspiration is effected by the contraction of the diaphragm, and by the intercostal and other muscles elevating or bringing forward the ribs, and thus throwing the sternum farther away from the vertebral column. As the surface of the lung must follow the chest-wall, the organ is itself expanded, and air rushes in through the trachea to fill all the minute cells in which the ultimate ramifications of the bronchi terminate. In ordinary expiration very little muscular power is expended, the elasticity of the lungs and surrounding parts being sufficient to cause a state of contraction and to drive out at least a portion of the air contained in the cells, when the muscular stimulus is withdrawn. The lungs are sometimes simple externally, as in the *Sirenia* (where they are greatly elongated) and the *Cetacea*, but they are more often divided by deep fissures into one or more lobes. The right lung is usually larger and more subdivided than the left. It often has a small distinct lobe behind, wanting on the left side, and hence called *lobulus azygos*.

Air sacs. Most mammals have in connexion with the air passages certain diverticuli or pouches containing air, the use of which is not always easy to divine. The numerous air sinuses situated between the outer and inner tables of the bones of the head, which in Man are represented by the antrum of Highmore and the frontal and sphenoidal sinuses, and which attain their maximum of development in the Indian Elephant, are obviously for the mechanical purpose of allowing expansion of the bone surface without increase of weight. They are connected with the nasal passages. The Eustachian tubes pass from the back of the pharynx into the cavity of the tympanum, into which and the mastoid cells they allow air to pass. In the *Equidæ* there are large post-pharyngeal air sacs in connexion with them. The Dolphins have an exceedingly complicated system of air sacs in connexion with the nasal passages just within the nostrils, and the Tapir and Horses have blind sacs in the same situation. In the males of some Seals (*Cystophora* and *Macrorhinus*) large pouches, which the animal can inflate with air, but which at other times are flaccid, and which are not developed in the young animal or the female, arise from the upper part of the nasal passages, and lie immediately under the skin of the face. These are very analogous, although not in the same situation, to the gular pouch of the male Bustard. The larynx has frequently membranous pouches in connexion with it, into which air passes. These may be lateral and opening just above the vocal cords, constituting the *sacculi laryngis*, found in a rudimentary state in Man, and attaining an enormous development, reaching to the shoulders and axillæ, in some of the Anthropoid Apes; or they may be median, opening in front either above or below the thyroid and cricoid cartilages, as in the Howling and other Monkeys, and also in the Whalebone Whales and Great Anteater.

Kidneys. *Urinary Organs.*—The kidneys of mammals are more compact and definite in form than in other vertebrates, being usually more or less oval, with an indent on the side turned towards the middle line from and into which the vessels and ducts pass. They are distinctly divided into a cortical secretory portion, composed mainly of convoluted tubes, and containing Malpighian bodies, and a medullary excreting portion, formed of straight tubes converging towards a papilla, embraced by the commencement of the ureter or duct of the organ. The kidneys of some mammals, as most Monkeys, Carnivores, Rodents, &c., are simple, with a single papilla into which all the renal tubuli enter. In others, as Man, there are many pyramids of the medullary portion, each with its papilla, opening into a division (calyx) of the upper end of the ureter. Such kidneys are, either in the embryonic condition only or throughout life, lobulated on the surface. In some cases, as in Bears, Seals, and especially the *Cetacea*, the lobulation is carried further, the whole organ being composed of a mass of renules, loosely united by connective tissue, and with separate ducts, which soon join to form the common ureter. In all mammals except the Monotremes the ureters terminate by slit-like valvular openings in the urinary bladder. Bladder. This receptacle when filled discharges its contents through the single median urethra, which in the male is almost invariably included in the penis, and in the females of some species of Rodents, Insectivores, and Lemurs has a similar relation to the clitoris. In the Monotremes, though the bladder is present, the ureters do not enter into it, but into the urogenital canal some distance below it, the orifice of the genital duct intervening.

Nervous System and Organs of Sense.

The brain of mammals shows a higher condition of Brain. organization than that of other vertebrates. The cerebral hemispheres have a greater preponderance compared to other parts, especially to the so-called optic lobes, or corpora quadrigemina, which are completely concealed by them. The commissural system of the hemispheres is much more complete, both fornix and corpus callosum being present in some form; and, when the latter is rudimentary, as in Marsupials and Monotremes, its deficiency is made up for by the great size of the anterior commissure. The lateral lobes of the cerebellum, wanting in lower vertebrates, are well developed and connected by a transverse commissure, the pons Varolii. The whole brain, owing especially to the size of the cerebral hemispheres, is considerably larger relatively to the bulk of the animal than in other classes, but it must be recollected that the size of its brain depends upon many circumstances besides the degree of intelligence which an animal possesses, although this is certainly one. Man's brain is many times larger than that of all other known mammals of equal bulk, and even three times as large as that of the most nearly allied Ape. Equal bulk of body is here mentioned, because, in drawing any conclusions from the size of the brain compared with that of the entire animal, it is always necessary to take into consideration the fact that in every natural group of closely allied animals the larger species have much smaller brains relatively to their general size than the smaller species, so that, in making any effective comparison among animals belonging to different groups, species of the same size must be selected. It may be true that the brain of a Mouse is, as compared with the size of its body, larger than that of a Man, but, if it were possible to reduce an animal having the general organization of a Man to the size of a Mouse, its brain would doubtless be very many times larger; and conversely, as shown by the rapid diminution of the relative size of the brain in all the large members of the Rodent order, a Mouse magnified to the size of a Man would, if the general rule were observed, have a brain exceedingly inferior in volume. Although the brain of the large species of Whales is, as commonly stated, the smallest in proportion to the bulk of the animal of any mammal, this does not invalidate the general proposition that the *Cetacea* have very large brains compared with terrestrial mammals, as the *Ungulata*, or even the aquatic *Sirenia*, as may be proved by placing the brain of a Dolphin by the side of that of a Sheep or Pig, or a Manatee of equal general weight. It is only because the universally observed difference between the slower ratio of increase of the brain compared with that of the body becomes so enormous in these immense creatures that they are accredited with small brains.

The presence or absence of "sulci" or fissures on the surface of the hemisphere, dividing it into "convolutions" or "gyri," and increasing the superficies of the cortical grey matter, as well as allowing the pia mater with its nutrient blood-vessels to penetrate into the cerebral substance, follow somewhat similar rules. They are related partly to the high or low condition of organization of the species, but also in a great degree to the size of the cerebral hemispheres. In very small species of all groups, even the *Primates*, they are absent, and in the largest species of groups so low in the scale as the Marsupials and Edentates they are found. They reach their maximum of development in the *Cetacea*.

The researches of palæontologists, founded upon studies of casts of the interior of the cranial cavity of extinct forms, have shown that, in many natural groups of mammals, if not in all, the brain has increased in size, and also in complexity of surface foldings, with the advance of time,—indicating in this, as in so many other respects, a gradual progress from a lower to a higher type of development.

erves. The twelve pairs of cranial nerves generally recognized in vertebrates are all usually found in mammals, though the olfactory nerves are excessively rudimentary, if not altogether absent, in the Toothed Whales. The spinal cord, or continuation of the central nervous axis, lies in the canal formed by the neural arches of the vertebræ, and gives off the compound double-rooted nerves of the trunk and the extremities corresponding in number to the vertebræ, through the interspaces between which they pass out to their destination. The cord is somewhat enlarged at the two points where it gives off the great nerves to the anterior and the posterior extremities, which from their interlacements soon after their origin are called respectively the brachial and lumbar plexuses. The ganglionic or sympathetic portion of the nervous system is well developed, and presents few modifications.

ense of uch. The sense of touch is situated in the skin generally, but is most acute in certain regions more or less specialized for the purpose by the presence of tactile papillæ, such as portions of the face, especially the lips and end of the snout, and the extremities of the limbs when these are used for other purposes than mere progression, and the under surface of the end of the tail in some Monkeys. The "vibrissæ" or long stiff bristles situated on the face of many mammals are rendered extremely sensitive to touch by the abundant supply of branches from the fifth nerve to their basal papillæ. In Bats, the extended wing membranes, and probably also the large ears and the folds and prominences of skin about the face of some species, are so sensitive as to receive impressions even from the different degrees of resistance of the air, and so enable the animals to avoid coming in contact with obstacles to their nocturnal flight.

The organs of the other special senses are confined to the head. Taste is situated in the papillæ scattered on the dorsal surface of the tongue. The organ of smell is present in all mammals except the Toothed Whales. It consists of a ramification of the olfactory nerves over a plicated, moist, mucous membrane, supported by folded plates of bone, placed on each side of the septum nasi in the roof, or often in a partially distinct upper chamber of the nasal passage, so arranged that, of the air passing into the lungs in inspiration, some comes in contact with it, causing the perception of any odorous particles with which it may be charged. Many mammals possess intense powers of smelling certain odours which others are quite unable to appreciate, and the influence which this sense exercises over the well-being of many species is very great, especially in indicating the proximity of others of the same kind, and giving warning of the approach of enemies. The development and modification of the sense of smell is probably associated with that of the odorous secretion of the cutaneous glands.

aste. mell.

ight. The organ of sight is quite rudimentary, and even concealed beneath the integument, in some burrowing Rodents and Insectivores, and is most imperfectly developed in the *Platanista*, or Freshwater Dolphin of the rivers of India. In all other mammals the eyeball has the structure characteristic of the organ in the higher *Vertebrata*, consisting of parts through which the rays of light are admitted, regulated, and concentrated upon the sensitive expansion of the optic nerve lining the posterior part of the ball. A portion of the fibro-vascular and highly pigmented layer, the choroid, which is interposed between the retina and the outer sclerotic coat, is in many mammals modified into a brilliantly coloured light-reflecting surface, the *tapetum lucidum*. There is never a pecten or marsupium, as in the *Sauropsida*, nor is the sclerotic ever supported by a ring of flattened ossicles, as is so frequently the case in the lower vertebrated classes. The eyeball is moved in various directions by a series of muscles—the four recti, two obliqui, and, except in the higher *Primates*, a posterior retractor muscle called choanoid. It is protected by the lids, generally distinctly separated into an upper and a lower movable flap, which, when closed, meet over the front of the eye in a more or less horizontal line; but sometimes, as in the *Sirenia*, the lids are not distinct, and the aperture is circular, closing to a point. In almost all mammals below the *Primates*, except the *Cetacea*, a "nictitating membrane" or third eyelid is placed at the inner corner of the eyeball, and works horizontally across the front of the ball within the true lids. Its action is instantaneous, being apparently for the purpose of cleaning the front of the transparent cornea, a function which is unnecessary in animals whose eyes are habitually bathed in water, and which in Man and his nearest allies is performed by winking the true eyelids. Except in *Cetacea* the surface is kept moist by the secretion of the lacrymal gland, placed under the upper lid at its outer side, and the lids are lubricated by the Harderian and Meibomian glands, the former being situated at the inner side of the orbit, and especially related to the nictitating membrane, the latter in the lining membrane of the lids.

The organ of hearing is enclosed in a bony capsule (periotic) situated in the side of the head, intercalated between the posterior (occipital) and the penultimate (parietal) segment of the skull. It has, in common with other vertebrates, three semicircular canals and a vestibule, but the cochlea is more fully developed than in *Sauropsida*, and, except in the Monotremes, spirally convoluted. The tympanic cavity is often dilated below, forming a smooth rounded prominence on the base of the skull, the tympanic bulla. The three principal ossicles, the "malleus," "incus," and "stapes," are always present, but variable in characters. In the *Sirenia*, *Cetacea*, and Seals they are massive in form, being in the first-named order of larger size than in any other mammals. In the *Cetacea* the malleus is ankylosed to the tympanic; in other mammals it is connected only with the membrana tympani. The stapes in the lower orders —Edentates, Marsupials, and Monotremes—has a great tendency to assume the columnar form of the corresponding bone in *Sauropsida*, its two rami entirely or partially coalescing.[1] The tympanic membrane (drum of the ear) forms the outer wall of the cavity. In the fœtal state it is level with the external surface of the skull, and remains so permanently in a few mammals, as the American Monkeys; but commonly, by the growth of the squamosal bone, it becomes deeply buried at the bottom of a bony tube (*meatus auditorius externus*), which is continued to the surface of the skin in a fibrous or fibro-cartilaginous form. In Whales, owing to the thickness of the subcutaneous adipose tissue, this is of great length, and is also extremely narrow. In most aquatic and burrowing animals the meatus opens upon the surface by a simple aperture, but

Hearing.

[1] The modifications of these bones are fully described by A. Doran, "Morphology of the Mammalian *Ossicula auditus*," *Trans. Linn. Soc.*, ser. 2, vol. i. pp. 371–497, pl. lviii.–lxiv., 1878.

in the large majority of the class there is a projecting fold of skin, strengthened by fibro-cartilages, called the pinna or auricle, or "external ear," of very variable size and shape, generally movably articulated on the skull, and provided with muscles to vary its position, as it helps to collect and direct the vibrations of sound into the meatus.

Reproductive Organs.

Testes. In the male the testes retain nearly their primitive or internal position throughout life in the *Monotremata*, *Sirenia*, *Cetacea*, most *Edentata*, *Hyracoidea*, *Proboscidea*, and Seals, but in other orders they either periodically (as in *Rodentia*, *Insectivora*, and *Chiroptera*) or permanently pass out of the abdominal cavity through the inguinal canal, forming a projection beneath the skin of the perineum, or becoming suspended in a distinct pouch of the integument called scrotum. All the Marsupials have a pedunculated scrotum, the position of which differs from that of other mammals, being in front of, instead of behind, the preputial orifice. The presence, absence, or comparative size and number of the accessory generative glands—prostate, vesicular, and Cowper's glands, as they are called—vary much in different groups of mammals.

Penis. The penis is almost always completely developed, consisting of two corpora cavernosa attached to the ischial bones, and of a median corpus spongiosum enclosing the urethra, and forming the glans at the distal portion of the organ. In Marsupials, Monotremes, and the Sloths and Anteaters, the corpora cavernosa are not attached directly to the ischia, and in the last-named the penis is otherwise of a very rudimentary character, the corpus spongiosum not being present. In many Marsupials the glans penis is bifurcated. In most *Primates*, *Carnivora*, *Rodentia*, *Insectivora*, and *Chiroptera*, but in no other orders, an *os penis* is present.

Ovaries and oviduct. In the female, the ovaries retain permanently their original abdominal position, or only descend a short distance into the pelvis. They are of comparatively smaller size than in other vertebrates, and have a definite flattened oval form, and are enclosed in a more or less firm "tunica albugenia." The oviduct has a trumpet-like, and usually fimbriated abdominal aperture, and is more or less differentiated into three portions:—(1) a contracted upper part, called in Man and the higher mammals "Fallopian tube"; (2) an expanded part with muscular walls, in which the ovum undergoes the changes by which it is developed into the fœtus, called the "uterus"; (3) a canal, the "vagina," separated from the last by a valvular aperture, and terminating in the urino-genital canal, or common urinal and genital passage, which in higher mammals is so short as scarcely to be distinct from the last. The complete distinction of the oviducts of the two sides throughout their whole length, found in all lower vertebrates, only occurs in this class in Monotremes, a prevailing mammalian characteristic being their more or less perfect coalescence in the middle line to form a single median canal. In the Marsupials this union only includes the lower part of the vagina; in most *Placentalia* it extends to the whole vagina and a certain portion of the uterus, which cavity is then described as "bicornuate." In the higher mammals, as in Man, and also in some of the Edentates, the whole of the uterus is single, the contracted upper portion of the oviducts or Fallopian tubes, as they are then called, entering its upper lateral angles by small apertures. In certain lower forms of mammals the urino-genital canal opens with the termination of the rectum into a common cloaca, as in other vertebrates; but it is characteristic of the majority of the class that the two orifices are more or less distinct externally.

Mammary glands. Mammary glands, which secrete the milk by which the young are nourished during the first portion of their existence after birth, are present in both sexes in all mammals, though usually only functional in the female. In the Monotremes alone, their orifices are mere scattered pores in the skin, but in all others they are situated upon the end of conical elevations, called mammillæ or teats, which, taken into the mouth of the young animal, facilitate the process of sucking. These are always placed in pairs upon some part of the ventral surface of the body, but varying greatly in number and position in different groups. In the *Cetacea*, where the prolonged action of sucking would be incompatible with their subaqueous life, the ducts of the glands are dilated into large reservoirs from which the contents are injected into the mouth of the young animal by the action of a compressor muscle.

Secondary sexual characters. Secondary sexual characters, or modifications of structure peculiar to one sex, but not directly related to the reproductive function, are very general in mammals. They almost always consist of the acquisition or perfection of some character by the male as it attains maturity, which is not found in the female or the young in either sex. In a large number of cases these clearly relate to the combats in which the males of many species engage for the possession of the females during the breeding season; others are apparently ornamental, and of many it is still difficult to apprehend the meaning. Many suggestions on this subject will, however, be found in the chapters devoted to it in Darwin's work on *The Descent of Man and Selection in Relation to Sex*, where most of the best-known instances are collected. Superiority of size and strength in the male of many species is a well-marked secondary sexual character related to the purpose indicated above, being probably perpetuated by the survivors or victors in combats transmitting to their descendants those qualities which gave them advantages over others of their kind. To the same category belong the great development of the canine teeth of the males of many species which do not use these organs in procuring their food, as the Apes, Swine, Musk and some other Deer, the tusk of the male Narwhal, the antlers of Deer, which are present in most cases only in the males, and the usual superiority in size and strength of the horns of the *Bovidæ*. Other secondary sexual characters, the use of which is not so obvious, or which may only relate to ornament, are the presence of masses or tufts of long hair on different parts of the body, as the mane of the male Lion and Bison, the beards of some Ruminants and Bats (as *Taphozous melanopogon*), Monkeys, and of Man, and all the variations of coloration in the sexes, in which, as a general rule, the adult male is darker and more vividly coloured than the female. Here may also be mentioned the presence or the greater development of odoriferous glands in the male, as in the Musk Deer, and the remarkable perforated spur with its gland and duct, so like the poison-tooth of the venomous serpents, found in the males of both *Ornithorhynchus* and *Echidna*, the use of which is at present unknown.

Placenta. *Placenta.*—The development of the mammalian ovum, and the changes which the various tissues and organs of the body undergo in the process of growth, are too intricate subjects to be explained without entering into details incompatible with the limits of this article, especially as they scarcely differ, excepting in their later stages, from those of other vertebrates, upon which, owing to the greater facilities these present for examination and study, the subject has been more fully worked out. There are, however, some points which require notice, as peculiar to the mammalian class, and as affording at least some hints upon the difficult subject of the affinities and classification of the members of the group.

The nourishment of the fœtus during intra-uterine life takes place through the medium of certain structures, partly belonging to the fœtus itself and partly belonging to the inner parietes of the uterus of the parent. These in their complete form constitute the complex organ called the "placenta," which serves as the medium of communication between the mother and fœtus, and in which the physiological processes that are concerned in the nutrition of the latter take place; but, as we shall see, though a placenta, in the usual acceptation of the term, is peculiar to the mammalian class, it is not in all of its members that one is developed. The structures to which we shall have especially to refer are the outer tunic of the ovum, to which, however formed, the term "chorion" is commonly applied, and two sac-like organs connected with the body cavity of the embryo, both formed from the splanchnic mesoblast, lined by a layer of the hypoblast. These are the "umbilical vesicle" or "yolk sac" and the "allantois."

The umbilical vesicle is a thin membrane enclosing the yolk, which by the doubling in of the ventral walls of the embryo becomes gradually formed into a distinct sac external to the body, with a pedicle (the omphalo-enteric duct) by which for a time a communication is maintained between its cavity and the intestinal canal. In the walls of this sac blood-vessels (omphalo-meseraic or vitelline) are developed in connexion with the vascular system of the embryo, through which, either by their contact with the outer surface of the walls of the ovum, or by the absorption through them of the contents of the yolk sac, the nutrition of the embryo in the lower vertebrates chiefly takes place. In mammals the umbilical vesicle plays a comparatively subordinate part in the nourishment of the fœtus, its function being generally superseded by the allantois.

The last-named sac commences at a very early period as a diverticulum from the hinder end of the alimentary tract of the embryo. Its proximal portion afterwards becomes the urinary bladder, the contracted part between this and the cavity of the allantois proper constituting the urachus, which passes out of the body of the fœtus at the umbilicus together with the vitelline duct. The mesoblastic tissue of the walls of the allantois soon becomes vascular; its arteries are supplied with fœtal blood by the two hypogastric branches of the iliacs, or main divisions of the abdominal aorta, and the blood is returned by venous trunks which unite to form the single umbilical vein which runs to the under surface of the liver, where, part of it joining the portal vein and part entering the vena cava directly, it is brought to the heart. These are the vessels which, with their surrounding membranes, constitute the umbilical cord, the medium of communication between the fœtus and the placenta, when that organ is fully developed.

The nature of the fœtal membranes of the *Monotremata* is not known. In the *Marsupialia* the observations made many years ago by Professor Owen, upon the development of the Kangaroo, have recently been confirmed by Dr H. C. Chapman,[1] but fuller investigations in different species and at different stages are still much to be desired. As far as is known, up to the period of the very premature birth of these animals the outer covering of the ovum or chorion is free from villi and not adherent to the uterine walls, for, though fitting into the folds of the latter, it is perfectly and readily separable in its entire extent from them. The umbilical vesicle is large, vascular, and adherent to a considerable portion of the chorion, while the allantois is relatively small, and, though the usual blood-vessels can be traced in it, it does not appear to contract any connexion with the chorion, and therefore much less with the walls of the uterus, of such a nature as to constitute a placenta. While in the uterus the nourishment of the fœtus seems therefore to be derived from the umbilical vesicle, as in reptiles and birds, rather than from the uterine walls by means of the allantoic vessels, as in the higher mammals. The latter vessels, in fact, play even a much less important part in the development of these animals, not only than in the placental mammals, but even than in the *Sauropsida*, for they can scarcely have the respiratory function assigned to them in that group. Pulmonary respiration and the lacteal secretion of the mother very early supersede all other methods of providing the due supply both of oxygen and of food required for the development and growth of the young animal. In this sense the Marsupials may be looked upon as the most typically "mammalian" of the whole class. In no other group do the milk-secreting glands play such an important part in providing for the continuity of the race.

In the third primary division of the *Mammalia*, the so-called *Placentalia*, the umbilical vesicle generally does not quite unite with the chorion, and disappears as development proceeds, so that no trace of it can be seen in the membranes of an advanced embryo; but it may persist until the end of intra-uterine life as a distinct sac in the umbilical cord, or lying between the allantois and amnion. The disappearance or persistence of the umbilical vesicle does not, according to our present knowledge, appear to be correlated with a higher or lower general grade of development, as might be presupposed. It is stated to have been found in Man even up to the end of intra-uterine life, and also in the *Carnivora*, while in the *Ungulata* and *Cetacea* it disappears at an earlier age. In many, if not all, of the *Rodentia*, *Insectivora*, and *Chiroptera*, it plays a more important part, becoming adherent to a considerable part of the inner surface of the chorion, to which it conveys blood-vessels, although villi do not appear to be developed from the surface of this part, as they are on the portion of the chorion supplied by the allantoic vessels. These orders thus present to a certain extent a transitional condition from the Marsupials, although essentially different, in possessing the structures next to be described.

The special characteristic of the whole of the placental mammals constituting the majority of the class, is that the allantois and its vessels become intimately blended with a smaller or greater part of the parieties of the ovum, forming a structure on the outer surface of which villi are developed, and which, penetrating into corresponding cavities of the "decidua," or soft, vascular, hypertrophied lining membrane of the uterus, constitutes the placenta. This organ may be regarded, as Professor Turner says, both in its function and in the relative arrangement of its constituent textures, as a specially modified secreting gland, the ducts of which are represented by the extremities of the blood-vessels of the fœtal system. The passage of material from the maternal to the fœtal system of vessels is not a simple percolation or diffusion through their walls, but is occasioned by the action of a layer of cells derived from the maternal or uterine structures, and interposed between the blood-vessels of the maternal part of the placenta and those of the villi covering the chorion, in which the embryonic vessels ramify.

The numerous modifications in the details of the structure of this organ relate to increasing the absorbing capacity of the vessels of the chorion, and are brought about either by increasing the complexity of the fœtal villi and maternal crypts over a limited area, or by increasing the area of the part of the chorion covered by the placental villi, or by various combinations of the two methods.

[1] *Proc. Acad. Nat. Sc. Philadelphia*, December 27, 1881; *Ann. Mag. Nat. Hist.*, April 1882.

The first class of variations has given rise to a distinction into two principal kinds of placenta—(1) simple or non-deciduate, and (2) deciduate. In the former the fœtal villi are received into corresponding depressions of the maternal surface, from which at the period of parturition they are simply withdrawn. In the second or more complex form the relation is more intimate, a layer of greater or less thickness of the lining membrane of the uterus, called "decidua," becoming so intimately blended with the chorion as to form part of the placenta proper, or that structure which is cast off as a solid body at parturition. In other words, in the one case the line of separation between the placenta and uterus at birth takes place at the junction of the fœtal and maternal structures, in the other through the latter, so that a portion of them, often of considerable thickness, and containing highly organized structures, is cast off with the former. It has been thought that the distinction between these two forms of placentation is so important as to constitute a sufficiently valid basis for a primary division of the placental mammals into two groups. It has, however, been shown that the distinction is one rather of degree than of kind, as intermediate conditions may exist, and it is not improbable that in different primary groups the simpler, non-deciduate form may have become developed independently into one or other of the more complex kinds.

Apart from its intimate structure, the placenta may be met with of very varied general form. It may consist of villi scattered more or less regularly over the greater part of the surface of the chorion, the two extremities or poles being usually more or less bare. This form is called the "diffused placenta." It is probably a primitive condition, from which most of the others are derived, although its existence must presuppose the absence of the umbilical vesicle as a constituent of the chorionic wall. It is found at present in the Manis among Edentates, the *Cetacea*, *Sirenia*, the Perissodactyle Ungulates, and the Camels, Pigs, and Chevrotains among the Artiodactyles. Such placentæ are always non-deciduate. In the true Ruminants or *Pecora*, among the Artiodactyle Ungulates, the villi are aggregated in masses called cotyledons, with bare spaces between. Such a placentation is called "polycotyledonary." In another modification the villi are collected in a more or less broad band encircling the chorion, leaving a very large portion of the two poles bare, constituting the "zonary placenta," characteristic of the *Carnivora*, and also occurring in the Elephant, Hyrax, and *Orycteropus*. The fact of the form of the placenta of these three last-named animals agreeing together, and with that of the *Carnivora*, does not, however, necessitate the ascription of zoological affinities, as the placenta of the *Carnivora* has been shown to be at first discoidal, and to become zonary by spreading round the chorion in the course of development. In the other cases, although it must be admitted that the early stages have not been well observed, it is quite probable that it may be derived from a diffused placenta, in which the fœtal villi have disappeared from a larger space than usual of the two poles of the ovum.

In another form one pole only of the chorion is non-vascular, the placenta assuming a dome or bell shape, as in the Lemurs and the Sloths. The transition from this, by the gradual restriction of the vascular area, is easy to the oval or discoidal form of placenta of the Anteaters, Armadillos, and *Primates*. The discoidal placenta of the Rodents, Insectivores, and *Chiroptera*, though showing so much superficial resemblance to that of the last-named order as to have caused them formerly to be associated in one primary group, is now known to be developed in another manner, not by the concentration of villi from a diffused to a limited area, but by retaining the area to which it was originally restricted in consequence of the large surface of chorion occupied, as before mentioned, by the umbilical vesicle. To compensate for the smallness of area, the complex or deciduate structure has been developed. We may conclude that, although the characters and arrangement of the fœtal structures may not have that extreme importance which has been attributed to them by some zoologists, they will form, especially when more completely understood, valuable aids in the study of the natural affinities and evolution of the *Mammalia*.[1]

CLASSIFICATION OF THE MAMMALIA.

As stated at the commencement of this article, the mammalian class, as at present known either by existing or extinct forms, is completely isolated from all other groups of the animal kingdom, but it is impossible to refrain from speculating as to its origin and nearest affinities. In arranging the classes of vertebrates in a linear series it is customary to place them in the following order—*Pisces*, *Amphibia*, *Reptilia*, *Aves*, *Mammalia*,—an order which may possibly indicate the relative degree of elevation to which the most completely developed members of each class attain, though it would be a great mistake to suppose that such an arrangement expresses the true relationship of one to the other, and still less must it be imagined that in the process of evolution any of the higher classes are necessarily derived directly from those nearest below them in this serial arrangement. On the contrary, some arguments recently set forth by Professor Huxley[2] point very strongly to the conclusion that, in looking among vertebrates for the progenitors of the *Mammalia*, we must pass over all known forms of birds and reptiles, and go straight down to the *Amphibia*. In addition to the characters derived from the conformation of the pelvis upon which the argument is primarily based, the following reasons are given for this conclusion:—"The *Amphibia* are the only air-breathing *Vertebrata* which, like mammals, have a dicondylian skull. It is only in them that the articular element of the mandibular arch remains cartilaginous, while the quadrate ossification is small, and the squamosal extends down over it to the osseous elements of the mandible, thus affording an easy transition to the mammalian condition of those parts. The pectoral arch of the Monotremes is as much amphibian as it is sauropsidian; the carpus and the tarsus of all *Sauropsida*, except the *Chelonia*, are modified away from the Urodele type, while those of the mammal are directly reducible to it. Finally, the fact that in all *Sauropsida* it is a right aortic arch which is the main conduit of arterial blood leaving the heart, while in mammals it is a left aortic arch which performs this office, is a great stumbling-block in the way of the derivation of the *Mammalia* from any of the *Sauropsida*. But, if we suppose the earliest forms of both the *Mammalia* and the *Sauropsida* to have had a common Amphibian origin, there is no difficulty in the supposition that, from the first, it was a left aortic arch in the one series, and the corresponding right aortic arch in the other, which became the predominant feeder of the arterial system."

There is so much in common between the very aberrant Monotremes, upon the structure of which the above conclusions are mainly based, and all other known mammals that we cannot but suppose they are derived, perhaps at some remote period, from one stock, some of the predominating characters of which survive in the existing

[1] For a full exposition of the present state of knowledge on this subject, see the various memoirs of Professor Turner, and especially F. M. Balfour's *Treatise on Comparative Embryology*, 1881, vol. ii.

[2] *Proceedings of the Royal Society of London*, vol. xxviii., 1879, p. 395.

Monotremes, though lost in most other members of the class. These "Prototheria," as Professor Huxley terms them, have in their turn probably been derived from the same source as that in which the existing *Amphibia* on the one hand and the *Sauropsida* on the other have had their origin. The great divisions of the *Vertebrata* may be looked upon therefore as parallel, or rather diverging groups, each tending towards its own specialization, not in any way in the light of ancestor and descendant. No further advance of the Sauropsidian type, which has reached its highest perfection in the modern volant birds, would bring it nearer to the mammalian organization.

Restricting ourselves now to the class of mammals, as differentiated from other vertebrates, it will be unnecessary to repeat the oft-told history of the various attempts to express the prevailing knowledge of their structure and affinities in a systematic manner called a classification. The systems of Ray, Linnæus, Cuvier, Owen, Milne-Edwards, Huxley, and others mark successive epochs of that knowledge. A perfect arrangement of any group of animals can only be obtained simultaneously with a perfect knowledge of their structure and life history, and from this, it need scarcely be said, we are still very far removed. If, as was formerly the case, classifications could be confined to existing species, the work would be far less difficult. By the extinction of intermediate forms the surviving groups have mostly come to be much isolated, and their limits can be readily determined and defined. The discovery of extinct species, which appears to be taking place at a constantly increasing rate, is by degrees breaking down these boundaries, and making definitions impossible, though at the same time it is throwing much light upon the affinities and probable origin of many groups now widely separated. A source of difficulty, and perhaps error, which this advancing knowledge has introduced, arises from the necessity of determining the position and relation of so many forms by the bones and teeth alone, without any hope of deriving aid from all those other structures of which we avail ourselves in the case of recent animals. These considerations will show that any classification advanced at present must be regarded as provisional. There are, however, some positions which seem to be so firmly established that it is very unlikely that we shall be dislodged from them by any further increase of knowledge, and which we should carefully distinguish from others which are acknowledged to be doubtful, and adopted rather for convenience, owing to the necessity of having some arrangement, than as representing unimpeachable truth.

ree at ural divisions.

One of the most certain and fundamental points in the classification of the *Mammalia* is, that all the animals now composing the class can be grouped primarily in three natural divisions, which, presenting very marked differentiating characters, and having no existing, or yet certainly demonstrated extinct, intermediate or transitional forms, may be considered as subclasses of equal value, taxonomically speaking, though very different in the numbers and importance of the animals at present composing them. These three groups are often called by the names originally proposed for them by De Blainville—(1) *Ornithodelphia*, (2) *Didelphia*, (3) *Monodelphia*,—the first being equivalent to the order *Monotremata*, the second to the *Marsupialia*, and the third including all the remaining members of the class. Although actual palæontological proof is wanting, there is much reason to believe that each of these, as now existing, are survivors of distinct branches to which the earliest forms of mammals have successively given rise, and for which hypothetical branches Huxley has proposed the names of *Prototheria*, *Metatheria*, and *Eutheria*,[1] names which, being far less open to objection than those of Blainville, we shall here use as equivalents for the latter.

Prototheria.

The characters of the *Prototheria* can only be deduced from the two existing families, as hitherto no extinct animals which can be referred to other divisions of this remarkable and well-characterized group have been discovered. These two isolated forms, in many respects widely dissimilar, yet having numerous common characters which unite them together and distinguish them from the rest of the *Mammalia*, are the *Ornithorhynchidæ* and the *Echidnidæ*, both restricted in their geographical range to the Australian region of the globe. Taken altogether they represent the lowest type of evolution of the mammalian class, and most of the characters in which they differ from the other two subclasses tend to connect them with the inferior vertebrates, the *Sauropsida* and *Amphibia*; for, though the name *Ornithodelphia* owes its origin to the resemblance of the structure of the female reproductive organs to those of birds, there is nothing especially bird-like about them.

Their principal distinctive characters are these. The brain has a very large anterior commissure, and a very small corpus callosum, agreeing exactly in this respect with the next group. The cerebral hemispheres, in *Echidna* at least, are well developed and convoluted on the surface. The auditory ossicles present a low grade of development, the malleus being very large, the incus small, and the stapes columelliform. They have no true teeth, though the jaws of *Ornithorhynchus* are provided with horny productions, which functionally supply their place. The coracoid bone is complete, and articulates with the sternum, and there is a large "interclavicle" or episternum in front of the sternum, and connecting it with the clavicles. There are also "epipubic" bones. The oviducts (not differentiated into uterine and Fallopian portions) are completely distinct, and open as in oviparous vertebrates separately into a cloacal chamber, and there is no distinct vagina. The testes of the male are abdominal in position throughout life, and the vasa deferentia open into the cloaca, not into a distinct urethral passage. The penis, attached to the ventral wall of the cloaca, is perforated by a canal in the greater part of its length, but not at the base, which is open as in reptiles and those birds which have such an organ, and brought only temporarily in contact with the termination of the vasa deferentia, so as to form a seminal urethra when required, but never transmits the urinary secretion. This condition is a distinct advance on that of the *Sauropsida* in the direction of the more complete development of these parts in most of the other *Mammalia*. The ureters do not open into the bladder, but behind it into the dorsal wall of the genito-urinary passage. The mammary glands have no distinct nipple, but pour out their secretion through numerous apertures in the skin. The early stages of the development of the young are not yet fully known, but they are produced in a very rudimentary condition, and appear never to be nourished by means of an allantoic placenta.

Metatheria.

The *Metatheria* or *Didelphia* are represented at present by numerous species, presenting great diversities of general appearance, structure, and habits, although all united by many essential anatomical and physiological characters, which, taken altogether, give them an intermediate position between the *Prototheria* and the *Eutheria*. In the structure of the brain and the presence of epipubic bones they agree with the former, while in the structure of the ear bones and the shoulder girdle and the presence of teats on the mammary glands they resemble the latter, the reproductive organs belonging to neither one nor the other type, but presenting a special character representing an intermediate grade of development. The ureters open into the base of the bladder. The oviducts are differentiated into

[1] *Proceedings of the Zoological Society*, 1880, p. 649.

uterine and Fallopian portions, and open into a long and distinct vagina, quite separate from the cystic urethra. The penis is large, but its crura are not directly attached to the ischia. The spongy body has a large bifurcated bulb. The young are born in an exceedingly rudimentary condition, and are never nourished by means of an allantoic placenta, but are transferred to the nipple of the mother, to which they remain firmly attached for a considerable time, nourished by the milk injected into the mouth by compression of the muscle covering the mammary gland. They are therefore, as previously remarked (see p. 369), the most typically mammalian of the whole class. The nipples are nearly always concealed in a fold of the abdominal integument or "pouch" (marsupium) which serves to support and protect the young in their early helpless condition. The existing species of this group are entirely confined to the Australian region and the American continent, though in former times they had a more extended geographical range. The earliest mammals hitherto discovered appear (as far as the scanty evidence at present obtainable permits any such conclusion to be hazarded) to have belonged to this type, although it is reasonable to conclude that *Prototheria* (unless upon the improbable supposition that the existing forms have resulted from a process of degradation), and perhaps *Eutheria*, were their contemporaries far back in the Mesozoic age

Eutheria. The *Eutheria*, *Monodelphia*, or "placental mammals" (so called because the fœtus is always nourished while within the uterus of the mother by means of an allantoic placenta) include at present by far the greater proportion of the class. While the survivors of the other groups have probably been for a long time in a stationary condition, these have, as there is already good evidence to show throughout all the Tertiary geological age, and by inference for some time before, been multiplying in numbers and variations of form, and attaining higher stages of development and specialization in various directions. They consequently exhibit far greater diversity of external or adaptive modification than is met with in either of the other subclasses,—some being fitted to live as exclusively in the water as fishes, and others to emulate the aerial flight of birds.

To facilitate the study of the different component members of this large group, it is usual to separate them into certain divisions which are called "orders." In the main zoologists are now of accord as to the general number and limits of these divisions among the existing forms, but the affinities and relationships of the orders to one another are far from being understood, and there are very many extinct forms already discovered which do not fit at all satisfactorily into any of the orders as commonly defined.

Commencing with the most easily-distinguished, we may first separate a group called *Edentata*, composed of several very distinct forms, the Sloths, Anteaters, and Armadillos, which under great modifications of characters of limbs and digestive organs, as well as habits of life, have just enough in common to make it probable that they are the very specialized survivors of an ancient group, most of the members of which are extinct, but which the researches of palæontology have not yet revealed to us. The characters of their cerebral, dental, and in many cases of their reproductive organs show an inferior grade of organization to that of the generality of the subclass. The next order, about the limits of which there is no difficulty, is the *Sirenia*, aquatic vegetable-eating animals, with complete absence of hind limbs, and low cerebral organization,—represented in our present state of knowledge by but two existing genera, the Dugongs and Manatees, and by a few extinct forms, which, though approaching a more generalized mammalian type, show no special characters allying them to any of the other orders. Another equally well-marked and equally isolated, though far more numerously represented and diversified order, is that of the *Cetacea*, composed of the various forms of Whales, Dolphins, and Porpoises. In aquatic habits, external fish-like form, and absence of hind limbs they resemble the last, though in all other characters they are as widely removed as are any two orders among the *Eutheria*. The association by systematists of the *Cetacea* and *Sirenia* in one group can only be made either in ignorance of their true structure, or in an avowedly artificial system.

All the remaining orders are more nearly allied together, the steps by which they have become modified from one general type being in most cases not difficult to realize. Their dentition especially, however diversified in detail, always responds to the formula already described (see p. 353); and, although the existing forms are broken up into groups in most cases easy of definition, the discoveries already made in palæontology have in great measure filled up the gaps between them.

Very isolated among existing *Eutheria* are the two species of Elephant constituting the order called *Proboscidea*. These, however, are now known to be the survivors of a large series of similar animals, Mammoths, Mastodons, and *Dinotheria*, which as we pass backwards in time gradually assume a more ordinary or generalized type; and the interval which was lately supposed to exist between even these and the rest of the class is partially bridged over by the discovery in American Eocene and early Miocene formations of the gigantic *Dinocerata*, evidently offshoots of the great group of hoofed animals, or *Ungulata*, represented in the actual fauna by the Horses, Rhinoceroses, Tapirs, Swine, and Ruminants. Almost as isolated as the *Proboscidea* among existing mammals are the few small species constituting the genus *Hyrax*, and in their case palæontology affords no help at present, and therefore, pending further discoveries, it has been thought advisable in most recent systems to give them the honour of an order to themselves, under the name of *Hyracoidea*. But the number of extinct forms already known allied to the *Ungulata*, but not coming under the definition of either of the two groups (*Artiodactyla* and *Perissodactyla*) under which all existing species range themselves, is so great that either many new orders must be made for their reception or the definition of the old order *Ungulata* so far extended as to receive them all, in which case both *Proboscidea* and *Hyracoidea* might be included within it. Again the *Rodentia*, or gnawing animals—Rabbits, Rats, Squirrels, Porcupines, Beavers, &c.—are, if we look only at the present state of the class, most isolated. No one can doubt what is meant by a Rodent animal, or have any difficulty about defining it clearly, at least by its dental characters; yet our definitions break down before the extinct South American *Mesotherium*, half Rodent and half Ungulate, which leads by an easy transition to the still more truly Ungulate Toxodon, for the reception of which a distinct order (*Toxodontia*) has been proposed. The *Insectivora* and the *Carnivora* again are at present quite distinct orders, but they merge into one another through fossil forms, and are especially connected by the large group of primitive *Carnivora*, so abundantly represented in the Eocene deposits both of America and Europe, to which Cope has given the name of *Creodonta*. The transition from the Insectivores to the Lemurs is not great, and, strange to say, however different they now appear, the early forms of Lemurs are not easily distinguished from the primitive Ungulates. The Bats or *Chiroptera* are allied to the *Insectivora* in all characters but the extraordinary modification of their anterior extremities into wings, but this, like the want of the hind limbs in the *Cetacea* and *Sirenia*, makes such a clear distinction between them and all other mammals that, in the absence of any knowledge of intermediate or transitional forms, they can be perfectly separated, and form as well defined an order as any in the class. Lastly, we have the important and well-characterized group, called *Primates*, including all the Monkeys and Man, and the question is not yet solved as to how and through what forms it is linked on to the other groups. It is commonly assumed that the Lemurs are nothing more than inferior *Primates*, but the interval between them in the actual fauna of the world is very great, and our knowledge of numerous extinct species recently discovered in America, said to be intermediate in characters, is not yet sufficiently perfect to enable us to form a definite opinion upon the subject.

The distinctive characters of the generally recognized orders of mammals, with an account of their subdivisions and the principal forms contained in each, will be given further on.

GEOGRAPHICAL DISTRIBUTION OF MAMMALIA.

The existing species of few classes of the animal kingdom are better known than those of the *Mammalia*, and, owing to the comparatively limited methods of locomotion or transport which most of them possess, the area of distribution of each species is more definite and restricted than in some other classes. In the articles BIRDS and DISTRIBUTION the various regions into which naturalists have divided the earth's surface, according to the prevailing characters of its animal inhabitants, have been described, and in the latter the main facts connected with the distribution of mammals have been treated of. In the account of each group contained in the present article the particular circumstances relating to its geographical range will be mentioned. There is little therefore needed here, except a brief summary of the most important facts relating to this interesting subject.

As regards their distribution over the surface of the earth, mammals may be divided into three groups according to their principal methods of locomotion—(1) aerial, (2) aquatic, and (3) terrestrial.

rial mm- als.

1. *Aerial Mammals.*—This group only comprises the animals composing the single order *Chiroptera*, which differ from all other mammals in the fact that their principal means of transport from place to place is by aerial flight, as in the majority of birds and insects. Broad expanses of water, which form natural barriers to the spread of terrestrial mammals, are therefore no obstacles to their distribution; accordingly we find the general rule that mammals are not inhabitants of oceanic islands modified in their case. But even in this group, notwithstanding their exceptional powers of locomotion, different species, genera, and families inhabit very definite areas. Each zoological region of the earth has its characteristic Bats; and those of the New World and of the Old World are, with very few exceptions, quite distinct. This subject will be more fully treated of under the order *Chiroptera*.

quatic mm- als.

2. *Aquatic Mammals.*—Many mammals grouped for the present purpose as terrestrial pass a great portion of their lives in brooks, lakes, or rivers, and, being dependent upon such waters for obtaining their subsistence, are necessarily confined to their vicinity; but the truly aquatic mammals, or those living constantly in the water, and unable to move their quarters from place to place by land, are the orders *Cetacea* and *Sirenia*, with which may also be grouped the Seals, forming the Pinniped division of the order *Carnivora*.

For the marine *Cetacea*, animals mostly of large size and endowed with powers of rapid locomotion, there are obviously no barriers to universal distribution over the surface of the earth covered by sea, except such as are interposed by uncongenial temperature or absence of suitable food. Nevertheless it was thought some years ago that the fact of a Whale or a Dolphin occurring in a sea distant from that in which it had usually been found was sufficient justification for considering it as a distinct species and imposing a new name upon it. There are now, however, so many cases known in which Cetaceans from the northern and southern seas, from the Atlantic and the Pacific Oceans, present absolutely no distinguishing external or anatomical characters upon which specific determination can be based that the opposite view is gaining ground; and, as some species are undoubtedly very widely distributed, almost cosmopolitan in fact, there seems little reason why many others should not be included in the same category. The evidence is satisfactory enough in those cases in which the intermediate regions are inhabited by the same forms, the cases of "continuous areas" of distribution. In those in which the areas of distribution are apparently discontinuous, there may be more room for doubt; but it must not be forgotten that the negative evidence is here of much less value than in the case of land animals, as the existence of Cetaceans in any particular part of the ocean is most easily overlooked. The great Sperm Whale (*Physeter macrocephalus*) is known to be almost cosmopolitan, inhabiting or passing through all the tropical and temperate seas, although not found near either pole. At least three of the well-known species of Rorqual (*Balænoptera*) of the British coasts are represented in the North Pacific, on the South American shores, and near New Zealand by species so closely allied that it is difficult to point out any valid distinctive characters, though it may perhaps be desirable to wait for a more complete examination of a large series of individuals before absolutely pronouncing them to be specifically identical. There is nothing yet known by which we can separate the "Humpback Whales" (*Megaptera*) of Greenland, the Cape of Good Hope, and Japan. The same may be said of the common Dolphin of the European seas (*Delphinus delphis*) and the so-called *D. bairdii* of the North Pacific and *D. forsteri* of the Australian seas. The Pilot Whale (*Globicephalus melas*) and the *Pseudorca* of the North Atlantic and of New Zealand are also precisely alike, as far as present knowledge enables us to judge. Many other similar cases might be given. Captain Maury collected much valuable evidence about the distribution of the larger *Cetacea*, and, finding Right Whales (*Balæna*) common in both northern and southern temperate seas, and absent in the intermediate region, laid down the axiom that "the torrid zone is to the Right Whale as a sea of fire, through which he cannot pass." Hence all cetologists have assumed that the Right Whale of the North Atlantic (*B. biscayensis*), that of the South Seas (*B. australis*), and that of the North Pacific (*B. japonica*) are necessarily distinct species. The anatomical structure and external appearance of all are, however, as far as yet known, marvellously alike, and, unless some distinguishing characters can be pointed out, it seems scarcely justifiable to separate them upon geographical position alone; as, although the tropical seas may be usually avoided by them, it scarcely seems impossible, or even improbable, that some individuals of animals of such size and rapid powers of swimming may not have at some time traversed so small a space of ocean as that which divides the present habitual localities of these supposed distinct species. If identity or diversity of structural characters is not to be allowed as a test of species in these cases, as it is usually admitted to be in others, the study of their geographical distribution becomes an impossibility.

Although many species are thus apparently of such wide distribution, others are certainly restricted; thus the

Arctic Right Whale (*Balæna mysticetus*) has been conclusively shown to be limited in its range to the region of the northern circumpolar ice, and no corresponding species has been met with in the southern hemisphere. In this case, not only temperature, but also the peculiarity of its mode of feeding, may be the cause. The Narwhal and the Beluga have a very similar distribution, though the latter occasionally ranges farther south. The Hyperoodons are restricted to the North Atlantic, never entering, as far as is yet known, the tropical seas. Other species are exclusively tropical or austral in their range. One of the true Whalebone Whales (*Neobalæna marginata*) has only been met with hitherto in the seas round Australia and New Zealand, a large Ziphioid (*Berardius arnouxi*) only near the last-named islands.

The *Cetacea* are not limited to the ocean, or even to salt water, some entering large rivers for considerable distances, and some being exclusively fluviatile. One species of *Platanista* is extensively distributed throughout nearly the whole of the river systems of the Ganges, Brahmaputra, and Indus, ascending as high as there is water enough to swim in, but apparently never passing out to sea. The individuals inhabiting the Indus and the Ganges must therefore have been for long ages isolated without developing any definite distinguishing anatomical characters, for those by which the supposed *P. indi* was formerly separated from *P. gangetica* have been shown by Anderson to be of no constant value. *Orcella fluminalis* appears to be limited to the Irawaddy river, and at least two distinct species of Dolphin, belonging to different genera, are found in the waters of the upper Amazon. It is remarkable, however, that none of the great lakes or inland seas of the world are, according to our present knowledge, inhabited by Cetaceans. A regular seasonal migration has been observed in many of the oceanic *Cetacea*, especially those inhabiting the North Atlantic, but further observations upon this subject are still much needed.

The great difference in the manner of life of the *Sirenia*, as compared with that of the *Cetacea*, causes a corresponding difference in their geographical distribution. Slow in their movements, and feeding exclusively upon vegetable substances, water-grasses, or fuci, they are confined to rivers, estuaries, or coasts where these grow, and are not denizens of the open sea, although of course there is a possibility of accidental transport by the assistance of oceanic currents across considerable distances. Of the three genera existing within historic times, one (*Manatus*) is exclusively confined to the shores of the tropical Atlantic and the rivers entering into it, individuals scarcely specifically distinguishable being found both on the American and the African side of the ocean. The Dugong (*Halicore*) is distributed in different colonies, at present isolated, throughout the Indian Ocean from Arabia to North Australia. The *Rhytina* or Northern Sea-Cow was, for some time before its extinction, limited to a single island in the extreme north of the Pacific Ocean.

The Pinnipeds, although capable of traversing long reaches of ocean, are less truly aquatic than the last two groups, always resorting to the land or to extensive ice-floes for the purposes of breeding. The geographical range of each species is generally more or less restricted, usually according to climate, as they are mostly inhabitants either of the Arctic or Antarctic seas and adjacent temperate regions, very few being found within the tropics. For this reason the northern and the southern species are for the most part quite distinct. In fact, the only known exception is the case of a colony of the Sea-Elephant (*Macrorhinus leoninus*), the general range of which is in the southern hemisphere, inhabiting the coast of California. Even in this case a different specific name has been given to the northern form, but the characters by which it is distinguished are not of great importance, and probably, except for the abnormal geographical distribution, would never have been discovered. The most remarkable circumstance connected with the distribution of the Pinnipeds is the presence of members of the order in the three isolated great lakes or inland seas of Central Asia—the Caspian, Aral, and Baikal—which, notwithstanding their long isolation, have varied but slightly from species now inhabiting the Polar Seas.

Terrestrial mammals.

3. *Terrestrial Mammals.*—One of the most important facts connected with the present distribution of terrestrial mammals, but one of which the cause is sufficiently obvious, is their entire absence, except where introduced by the direct agency of man, from all oceanic islands, including even the great New Zealand group. Another, equally striking, but less easily explained, is the very marked isolation as regards its mammalian fauna of the Australian region of zoologists. When once the narrow neutral ground on the border line between this and the Oriental region is passed, there is not found, notwithstanding the vast extent of land it comprises, a single indigenous placental or monodelphous mammal, except a few species of a single family (*Muridæ*) of the very wide spread order *Rodentia*,—the Wild Dog or Dingo having been in all probability introduced. On the other hand, the members of the other two subclasses, the *Prototheria* or *Ornithodelphia* and the *Metatheria* or *Didelphia*, are almost entirely restricted to this region. It might have been said entirely, but for the presence of one family (*Didelphidæ*) of the latter group in America.

The *Eutheria* or *Monodelphia* are distributed throughout the remaining geographical regions, as described in the article DISTRIBUTION, and in many cases form valuable indications by which the natural boundaries of these divisions have been traced. Many anomalies, otherwise inexplicable in the present range of families and species, have been cleared up by the study of their distribution in former geological epochs, a subject in relation to which the present facts of distribution should always be studied. There are few lines of evidence so conclusive as this in favour of the existing species being modified lineal descendants of those which have lived in previous times upon the earth.[1]

HISTORY OF THE MAMMALIA IN PAST TIMES.

As already intimated, such knowledge as we yet possess of the history of mammals in past times is of very recent growth, and is still extremely incomplete. The very rapid advances which have been made in the last few years, especially in consequence of the explorations of rich fossiliferous beds in North America, have not only completely changed the present aspect of the science, but give such promise for the future that any sketch which we might now attempt of this branch of the subject could only be regarded as representing a transient phase of knowledge. It will be well, however, to gather together in this place the leading facts now ascertained with regard to the most ancient forms, as, owing to the uncertainty of their relationship with any of the existing orders, they will be most conveniently treated of separately, while the ascertained facts relating to the geological history of the forms more nearly allied to those now living will be more appropriately described under the account of the different groups into which the class may now be divided.

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[1] On this subject, see A. Murray, *Geographical Distribution of Mammals*, 1866; and especially A. R. Wallace, *The Geographical Distribution of Animals*, 2 vols., 1876, and *Island Life*, 1881.

Mammals of the Mesozoic Period.[1]

The hitherto discovered remains of mammals which existed anterior to the Tertiary period all belong to creatures of very small size, the largest scarcely exceeding the common Polecat or Squirrel. Some are known only by a few isolated teeth, others by nearly complete sets of these organs, and the majority by more or less perfect specimens of the rami of the lower jaw. It is a very curious circumstance that this part of the skeleton alone has been preserved in such a large number of instances. No complete cranium has ever been found, nor is there satisfactory evidence of the structure of the vertebral column or of the limbs of any single individual. The species already described from European strata amount to nearly thirty, which have been arranged in fifteen genera. Of these by far the greater number have been found at a single spot near Swanage in Dorsetshire, in a bed of calcareous mud only 40 feet long, 10 feet wide, and averaging 5 inches in depth. The marvellous results obtained by the exploration by Mr S. H. Beckles of this small fragment of the earth's surface show by what accidents, as it were, our knowledge of the past history of life has been gained, and what may still remain in store where little thought of at present. A bed, apparently equally rich, has recently been discovered in the Territory of Wyoming, North America, the contents of which are being made known by Professor Marsh.

1. *Mammals of the Triassic Period.*—The Rhætic formations, so named from the Rhætian Alps of Bavaria, are the highest beds of the Trias, and are situated above the New Red Sandstone, and just below the Lias. In 1847 Professor Pleininger of Stuttgart, while assiduously sifting some sand from this formation, belonging to the Keuper of Diegerloch and Steinenbronn, discovered, among an immense mass of teeth, scales, and unrecognizable fragments of skeletons of fish and saurians, two minute teeth, each with well-defined, enamelled, tuberculated crowns and distinct roots, plainly showing their mammalian character. These, the oldest known evidence of the class, were considered by their discoverer to indicate a predaceous and carnivorous animal of very small size, to which he gave the name of *Microlestes antiquus.* Subsequently Mr C. Moore discovered in a bone bed of Rhætic age filling a fissure in the mountain limestone at Holwell, near Frome in Somersetshire, various isolated teeth with their crowns much worn, but apparently including both upper and lower molars and a canine, which are assigned by Professor Owen to Pleininger's genus *Microlestes,* and described specifically as *M. moorei.* Under the name of *Hypsiprymnopsis rhæticus* Prof. Boyd Dawkins[2] has described a single tooth with two roots which he discovered in a Rhætic marlstone at Watchet in Somersetshire, and which may be even somewhat older than the last. Professor Dawkins finds the nearest analogue of this tooth among recent mammals in the large trenchant premolar of the Rat-Kangaroo or *Hypsiprymnus* (see vol. xiii. p. 840, fig. 4), a resemblance not concurred in by Professor Owen, who refers it to the genus *Microlestes.* The minute size and worn condition of the tooth render it extremely difficult to form a decided opinion upon its characters, and therefore upon the affinities of the animal to which it belonged.

Still more satisfactory evidence of the presence of mammals at a period at least as ancient as the European Trias is afforded by the discovery of three nearly perfect mandibular rami in the Chatham coal-field of North Carolina by Dr Emmons, who, however, placed them as far back in age as the Permian, or altogether beyond the Mesozoic stage, a conclusion not now received. Of this animal, called *Dromatherium sylvestre,* the complete dentition of the lower jaw is known, and consists of three pointed incisors, separated by intervals, one canine, and ten molars, of which the first three have simple subcompressed crowns, and the remainder are multicuspid. The jaw figured by Dr Emmons[3] is $\frac{9}{10}$ of an inch in length. He considered it to belong to a placental Insectivore, but the number of molar teeth exceeds that of any existing member of that order, and is only found in some Marsupials. It was associated in the same bed with thecodont reptiles.

2. *Mammals of the Jurassic Period.*—In the ascending order of geological age the next remains of mammals have been met with in the Lower Oolite at Stonesfield in Oxfordshire, where they are associated with wing cases of insects, Plesiosaurs, Crocodiles, and Pterodactyles. From this bed several specimens have been met with at various times, which have been placed in three genera.

A. *Amphitherium,* Blainville, 1838. The specimen (*A. prevostii,* see fig. 15) upon which this genus was founded, was discovered in 1812, and examined in 1818 at Oxford by Cuvier, who pronounced it to be mammalian, and to resemble the jaw of an Opossum. This conclusion was afterwards disputed by De Blainville and others, who

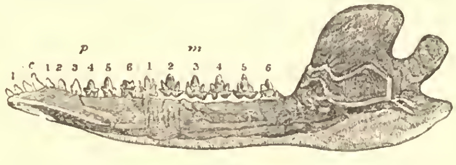

FIG. 15.—Lower Jaw and Teeth of *Amphitherium prevostii* (twice nat. size). From Owen.

believed it to be reptilian, but the original determination is now generally accepted.[4] Three rami of mandibles, all more or less perfect, are now known. The length of the jaw is rather less than an inch. It contains sixteen teeth, which, as defined by shape only, are—*i* 3, *c* 1, *p* 6, *m* 6, so that if the upper jaw had a corresponding number

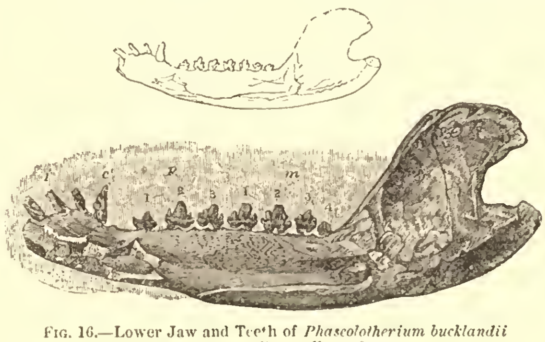

FIG. 16.—Lower Jaw and Teeth of *Phascolotherium bucklandii* (nat. size in outline). From Owen.

there would be sixty-four teeth in all,—a greater number than in any existing heterodont mammal, though equalled by some of the species from the Purbeck. The nearest approach to this number is in *Myrmecobius* among recent Marsupials. The incisors are rather long and slender, the canines apparently not much larger than the incisors, all the premolars and molars two-rooted—the former with a single large pointed cusp and small basal cusp on one or both sides, the latter quinquecuspidate. The lower margin

[1] The subjects referred to under this heading are mostly described and figured in detail in Owen's "Monograph of the Fossil Mammalia of the Mesozoic Formations," *Palæontographical Society's Publications,* 1871; and in various papers by Marsh, in the *American Journal of Science and Arts,* 1878–80.

[2] *Quart. Jour. Geol. Soc.,* vol. xx. p. 411, 1864.

[3] *American Geology,* part vi., p. 93, 1857.

[4] A full description of this interesting fossil, with a history of the discussion regarding its nature, is given in Owen's *British Fossil Mammals and Birds.*

of the angular process is slightly inflected, and the mylohyoid groove persistent, as in some of the existing Marsupials and in Whalebone Whales. This groove, a remnant of that which originally lodges Meckel's cartilage, mistaken for a suture, was once considered evidence of the reptilian nature of these jaws. A second species is described as *A. broderipii* (Owen).

B. *Phascolotherium*, Owen, 1839. This is founded on a right ramus of the lower jaw, presenting the inner side to view. Its length is 1·4 inch. The number of teeth resemble those of existing insectivorous mammals, being *i* 3 or 4, *c* 1, *p* and *m* 7, but not clearly defined from each other. One species, *P. bucklandii* (fig. 16).

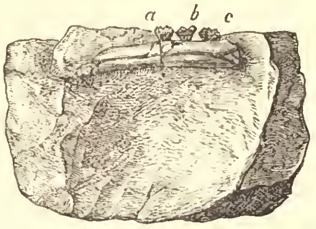

Fig. 17.—*Stereognathus.* Portion of Jaw, embedded in Oolitic matrix (nat. size). From Owen.

C. *Stereognathus*, Charlesworth, 1854. *S. ooliticus* (fig. 17) is founded on a fragment of a jaw of minute size with three molar teeth *in situ.* The grinding surface is of quadrate form, of very little height, and supports six subequal cusps. Its affinities are quite problematical.

The freshwater bed previously alluded to, situated at Durdlestone Bay near Swanage, belongs to the Middle Purbeck series, intervening between the Middle Oolite and the Wealden. The first discovery of mammalian bones was made in this spot by Mr W. R. Brodie in 1854, but the subsequent explorations of Mr S. H. Beckles have yielded a surprising number of species. They are associated with numerous saurians, insects, and freshwater shells, as *Paludina*, *Planorbis*, and *Cyclas.* No less than eleven genera from this locality alone are fully described in Professor Owen's memoir. These may be grouped as follows :—

A. With teeth arranged on the insectivorous type. Mandibular incisors more than two; canines well developed; premolars and molars cuspidate, seven or more :—(*a*) molars and premolars more than eight, mostly twelve (*Spalacotherium*, *Amblotherium*, *Peralestes*, *Achyrodon*, *Peraspalax*, *Peramus*, *Stylodon* and *Bolodon*—the last known only by the maxillary teeth);

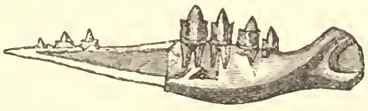

Fig. 18.—*Spalacotherium tricuspidens* (twice nat. size), Purbeck beds. From Owen.

(*b*) molars and premolars seven or eight (*Triconodon* and *Triacanthodon*). As any synopsis of the characters of these genera would be scarcely intelligible without minute descriptions and reference to figures, the reader who desires further information is referred to the memoir cited above.

Fig. 19.—Jaw of *Triconodon mordax* (nat. size). From Owen.

B. With a single, strong, pointed, slightly curved incisor, placed close to the median line as in Rodents. No canine. Three or four compressed, trenchant, obliquely grooved premolars, increasing in size from first to last, and two small molars with low multituberculated crowns. Genus *Plagiaulax*, Falconer. This remarkable and highly specialized type has been the occasion of one of the most interesting discussions on the inferences which may be drawn as to the affinities and habits of an otherwise unknown animal from the structure of a small portion of its organization which occurs in the annals of natural history, a discussion carried on with great ability, ingenuity, and wealth of illustration on both sides. Dr Falconer maintained that it was more nearly allied to the Rat-Kangaroo (*Hypsiprymnus*) than to any other existing form, and that, as it is known that these animals feed upon grass and roots, "it may be inferred of *Plagiaulax* that the species were herbivorous or frugivorous. I can see nothing in the character of their teeth," he adds, "to

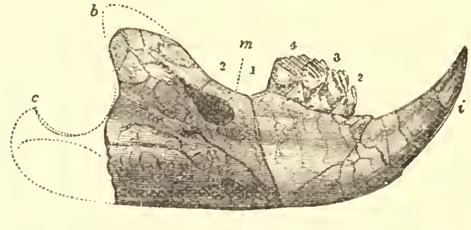

Fig. 20.—*Plagiaulax becclesii* (twice nat. size). From Owen.

indicate that they were either insectivorous or omnivorous." Professor Owen, on the other hand, from the same materials came to the conclusion that "the physiological deductions from the above-described characteristics of the lower jaw and teeth of *Plagiaulax* are that it was a carnivorous Marsupial. It probably found its prey in the contemporary small insectivorous mammals and Lizards, supposing no herbivorous form like *Stereognathus* to have co-existed during the Upper Oolite period."

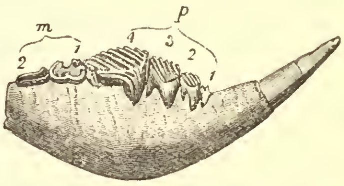

Fig. 21.—*Plagiaulax minor* (four times nat. size). From Lyell.

It is impossible here to give at any length the arguments by which these opposing views are respectively supported, but it may be indicated that the first-mentioned is strongly countenanced by the consideration of the following facts :—(1) all existing Marsupials may be divided, as far as their dentition is concerned, into two groups—(*a*) those which have a pair of large more or less procumbent incisors close to the symphysis of the lower jaw, and rudimentary or no canines (diprotodont dentition; families *Phascolomyidæ*, *Macropodidæ*, and *Phalangistidæ*), and (*b*) those which have numerous small incisors, and large pointed canines (polyprotodont dentition; families *Peramelidæ*, *Dasyuridæ*, and *Didelphidæ*); (2) the vast majority of the former group are purely vegetable feeders, and almost all of the latter are carnivorous or insectivorous; and (3) *Plagiaulax*, so far as its structure is known, belongs obviously to the former group, and, as we have no sure basis for inferences as to the habits of an unknown animal but the knowledge of the habits of such as are known, we have no grounds for supposing that its habits differed from those of its structural congeners.[1]

That the two types of dentition still found among Marsupials should have existed side by side in so remote a period of time as that in which the Purbeck bone bed was deposited, and that one of these types should have already attained so singular a degree of specialization, is one of the most remarkable facts yet revealed by mammalian palæontology. Whether the teeth of the upper jaw correspond also to the modern diprotodont type is a question of great interest, for the solution of which we must await future discoveries, of which we have more hope since the announcement by Professor Marsh of the existence, in considerable numbers, of small mammals in the American Jurassic formations of the Rocky Mountains, which conform in all

[1] The whole discussion is contained in the following memoirs :—(1) H. Falconer, "Description of Two Species of the Fossil Mammalian genus *Plagiaulax*, from Purbeck," *Quart. Jour. Geol. Soc.*, August 1857; (2) R. Owen, art. "Palæontology," *Encyclopædia Britannica*, 8th ed., 1859; (3) H. Falconer, "On the Disputed Affinity of the Mammalian genus *Plagiaulax*," *Quart. Jour. Geol. Soc.*, November 1860; (4) R. Owen, "Monograph of the Fossil Mammalia of the Mesozoic Formation," *Palæontographical Society*, 1871.

their general characters to those of the English Purbecks, some being even considered to be generically identical. Both polyprotodont and diprotodont types are represented, the latter by a species called by its discoverer *Ctenacodon serratus*, very closely allied to *Plagiaulax*.

It will be of very great interest to know the mode of succession of the teeth of those early mammals, as it may throw some light upon the question of the relation of the succession of teeth in mammals generally with the same process in the inferior classes of the *Vertebrata*. There is, however, as yet very little, if any, reliable evidence upon the subject, but such as there is rather points to the fact of an absence or very feeble development of the diphyodont condition, resembling that of modern Marsupials. If this is so, it may lead to the somewhat startling conclusion that in the transition from the lower vertebrate to the mammal, by whatever process it took place, the indefinite reproduction of the teeth of the former was lost, and that a monophyodont condition supervened, which was again superseded by the peculiar definite diphyodont mode of succession characteristic of the most highly organized mammals.

There is nothing yet known in the structure of these small mammals of the Mesozoic ages of the world to connect them with the surviving representatives (the Monotremes) of the hypothetical *Prototheria*; but whether their position was among the *Metatheria* or *Eutheria*, or whether they represented generalized forms from which both these branches have been derived, it is impossible at present to say. To avoid the difficulty of endeavouring to find places for them in any of the existing groups, Marsh proposes[1] to found two new orders for their reception—*Pantotheria* for those of the polyprotodont or insectivorous type of dentition, and *Allotheria* for *Plagiaulax* and its allies. The former may be convenient, but it is scarcely advisable to separate the latter ordinally, as long as we continue to place *Phascolomys* and *Thylacinus*, *Chiromys* and *Lemur*, *Trichecus* and *Phoca* in the same orders, for *Plagiaulax* and *Amphitherium* do not differ in the characters of their jaws and teeth more than any of these examples, which show how much the dentition may be modified with comparatively little general diversity of structure.

This scanty evidence of mammalian life must bear a very small proportion to that which doubtless existed during the greater part of the vast Mesozoic period. The Cretaceous formations have as yet yielded no trace of the presence of animals of this class; but the number and variety of species met with in the earliest Tertiary formations, when already differentiation into most of the existing leading divisions had taken place, strikingly proves the imperfect state of our geological record during the immediately antecedent ages of the world.

CHARACTERS OF THE DIFFERENT ORDERS AND FAMILIES AND OF THE PRINCIPAL FORMS OF THE MAMMALIA.

Subclass PROTOTHERIA or ORNITHODELPHIA.

The principal distinguishing characteristics of this group have been already given (p. 371). They apply not only to the subclass, but of course equally to the one order MONOTREMATA, in which the few known members of the group are commonly associated. In addition to the more important characters enumerated above, the following, which are common to all existing species, may be mentioned.

The dorso-thoracic vertebræ are nineteen in number, and have no terminal epiphyses to their bodies. The transverse processes of the cervical vertebræ are of autogenous formation, and remain suturally connected with the remainder of the vertebra until the animal is full-grown. Though in this respect they present an approximation to the *Sauropsida* (Reptiles and Birds), they differ from that group, inasmuch as there is not a gradual transition from these autogenous transverse processes of the neck (or cervical ribs, as they may be considered) into the thoracic ribs, for in the seventh vertebra the costal element is much smaller than in the other, indicative of a very marked separation of neck from thorax, not seen in the *Sauropsida*. The upper ends of the ribs are attached to the sides of the bodies of the dorsal vertebræ only, and not to the transverse processes. The sternal ribs are well ossified, and there are distinct partly ossified intermediate ribs. The cerebral cavity, unlike that of the lower Marsupials or the Reptiles, with which they have so many structural affinities, is large and hemispherical, flattened below and arched above, and about as broad as long. The cribriform plate of the ethmoid is nearly horizontal. The cranial walls are very thin, and smoothly rounded externally, and the sutures become completely obliterated in adult skulls, as in Birds. The broad occipital region slopes upwards and forwards, and the face is produced into a long and depressed rostrum. The bony palate is prolonged backwards, so that the posterior nares are nearly on a level with the glenoid fossa. The mandible is without distinct ascending ramus; the coronoid process and angle are rudimentary, and the two halves are loosely connected at the symphysis. The fibula has a broad, flattened process, projecting upwards from its upper extremity above the articulation, like an olecranon. In the male there is an additional, flat, curved ossicle on the hinder and tibial side of the plantar aspect of the tarsus, articulating chiefly to the tibia, which supports in the adult a sharp-pointed perforated horny spur, with which is connected the duct of a gland situated beneath the skin of the back of the thigh, the function of which is not yet clearly understood. (A rudimentary spur is found in the young female *Ornithorhynchus*, but this disappears when the animal becomes adult.) The stomach is subglobular, simple; the alimentary canal has no ileo-cæcal valve, or marked distinction between large and small intestine, but has a small, slender vermiform cæcum with glandular walls. The liver is divided into the usual number of lobes characteristic of the *Mammalia*, and is provided with a gall-bladder.

Although agreeing in so many important characters, the existing members of the group evidently represent two very diverging branches, perhaps as far removed as are the members of some of the accepted orders of the *Eutheria*. It would, however, be encumbering zoological science with new names to give them any other than the ordinarily known family designations of *Ornithorhynchidæ* and *Echidnidæ*.

Family ORNITHORHYNCHIDÆ.

One genus, *Ornithorhynchus*, Blumenbach, 1800.[2] Cerebral hemispheres smooth. Premaxillæ and mandible expanded anteriorly and supporting a horny beak something like that of a duck, bordered by a naked and very sensitive membranous expansion. The place of teeth supplied functionally by horny structures, elongated, narrow, and sharp-edged along the anterior part of the sides of the mouth, and broad, flat-topped or molariform behind. Legs short, fitted for swimming; feet webbed, each with five well-developed toes armed with large claws, and beyond which in the fore feet the interdigital membrane is extended. Vertebræ: C 7, D 17, L 2, S 2,

[1] "Notice of Jurassic Mammals representing two New Orders," *American Journal of Science*, xx., September 1880. Accounts of further discoveries of forms allied to *Plagiaulax*, some surviving even to the earliest Tertiary period, are given by Cope in the *American Naturalist* for November 1881 and May 1882.

[2] The name *Platypus*, bestowed by Shaw in 1799, was preoccupied by a genus of *Coleoptera*.

C 21. Acetabulum not perforated. Tongue not extensile. Mucous membrane of small intestine covered with delicate, close-set transverse folds or ridges. Tail rather short, broad, and depressed. Eyes very small. Fur close and soft. One species, *O. anatinus* (Shaw), *O. paradoxus* (Blum.), the duck-billed Platypus, or Water-Mole of the colonists, entirely aquatic in habits, diving with great facility, and burrowing in the banks of rivers. It feeds on water insects, small mollusca, and worms, and inhabits Australia and Tasmania. See ORNITHORHYNCHUS.

Family ECHIDNIDÆ.

Cerebral hemispheres larger and well convoluted. Facial portion of skull produced into a long, tapering, tubular rostrum, at the end of which the anterior nares are situated. Rami of mandible slender, styliform. Opening of mouth small, and placed below the extremity of the rostrum. No laterally placed horny teeth, though the palate and tongue are furnished with spines. Tongue very long, vermiform, slender, and protractile. Lining membrane of small intestine villous, but without transverse folds. Feet not webbed, but with long strong claws fitted for scratching and burrowing. The hinder feet with the ends of the toes turned outwards and backwards in the ordinary position of the animal when on the ground. Tail very short. Acetabulum with a large perforation, as in Birds. Calcaneal spur and gland of the male much smaller than in *Ornithorhynchus.* Fur intermixed with strong, sharp-pointed spines. Terrestrial and fossorial in habits, feeding exclusively on ants, and recalling in the structure of the mouth and various other parts relating to the peculiar mode of life the true Anteaters of the order *Edentata.*

Recent discoveries have shown that there are two distinct forms of this family, which may even be considered of generic value.

Echidna (Cuvier, 1797) or *Tachyglossus* (Illiger, 1811).[1]—Claws five on each foot. Rostrum moderately developed and straight. Vertebræ: C 7, D 16, L 3, S 3, C 12. Tongue tapering at the tip, the spines restricted to the basal portion. The best-known species is *E. aculeata* (Shaw), found in Australia and Tasmania. The specimens from the latter locality, with longer fur almost concealing the spines, have been separated specifically under the name of *E. setosa* (Cuv.). Another species, *E. lawesii* (Ramsay), has lately been discovered in southern New Guinea. See ECHIDNA.

Acanthoglossus (Gervais).—Ungual phalanges and claws present only on the three middle digits of both fore and hind feet. Rostrum much elongated and curved downwards at the end. Vertebræ: C 7, D 17, L 4, S 3, C 12. Tongue somewhat spoon-shaped near the tip, and armed on its dorsal surface with three rows of recurved spines. One species: *A. bruijnii* (Peters and Doria) (fig. 22), from

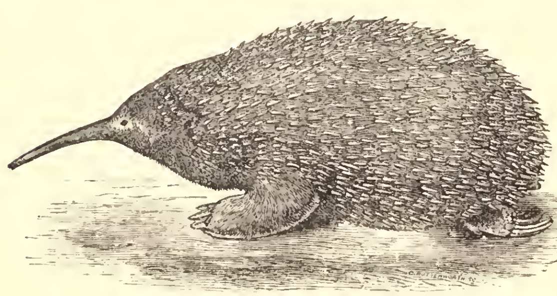

FIG. 22.—*Acanthoglossus bruijnii.* From Gervais.

the mountainous regions of the northern part of New Guinea; considerably larger than *E. aculeata.* The external characters and osteology of this animal, one of the most interesting of recent zoological discoveries, have been fully described and figured by Gervais (*Ostéographie des Monotrèmes*, Paris, 1878).

Among bones of extinct Marsupials of Pleistocene age from the Darling Downs, Mr Krefft found a portion of a humerus of an Echidna, considerably larger than the existing Australian species, which he has named *E. oweni.*[2] Notwithstanding the strong presumption of antiquity of the Monotrematous type, derived from its inferiority of structure, no fossil remains of earlier date, referable to it, or connecting it with the lower vertebrates on the one hand and the higher mammals on the other, have yet been discovered.

[1] The latter name is often used now, under the impression that *Echidna* is preoccupied by Forster (1778) for a genus of *Pisces*; but, as that was not characterized in a recognizable manner, the author even omitting to name the species for which it was intended, it is now generally considered a synonym for *Muræna* (see Günther's *Catalogue of Fishes*), and is scarcely sufficient to bar a name so universally acknowledged and so deeply rooted in mammalian literature. Merrem's genus *Echidna* (*Reptilia*) is of later date, viz., 1820.

[2] *Annals and Mag. Nat. Hist.*, 1868, vol. i. (ser. iv.) p. 113.

SUBCLASS METATHERIA OR DIDELPHIA.

Although the great diversity in external form, in many anatomical characters, and in mode of life of various animals of this section might lead to their division into groups equivalent to the orders of the *Eutheria*, it is more convenient on the whole to adhere to the usual custom of treating them all as forming one order called MARSUPIALIA, the limits of which are therefore equivalent to that of the subclass. The more essentially distinctive characters have been already pointed out (p. 371). These may be more fully stated as follows.

The brain is generally small in proportion to the size of the animal, and the surface folding of the cerebral hemispheres, though well marked in the larger species, is never very complex in character, and is absent in the smaller and medium-sized species. The arrangement of the folding of the inner wall of the cerebrum differs essentially from that of all known *Eutheria*, the hippocampal fissure being continued forward above the corpus callosum, which is of very small size. The anterior commissure is, on the other hand, greatly developed.[3]

There are always true teeth, implanted in the usual manner in both jaws, and divisible, according to their position and form, into incisors, canines, premolars, and molars; but they vary much in number and character in the different families. Except in the genus *Phascolomys*, the number of incisors in the upper and lower jaws is never equal. The true molars are very generally four in number on each side of each jaw. The chief peculiarity in the dentition lies, however, in the mode of succession. There is no vertical displacement and succession of the teeth, except in the case of a single tooth on each side of each jaw, which is always the hindermost of the premolar series, and is preceded by a tooth having more or less of the characters of a true molar (see fig. 23), and is the only tooth comparable to those

FIG. 23.—Teeth of Upper Jaw of Opossum (*Didelphys virginiana*), all of which are unchanged, except the third premolar, the place of which is occupied in the young animal by a molariform tooth, represented in the figure below the line of the other teeth.

called "milk teeth" in the diphyodont *Eutheria.* In some cases (as in *Hypsiprymnus*) this tooth retains its place and function until the animal has nearly, if not quite, attained its full stature, and is not shed and replaced by its successor until after all the other teeth of the permanent series, including the posterior molars, are fully in place and use. In others, as the Thylacine, it is most rudimentary in form and size, being shed or absorbed before any of the other teeth have cut the gum, and therefore quite functionless. It must further be noted that there are some Marsupials, as the Wombat, Koala, Myrmecobius, and the Dasyures, in which no such milk tooth, even in a rudimentary state, has yet been discovered, possibly in some cases from want of materials for observation at the right stage of development.

Epipubic or marsupial bones are present in both sexes of nearly all species. In one genus alone, *Thylacinus*, they are not ossified. The number of dorso-lumbar vertebræ is always nineteen, although there are some apparent exceptions caused by the last lumbar being

[3] W. H. Flower, "On the Commissures of the Cerebral Hemispheres of the *Marsupialia*," &c., *Phil. Trans.*, 1865, p. 633.

modified into a sacral vertebra. The number of pairs of ribs is nearly always thirteen. The tympanic bone remains permanently distinct. The carotid canal perforates the basi-sphenoid. The lacrymal foramen is situated upon or external to the anterior margin of the orbit, and there are generally large vacuities in the bony palate. The angle of the mandible is (except in *Tarsipes*) more or less inflected. The hyoid bones have always a peculiar form, consisting of a small, more or less lozenge-shaped basi-hyal, broad cerato-hyals, with the remainder of the anterior arch usually unossified, and stout, somewhat compressed thyro-hyals. There are two anterior venæ cavæ,[1] into each of which a "vena azygos" enters. In the male the testes are always contained in a scrotum which is suspended by a narrow pedicle to the abdomen in front of the penis. The vasa deferentia open into a complete and continuous urethra, which is also the passage by which the urine escapes from the bladder, and is perfectly distinct from the passage for the fæces, although the anus and the termination of the urethro-sexual canal are embraced by the same sphincter muscle. The glans is often bifurcated anteriorly. In the female the oviducts never unite to form a common cavity or uterus, but open separately into the vagina, which at least for part of its course is double. During the very short period in which the embryo is contained in the uterus, its nourishment seems to be derived from the umbilical vesicle, the allantoic vessels not reaching the surface of the chorion to form a true placenta. The mammæ vary much in number, but are always abdominal in position, have long teats, and in most of the species are more or less enclosed in a fold of the integument forming a pouch or marsupium, though in some this is entirely wanting, and the newly-born, blind, naked, and helpless young, attached by their mouths to the teat, are merely concealed and protected by the hairy covering of the mother's abdomen. In this stage of their existence they are fed by milk injected into their stomach by the contraction of the muscles covering the mammary gland, the respiratory organs being modified temporarily, much as they are permanently in the *Cetacea*,—the elongated upper part of the larynx projecting into the posterior nares, and so maintaining a free communication between the lungs and the external surface independently of the mouth and gullet, thus averting the danger of suffocation while the milk is passing down the latter passage.

The existing species of Marsupials are, with the exception of one family (the *Didelphidæ*), limited in geographical distribution to the Australian region, forming the chief mammalian fauna of Australia, New Guinea, and some of the adjacent islands. The *Didelphidæ* are almost purely neotropical, one or two species ranging northwards into the Nearctic region. Fossil remains of members of this family have also been found in Europe in strata of the Eocene and early Miocene period.

In dividing the Marsupials into minor groups, it may be observed that one of the most obvious distinctive characters among them is derived from the form and arrangement of the teeth. In certain species, as the Opossums, Dasyures, and Thylacines, the incisors are numerous, small, and subequal in size and the canines large, as in the typical placental Carnivores (fig. 24; compare with that of Lion, vol. xiv. p. 680). To these the term "polyprotodont" is applied, and they are all more or less carnivorous in their habits. In others the central incisors are very prominent, and the lateral incisors and canines absent or subordinate in function (fig. 25). These are called "diprotodont," and they are all wholly or in great part vegetable feeders.

[1] Except in *Belideus breviceps* (Forbes, *Proc. Zool. Soc.*, 1881, p. 188).

In one group of these, the Wombats, there are but two incisors above and the same number below; but all the others, including the Kangaroos, Koalas, and Phalangers,

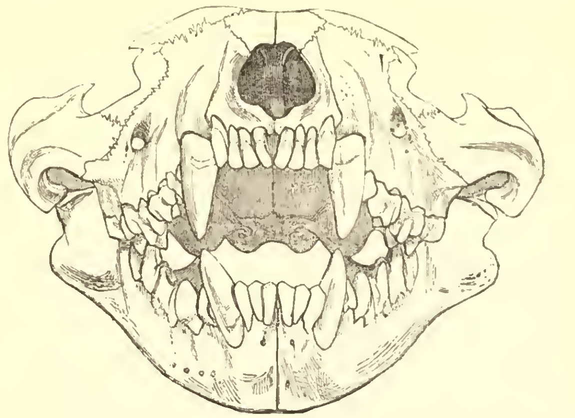

Fig. 24.—Front View of Skull of *Dasyurus ursinus*, showing polyprotodont and carnivorous dentition (*Proc. Geol. Soc.*, 1868, p. 313).

have two incisors below and as many as six above, three on each side, but of these the first or central pair is the most fully developed.

Though this division is extremely convenient, a difficulty in accepting it as marking a radical separation of the order into two primary stocks is caused by the *Peramelidæ*, which combine a polyprotodont form of dentition with a peculiar structure of the hind feet, so exactly resembling that of some of the best-marked diprotodonts, as the Kangaroos, that it is difficult to believe that it can have been developed independently. Taking various combinations of characters into consideration, the existing Marsupials readily group themselves into six very natural families, the characters of which can be thus defined :—

Fig. 25.—Front View of Skull of Koala (*Phascolarctos cinereus*), showing diprotodont and herbivorous dentition (*Proc. Geol. Soc.*, 1868, p. 313).

A. Teeth rooted.

a. Polyprotodont. — Incisors numerous, small, subequal. Canines larger than the incisors. Molars with sharp tubercles.

α. Incisors $\frac{5}{4}$. Hind feet with the four outer toes subequal, distinct, and a well-developed opposable hallux. 1. *Didelphidæ.*

β. Incisors $\frac{4}{3}$. Hind feet with four outer toes distinct, subequal. Hallux small or rudimentary; rarely opposable. 2. *Dasyuridæ.*

γ. Incisors $\frac{4}{3}$. Hind feet long, narrow. Fourth toe larger than all the others. Hallux rudimentary or absent. Second and third toes very slender and united in a common integument (syndactylous). 3. *Peramelidæ.*

b. Diprotodont.—Incisors $\frac{3}{1}$. Central upper and lower incisors large and cutting. Canines absent or small. Molars with bluntly tuberculated or transversely ridged crowns. Hind feet syndactylous.

α. Hind limbs disproportionately large, with feet as in *Peramelidæ.* 4. *Macropodidæ.*

β. Hind limbs not disproportionately large. Feet broad, with four subequal outer toes, and a large opposable hallux. 5. *Phalangistidæ.*

B. All the teeth with persistent pulps. Incisors $\frac{2}{2}$, large, scalpriform, with enamel on the outer surface only. No canines. Hind feet with four subequal outer toes; partially syndactylous and with rudimentary hallux. 6. *Phascolomyidæ.*

Family DIDELPHIDÆ.

Dentition: $i\,\frac{5}{4}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{4}{4}$; total 50. Incisors very small and pointed. Canines large. Premolars with compressed pointed crowns. Molars with numerous sharp cusps. The third premolar preceded by a deciduous multicuspidate molar, which remains in place until the animal is nearly adult. Limbs of moderate development, each with five complete and distinct toes, all of which are provided with short, compressed, curved, sharp claws of nearly equal size, except the first toe of the hind foot or hallux, which is large, widely separable from the others, to which it is opposed in climbing, and terminates in a dilated rounded extremity, without a nail. Tail generally long, partially naked and prehensile. Stomach simple. Cæcum of small or moderate size. Pouch in some complete, in others represented by two lateral folds of the abdominal integument, partially covering the teats, while in some all trace of it is absent. Vertebræ: C 7, D 13, L 6, S 2, C 19–35.

The *Didelphidæ*, or true Opossums, differ from all other Marsupials in their habitat, being peculiar to the American continent. They are mostly carnivorous or insectivorous in their diet, and arboreal in habits. One slightly aberrant form, with webbed hind feet, and aquatic mode of life, constitutes the genus *Chironectes.* The other numerous species are commonly included in the genus *Didelphys.* See OPOSSUM.

Family DASYURIDÆ.

Dentition: $i\,\frac{4}{3}$, $c\,\frac{1}{1}$, p and m numerous, variable. Incisors small; canines well developed; molars with pointed cusps. Limbs equal. Fore feet with five subequal toes with claws. Hind feet with the four outer toes well-developed, and distinct from each other and bearing claws; the first (or hallux) clawless, generally rudimentary, sometimes entirely wanting. Stomach simple. No cæcum. Predatory, carnivorous or insectivorous animals, inhabitants of Australia, Tasmania, and the southern parts of New Guinea and some of the adjacent islands. The aberrant genus *Myrmecobius,* though clearly a member of this family, is so sharply distinguished from all the others as to render a division into two subfamilies necessary.

Subfamily **Dasyurinæ**.—This comprises the more typical *Dasyuridæ,* in which the premolars and molars never exceed the normal number of seven on each side of each jaw, and in which the tongue is not specially extensile.

Thylacinus.—Dentition: $i\,\frac{4}{3}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{4}{4}=46$. Incisors small, vertical, the outer one in the upper jaw larger than the others. Summit of the lower incisors, before they are worn, with a deep transverse groove, dividing it into an anterior and a posterior cusp. Canines long, strong, and conical. Premolars with compressed crowns, increasing in size from before backwards. True molars in general characters resembling those of *Dasyurus,* but of more simple form, the cusps being not so distinct nor sharply pointed. Milk molar very small, and shed before the animal leaves the mother's pouch. General form very Dog-like. Head elongated. Muzzle pointed. Ears moderate, erect, triangular. Fur short and closely applied to the skin. Tail of moderate length, thick at the base and tapering towards the apex, clothed with short hair. Hallux (including the metacarpal bone) wanting. Vertebræ: C 7, D 13, L 6, S 2, C 23. Marsupial bones represented only by small unossified fibro-cartilages.

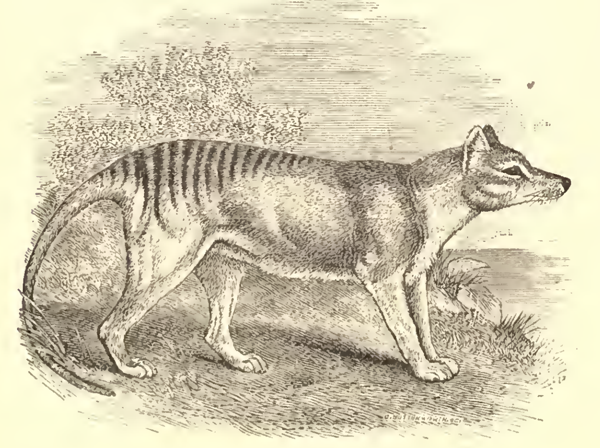

FIG. 26.—Thylacine (*Thylacinus cynocephalus*).

The only known species of this genus, *T. cynocephalus,* though smaller than a common Wolf, is the largest predaceous Marsupial at present existing. It is now entirely confined to the island of Tasmania, although fragments of bones and teeth found in caves afford evidence that a closely allied species once inhabited the Australian mainland. The general colour of the Thylacine is grey-brown, but it has a series of transverse black bands on the hinder part of the back and loins, whence the name of "Tiger" frequently applied to it by the colonists. It is also called "Wolf," and sometimes, though less appropriately, "Hyæna." Owing to the havoc it commits among the sheepfolds, it has been nearly exterminated in all the more settled parts of Tasmania, but still finds shelter in the almost impenetrable rocky glens of the more mountainous regions of the island. The female produces four young at a time.

Dasyurus.—Dentition: $i\,\frac{4}{3}$, $c\,\frac{1}{1}$, $p\,\frac{2}{2}$, $m\,\frac{4}{4}$; total 42. Upper incisors nearly equal, and placed vertically. In the smaller species the first is slightly longer, narrower, and separated from the rest. Lower incisors nearly vertical in the larger, but sloping forwards and upwards in the smaller species. Canines large and sharply pointed. Premolars, in the typical forms, with compressed and sharp-pointed crowns, and slightly developed anterior and posterior accessory basal cusps. True molars with numerous sharp-pointed cusps. In the upper jaw the first three with crowns having a triangular free surface, the fourth small, simple, narrow, and placed transversely. In the lower jaw the molars more compressed, with longer cusps; the fourth not notably smaller than the others. Ears of moderate size, prominent, and obtusely pointed. Hallux rudimentary, clawless, or absent; its metatarsal bone always present. Tail generally long and well clothed with hair. Vertebræ: C 7, D 13, L 6, S 2, C 18–20. The true Dasyures are mostly inhabitants of the Australian continent and Tasmania, where in the economy of nature they take the place of the smaller predaceous *Carnivora,* the Cats, Civets, and Weasels of other parts of the world. They hide themselves in the daytime in holes among rocks or in hollow trees, but prowl about at night in search of the small living mammals and birds which constitute their prey. The species are not numerous, and divide themselves into two sections. (1) *Dasyurus* proper includes *D. maculatus,* about the size of a common Cat, inhabiting Tasmania and the southern part of Australia; *D. viverrinus* or *maugei,* Tasmania and Victoria; *D. geoffroyi,* South Australia; *D. hallucatus,* North Australia; *D. albopunctatus,* New Guinea. (2) *Sarcophilus* contains one species, *D. ursinus,* differing from the others in being a larger and heavier animal, with a disproportionally large and broad head. Its teeth are relatively larger and more massive, and hence more crowded in the jaws; the premolars especially are scarcely compressed but rather conical; the lower molars want a cusp placed near the middle of the inner border, found developed in different degrees in all the species of the first section. This animal is peculiar to Tasmania, where it is commonly known by the name of "Devil." Its prevailing colour is black, its size about that of an English Badger, and its disposition remarkably savage and voracious.

Phascogale.—This genus (more properly *Phascologale*) comprises a considerable number of small Marsupials, none of them exceeding a common Rat in size, differing from the true Dasyures in possessing an additional premolar,—the dentition being $i\,\frac{4}{3}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{4}{4}$; total 46,—and having the teeth generally developed upon an insectivorous rather than a carnivorous pattern, the upper middle incisors being larger and inclined forwards, the canines relatively smaller, and the molars with broad crowns, armed with prickly tubercles. The muzzle is pointed. Ears moderately rounded and nearly naked. Fore feet with five subequal toes, with compressed, slightly curved pointed claws. Hind feet with the four outer toes subequal, with claws similar to those in the fore feet; the hallux almost always distinct and partially opposable, though small and nailless, sometimes absent. The food of these animals is almost entirely insects, which some pursue among the branches of trees, while others are purely terrestrial. They are found throughout Australia, and also in New Guinea and the Aru and some of the adjacent islands. Variations in the details of the dentition and of the structure of the hind limbs, and in the length and arrangement of the hairy covering of the tail, have given rise to several subdivisions which will probably be accepted as generic by most zoologists, although further investigations are required before their limits can be very satisfactorily defined.

P. cristicauda, a species with a thick compressed tail ornamented upon its apical half with a crest of black hair, differs from the others by the very reduced size of the third premolar in the upper and its complete absence in the lower jaw, thus forming an interesting transition in dentition towards *Dasyurus.* It constitutes the genus *Chætocercus* of Krefft. Another very aberrant form, *P. lanigera,* distinguished by the great elongation of the fore arm and hind foot, and the complete absence of hallux, is *Antechinomys* of the same author. It is an elegant little terrestrial mouse-like animal, with large oval ears and long tail with the terminal part bushy. *Antichinus* and *Podabrus* are names proposed for other divisions of the group.

Subfamily **Myrmecobiinæ**.—Molars and premolars exceeding the normal number of seven on each side. Tongue long and extensile.

Myrmecobius.—Dentition : $i\,\frac{4}{3}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{5}{5}$ or $\frac{6}{6}$; total 52 or 54, being the largest number of teeth in any existing Marsupial. The distinction between the molars and premolars is not certain, as it is not founded on a knowledge of the succession of the teeth, but on their form. The teeth are all small and (except the four posterior inferior molars) separated from each other by an interval. Head elongated, but broad behind. Muzzle long and pointed. Ears of moderate size, ovate, and rather pointed. Fore feet with five toes, all having strong, pointed, compressed claws, the second, third, and fourth nearly equal, the fifth somewhat and the first considerably shorter. Hind feet with no trace of hallux externally, but the metatarsal bone is present. Tail long, clothed with long hairs. Fur rather harsh and bristly. Female without any trace of a pouch, the young when attached to the nipples being concealed only by the long hair of the abdomen. Vertebræ : C 7, D 13, L 6, S 3, C 23.

Fig. 27.—*Myrmecobius fasciatus*. From Gould.

Of this singular genus but one species is known, *M. fasciatus*, found in western and southern Australia. It is about the size of an English squirrel, to which animal its long bushy tail gives it some resemblance; but it lives entirely on the ground, especially in sterile, sandy districts, feeding on ants. Its prevailing colour is chestnut-red, but the hinder part of the back is elegantly marked with broad, white, transverse bands on a dark ground.

Family PERAMELIDÆ.

Dentition : $i\,\frac{5}{3}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{4}{4}$; total 48. Upper incisors small, with short, broad crowns. Lower incisors moderate, narrow, proclivous. Canines well developed. Premolars compressed, pointed. Molars with quadrate tuberculated crowns. Third premolar preceded by a very minute molariform tooth, which remains in place until the animal is nearly full grown. Fore feet with two or three of the middle toes of nearly equal size, and provided with strong, sharp, slightly curved claws; the other toes rudimentary. Hind feet long and narrow; the hallux rudimentary or absent; the second and third toes very slender, and united in a common integument; the fourth very large, with a stout elongated conical claw; the fifth smaller than the fourth (see fig. 29). The ungual phalanges of the large toes of both feet cleft at their extremities (as in *Manis* among the *Edentata*, but in no other Marsupials). Head elongated. Muzzle long, narrow, and pointed. Stomach simple. Cæcum of moderate size. Pouch complete, generally opening backwards. Alone among Marsupials they have no clavicles.

The *Peramelidæ* form a very distinct family, in some respects intermediate between the sarcophagous *Dasyuridæ* and the phytophagous *Macropodidæ*. In dentition they resemble the former, but they agree with the latter in the peculiar structure of the hind feet. In the construction of the fore feet they differ from all other Marsupials. They may be divided into three genera.

Perameles.—Anterior and posterior extremities not differing greatly in development. Fore feet with three middle toes well developed, the third slightly larger than the second, the fourth somewhat shorter, provided with long, strong, slightly curved, pointed claws. First and fifth toes very short and without claws. Hind feet with hallux of one or two phalanges, forming a distinct tubercle visible externally ; the second and third toes very slender,

Fig. 28.—*Perameles gunnii*. From Gould.

of equal length, joined as far as the ungual phalanx, but with distinct claws ; the fifth intermediate in length between these and the largely developed fourth toe. Ears of moderate or small size, ovate, pointed. Tail rather short, clothed with short adpressed hairs. Fur short and harsh. Pouch opening backwards. Vertebræ: C 7, D 13, L 6, S 1, C 17.

The animals of this genus, commonly called "Bandicoots" in Australia, are all small, and live entirely on the ground, making nests composed of dried leaves, grass, and sticks in hollow places. They are rather mixed feeders; but insects, worms, roots, and bulbs constitute their ordinary diet. The various species are widely distributed over Australia, Tasmania, New Guinea, and several of the adjacent islands, as Aru, Kei, and New Ireland. The best known are—*P. fasciata*, *gunnii* (fig. 28), *myosurus*, *nasuta*, *obesula*, and *macrura* from Australia, and *P. dorcyana*, *saffrayana* and *longicauda* from New Guinea.

Macrotis.—Molar teeth curved, and with longer crowns and shorter roots than in the last. Hinder extremities proportionally longer, and hallux represented only by a small metatarsal bone. Muzzle much elongated and narrow. Fur soft and silky. Ears very large, long, and pointed. Tail long, its apical half clothed on the dorsal surface with long hairs. Pouch opening forwards. Vertebræ: C 7, D 13, L 6, S 2, C 23.

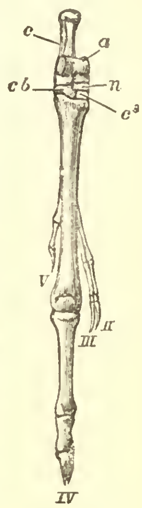

Fig. 29.—Skeleton of Hind Foot of *Chœropus castanotis*. *c*, os calcis; *a*, astragalus ; *cb*, cuboid ; *n*, navicular; *c*³, ectocuneiform; II, and III, the conjoined second and third digits; IV, the large and only functional digit; V, the rudimentary fifth digit. Compare this foot with that of the Kangaroo, vol. xiii. p. 839.

But one species is known, *M. lagotis*, from western Australia. It is the largest member of the family, being about the size of the common Rabbit, to which animal it bears sufficient superficial resemblance to have acquired the name of "Native Rabbit" from the colonists. It burrows in the ground, but in other respects resembles the Bandicoots in its habits.

Chœropus.—Dentition generally resembling that of *Perameles*, but the canines are less developed, and in the upper jaw two-rooted. Limbs very slender; posterior nearly twice the length of the anterior. Fore feet with the functional toes reduced to two, the second and third, of equal length, with closely united metacarpals and short, sharp, slightly curved, compressed claws. First toe represented by a minute rudiment of a metacarpal bone ; the fourth by a metacarpal and two small phalanges without a claw, and not reaching the middle of the metacarpal of the third ; fifth entirely absent. Hind foot long and narrow, mainly composed of the strongly developed fourth toe, terminating in a conical pointed nail, with a strong pad behind it ; the hallux represented by a rudimentary metatarsal ; the remaining toes completely developed, and with claws, but exceedingly slender; the united second and third reaching a little way beyond the metatarso-phalangeal articulation of the fourth; the fifth somewhat shorter. Tail not quite so long as the body, and covered with short hairs. Ears large and pointed, and folded down when the animal is at rest. Fur soft and loose. Pouch opening backwards. Vertebræ: C 7, D 13, L 6, S 1, C 20.

The only known species of this genus, chiefly remarkable for the singular construction of its limbs, is an animal about the size of a small Rat, found in the interior of the Australian continent. Its general habits and food appear to resemble those of the other

Fig. 30.—*Chœropus castanotis.* From Gould.

Peramelidæ. It was first described as *C. ecaudatus* by Ogilby from a mutilated specimen, but the specific name was afterwards changed by Gray to *castanotis.*

Family Macropodidæ.

The general characters of this family, and an account of the animals composing it, will be found in the article Kangaroo, vol. xiii. p. 838 *sq.*

Family Phalangistidæ.

Dentition (except in the aberrant genus *Tarsipes*): $i\,\frac{3}{1}$, the first above strong, curved, and cutting, the other two generally somewhat smaller; the single lower incisor large, more or less proclivous; $c\,\frac{1}{1 \text{ or } 0}$, upper small or moderate, conical and harp-pointed; lower absent or quite rudimentary; $p\frac{2-3}{1-3}$, variable; $m\,\frac{4}{4}$ or $\frac{3}{3}$, with four obtuse tubercles. Limbs subequal. Fore feet with five distinct, subequal toes with claws. Hind feet, short and broad, with five well-developed toes; the hallux large, nailless and opposable; the second and third slender and united by a common integument as far as the claws. Stomach simple. Cæcum present (except in *Tarsipes*), and usually large. Pouch complete. Animals of small or moderate size and arboreal habits, feeding on vegetable or mixed diet, inhabiting Australia and the Papuan Islands. Excluding *Phascolarctos* and especially *Tarsipes*, they form a very natural family. The latter is, however, evidently a modified form of the same general type, chiefly aberrant in the characters of its alimentary organs, which are adapted for a peculiar mode of subsistence. It may constitute a distinct subfamily.

Subfamily **Tarsipedinæ.**—Teeth almost rudimentary and variable in number. Tongue long, slender, pointed, and very extensile. Cæcum absent.

Tarsipes.—This is named from some supposed resemblance of its foot to that of the Lemurine genus *Tarsius*; but it must be remarked that it has none of the peculiar elongation of the calcaneum and scaphoid so characteristic of that genus. Head with elongated and slender muzzle. Mouth opening small. The two lower incisors are long, very slender, sharp-pointed, and horizontally placed. All the other teeth are simple, conical, minute, and placed at considerable and irregular intervals apart in the jaws, the number appearing to vary in different individuals and even on different sides of the two individuals. The formula in a specimen in the Museum of the Royal College of Surgeons is $i\,\frac{2-2}{1-1}$, $c\,\frac{1-1}{0-0}$, p and $m\frac{3-4}{2-3}$; total 20. Rami of the mandible extremely slender, nearly straight, and without coronoid process or inflected angle. Fore feet with five well-developed toes, with small, flat, scale-like nails, not reaching to the extremity of the digits. Hind feet rather long and slender compared with that of the *Phalangistinæ*, with well-developed opposable and nailless hallux; second and third digits syndactylous, with sharp compressed curved claws; the fourth and fifth free, and with small flat nails. Ears of moderate size and rounded. Tail longer than the body and head, scantily clothed with short hairs, prehensile. Vertebræ: C 7, D 13, L 5, S 3, C 24.

Of this singular genus but one species, *T. rostratus* (fig. 31), is known, about the size of a common Mouse. It inhabits western Australia, lives in trees and bushes, uses its tail in climbing, and feeds on honey, which it procures by inserting its long tongue into the blossoms of *Melaleucæ*, &c. One kept in confinement by Mr Gould was also observed to eat flies.

Fig. 31.—*Tarsipes rostratus.* From Gould.

Subfamily **Phalangistinæ.**

Teeth normal. Rudimentary lower canines present. Tongue of ordinary structure. No cheek pouches. Stomach and ascending colon simple. Cæcum long, simple. Tail well-developed.

A numerous group, varying in size from that of a Mouse to a large Cat, arboreal in their habits, and abundantly distributed throughout the Australian region. One section is distinguished by the possession of a flying membrane, or fold of skin, extending on each side of the body between the fore and hind legs, forming when the limbs are extended a kind of parachute, as in the Flying Squirrels, and also by a non-prehensile tail. This includes the genera *Petaurus*, *Belideus*, and *Acrobata*. The remainder have no such membrane, and have the tail more or less prehensile, the under surface at least of the apical portion being bare. These are the typical Phalangers, or "Opossums" as they are commonly called in Australia (genus *Phalangista*), and their various modifications, as *Cuscus*, *Pseudochirus*, and *Dactylopsila*. These will be more fully described in the article Phalanger.

Subfamily **Phascolarctinæ.**—Teeth normal; no rudimentary lower canines. Tongue of ordinary structure. Distinct cheek pouches. Stomach with a special gland near the cardiac orifice. Cæcum very long, and (with the upper portion of the colon) dilated and provided with numerous longitudinal folds of mucous membrane. In many anatomical characters, especially the possession of a special gastric gland, this group resembles the *Phascolomyidæ*, to which it obviously forms a transition.[1]

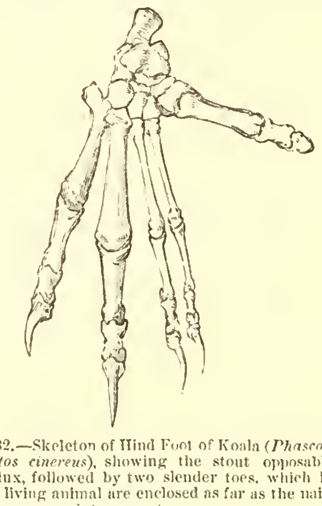

Fig. 32.—Skeleton of Hind Foot of Koala (*Phascolarctos cinereus*), showing the stout opposable hallux, followed by two slender toes, which in the living animal are enclosed as far as the nails in a common integument.

Phascolarctos.—Dentition: $i\,\frac{3}{1}$, $c\,\frac{1}{0}$, $p\,\frac{1}{1}$, $m\,\frac{4}{4}$; total 30. Upper incisors crowded together, cylindroidal, the first much larger than the others, with a bevelled cutting edge (fig. 25). Canine very small; a considerable interval between it and the premolar, which is as long from before backwards but not so broad as the true molars, and has a cutting edge, with a smaller parallel inner ridge. The molars slightly diminishing in size from the first to the fourth, with square crowns, each bearing four pyramidal cusps. The lower incisors are semiproclivous, com-

[1] *Cf.* W A Forbes, "Anatomy of the Koala," *Proc. Zool. Soc.*, 1881, p. 180.

pressed and tapering, bevelled at the ends. Premolars and molars in continuous series, as in the upper jaw. Fore feet with the two inner toes slightly separated from and opposable to the remaining three, all with strong, curved, and much compressed claws. Hind foot with the hallux placed very far back, large and broad, the second and third (united) toes considerably smaller than the other two; the fourth the largest. No external tail. Fur dense and woolly. Ears of moderate size, thickly clothed with long hairs. Vertebræ: C 7, D 11, L 8, S 2, C 8. Ribs eleven pairs, a rare exception to the usual number (13) in the *Marsupialia*.

There is but one species, the Koala or Native Bear of the Australian colonists (*P. cinereus*), found in the south-eastern parts of the Australian continent. It is about 2 feet in length, and of an ash-grey colour, an excellent climber, and residing generally in lofty *Eucalyptus* trees, on the buds and tender shoots of which it feeds, though occasionally descending to the ground in the night.

Kindred Fossil Forms.

Here may be noticed several genera of extinct Marsupials, the remains of which have been found in the post-Tertiary deposits of Australia, which agree with the *Macropodidæ* and the *Phalangistidæ* in having $\frac{3}{1}$ incisors, those of the lower jaw very large and proclivous. As the whole of their structure, especially that of the hind feet, is not yet known, their precise affinities cannot be determined.

Diprotodon.—Dentition: $i\,\frac{3}{1}$, $c\,\frac{0}{0}$, $p\,\frac{1}{1}$, $m\,\frac{4}{4}$; total 28. The first upper incisor very large and scalpriform. True molars with prominent transverse ridges, as in *Macropus*, but wanting the longitudinal connecting ridge. Anterior and posterior limbs less disproportionate than in tho Kangaroos. *D. australis* is a gigantic animal compared with all existing Marsupials, surpassing a Rhinoceros in bulk.

Nototherium.—Dental formula as in the last, from which it differs chiefly in the incisor teeth, especially those of the lower jaw, being much smaller. The skull is short, with the zygomatic arches extremely broad. *N. mitchelli* and *inerme*, both animals of great size, though inferior to *Diprotodon*.

Thylacoleo.—Dentition of adult: $i\,\frac{3}{1}$, $c\,\frac{1}{0}$, $p\,\frac{3}{1}$, $m\,\frac{1}{2}$; total 24. First upper incisor much larger than the others; canine and first two premolars rudimentary. In the lower jaw there are also one or two small and early deciduous premolars; posterior premolars of both jaws formed on the same type as that of *Hypsiprymnus*, but relatively much larger; true molars rudimentary, tubercular. One species, *T. carnifex*. This animal presents a most anomalous condition of dentition, the functional teeth being reduced to one pair

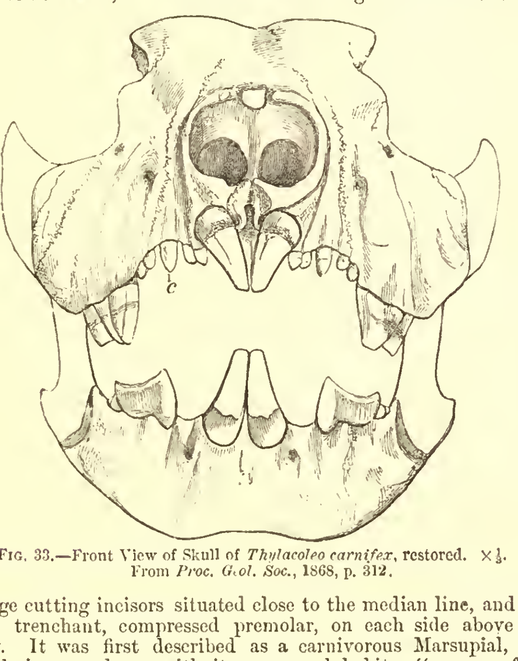

FIG. 33.—Front View of Skull of *Thylacoleo carnifex*, restored. ×½. From *Proc. Geol. Soc.*, 1868, p. 312.

of large cutting incisors situated close to the median line, and one great, trenchant, compressed premolar, on each side above and below. It was first described as a carnivorous Marsupial, and named, in accordance with its presumed habits, "as one of the fellest and most destructive of predatory beasts;" but, as its affinities are certainly with the *Phalangistidæ* and *Macropodidæ*, and its dentition completely unlike that of any known predaceous animal, this view has been called in question.[1]

[1] The lowest Eocene formation of New Mexico has recently yielded an animal (*Ptilodus mediævus*) having a mandibular dentition allied to that of *Thylacoleo*, and which goes some way to bridge over the gap, both in structure and time, between this and the Mesozoic *Plagiaulacidæ* (see Cope in *American Naturalist*, June 1882).

Family PHASCOLOMYIDÆ.

Dentition: $c\,\frac{1}{1}$, $i\,\frac{0}{0}$, $p\,\frac{1}{1}$, $m\,\frac{4}{4} = 24$. All the teeth with persistent pulps. The incisors large, scalpriform, with enamel only on the front surface, as in the *Rodentia*. The molars strongly curved, forming from the base to the summit about a quarter of a circle, the concavity being directed outwards in the upper and inwards in the lower teeth. The first of the series (generally called "premolar," though it appears to have no milk predecessor) single-lobed; the other four composed of two lobes, each subtriangular in section. Limbs equal, stout, and short. Fore feet with five distinct toes, each furnished with a long, strong, and slightly curved nail, the first and fifth considerably shorter than the other three. Hind feet with a very short nailless hallux, the second, third, and fourth toes partially united by integuments, of nearly equal length, the fifth distinct and rather shorter; all four provided with long and curved nails. In the skeleton of the foot, the second and third toes are distinctly more slender than the fourth, showing a slight tendency towards the peculiar character so marked in the last three families. Tail rudimentary. Stomach simple, provided with a special gland situated near the cardiac orifice. Cæcum very short, wide, and with a peculiar vermiform appendage.

The species of this family are few, and all contained in one genus, *Phascolomys*, with two well-marked sections, one containing the Common and Broad-nosed Wombats, *P. wombat* and *platyrhinus*, the other the Hairy-nosed Wombat, *P. latifrons*. They are all terrestrial and burrowing animals, generally slow in their movements, and harmless in disposition; they feed on roots and other vegetable substances, and inhabit the southern parts of the Australian continent, Tasmania, and the islands of Bass's Straits. See WOMBAT.

Bibliography of Marsupialia.—G. R. Waterhouse, *Nat. Hist. of the Mammalia*, vol. i. "Marsupiata," 1846; J. Gould, *Mammals of Australia*, 1863; R. Owen, article "Marsupialia," in *Cyclop. of Anatomy and Physiology*, and various memoirs "On Extinct Mammals of Australia" in *Philosophical Transactions*; W. H. Flower, "On the Development and Succession of the Teeth in the Marsupialia," *Phil. Trans.*, 1867.

SUBCLASS EUTHERIA OR MONODELPHIA.

The remaining mammals are included in the EUTHERIA, PLACENTALIA, or MONODELPHIA, the leading characters of which have been given at p. 372. Their affinities with one another are so complex that it is impossible to arrange them satisfactorily in any serial order. The *Edentata* may be taken first as standing in some respects apart from all the others. The *Sirenia* and *Cetacea* are also somewhat isolated, having undergone most remarkable modifications from the normal mammalian type. The *Primates* must be placed at the head of the series. The position of the others is quite arbitrary, as none of the hitherto proposed associations of the orders into larger groups stand the test of critical investigation, and palæontological researches have already gone far to show that they are all modifications of a common heterodont, diphyodont, pentadactyle form.

ORDER EDENTATA.

The name assigned to this group (which some zoologists think ought rather to be ranked as a subclass than an order) by Cuvier is often objected to as inappropriate, for though some of the members are edentulous, others have very numerous teeth; and the Linnæan name *Bruta* is occasionally substituted. But that term is quite as objectionable, especially as the group to which Linnæus applied it is by no means equivalent to the order as now understood, as the names of the genera contained in it, viz., *Elephas*, *Trichechus*, *Bradypus*, *Myrmecophaga*, *Manis*, and *Dasypus*, will indicate. It contained, in fact, all the animals then known which are comprised in the modern orders of *Proboscidea*, *Sirenia*, and *Edentata*, together with the Walrus, one of the *Carnivora*. If retained at all, it should rather belong to the *Proboscidea*, as *Elephas* stands first in the list of genera, and was probably in the mind of Linnæus when he assigned the name to the group. Cuvier's order included the *Ornithorhynchus* and *Echidna*, the structure of which was then imperfectly known, and which are now by common consent removed to an altogether different section of the class, but otherwise its limits are those now adopted. The name *Edentata* is so generally used, and its meaning so well understood, that it would be very undesirable to change it now; in fact similar reasons might be assigned for ceasing to use nearly all the other current ordinal designations, for it might be equally well objected that all the *Carnivora* are not flesheaters, many of the *Marsupialia* have not pouches, and so forth.

If the teeth are not always absent, they invariably exhibit certain imperfections, which are indeed almost the only common characters which bind together the various extinct and existing members of the order. These are—that they are homodont and, with the remarkable exception of the genus *Tatusia*, monophyodont; they are never rooted but have persistent pulps; they are always deficient in one of the constituents which enter into the formation of the complete mammalian tooth, the enamel, and are never present either in the upper or lower jaw in the fore part of the mouth, the situation occupied by the incisors of other mammals.[1]

There is so great a difference in structure and habits between some of the existing animals assigned to this order that, beyond the negative characters just mentioned, there seems little to connect them. The Sloths and Anteaters, for instance, in mode of life, general conformation of limbs, structure of digestive organs, &c., appear at first sight almost as widely separated as any mammals. Palæontology has, however, thrown great light upon their relations, and proved their real affinities. Perfectly intermediate forms have been discovered in the great Ground Sloths of America, which have the dentition and general form of the head of the Sloths, combined with the limbs and trunk of the Anteaters. It is highly probable that the existing members of the order are very much differentiated representatives of a large group, the greater number of which are now extinct, and which have become so without ever attaining a high grade of organization. The great diversity of structure of the existing families, the high degree of specialization to which many have attained, the paucity of species and even of individuals, their limited area of distribution, and their small size compared with known ancestral forms, all show that this is an ancient and a waning group, the members of which seem still to hold their own either by the remoteness and seclusion of their dwelling-places, by their remarkable adaptation of structure to special conditions of life, or by aid of the peculiar defensive armature with which they are invested. Their former history can, however, only be thus surmised, rather than read, at present; for, though we have ample evidence of the abundance and superior magnitude of certain forms in the most recent or post-Tertiary geological age, and in one part of the world, beyond this time, *i.e.*, in the true Tertiary period, and in other parts of the world than America, the remains of animals of this order hitherto discovered are only fragmentary, giving a most imperfect idea of their actual structure, and affording no indications which serve to connect them with any other branch of the class.

The existing members of the order readily group themselves into five distinct families, the limits of which are perfectly clear. These are (1) *Bradypodidæ*, or Sloths; (2) *Myrmecophagidæ*, or Anteaters; (3) *Dasypodidæ*, or Armadillos; (4) *Manidæ*, Pangolins or Scaly Anteaters; and (5) *Orycteropodidæ*, Aard-varks or African Anteaters. The geographical distribution of these families coincides with their structural distinction, the first three being inhabitants of the New and the last two of the Old World. It has been usual to arrange these families into two large groups or suborders:—(1) the *Phyllophaga*, leaf-eaters, also called *Tardigrada*, containing the *Bradypodidæ* alone; and (2) the *Entomophaga*, insect-eaters, or *Vermilingua*, containing all the other families, from which sometimes the *Orycteropodidæ* are separated as a third suborder under the name of *Effodientia*. Such an arrangement is, however, an artificial one, founded on superficial resemblance. The bonds which unite the *Manidæ* to the *Myrmecophagidæ* are mainly to be found in the structure of the mouth, especially the extensile character of the tongue, the great development of the submaxillary glands, and the absence of teeth. These characters are exactly analogous to those found in the *Echidna* among Monotremes, the Woodpeckers among Birds, and the Chamæleon among Reptiles,—the fact probably being that in countries where Termites and similar insects flourish various distinct forms of vertebrates have become modified in special relation to this abundance of nutritious food, which could only be made available by a peculiar structure of the alimentary organs. A close study of the more essential portions of the anatomy of these animals[2] leads to the belief that all the American Edentates at present known, however diversified in form and habits, belong to a common stock. The *Bradypodidæ*, *Megatheriidæ*, and *Myrmecophagidæ* are closely allied, the modifications seen in the existing families relating only to food and manner of life. The ancestral forms may have been omnivorous, and gradually separated into the purely vegetable and purely animal feeders; from the former are developed the modern Sloths, from the latter the Anteaters. The Armadillos (*Dasypodidæ*) are another modification of the same type, retaining some generalized characters, as those of the alimentary organs, but in other respects, as their defensive armature, remarkably specialized. The two Old-World families *Manidæ* and *Orycteropodidæ* are so essentially distinct, both from the American families and from each other, that it may even be considered doubtful whether they are derived from the same primary branch of mammals, or whether they may not be offsets of some other branch, the remaining members of which have been lost to knowledge.

Family BRADYPODIDÆ.

Externally clothed with long, coarse, crisp hair. Head short and rounded. External ears inconspicuous. Teeth $\frac{5}{4}$ in each jaw, subcylindrical, of persistent growth, consisting of a central axis of vaso-dentine, with a thin investment of hard dentine, with a thick outer coating of cement; without (as far as is yet known) any succession. Fore limbs greatly longer than the hind limbs. All the extremities terminating in narrow, curved feet; the digits never exceeding three in number, encased for nearly their whole length in a common integument, and armed with long strong claws. Tail rudimentary. Stomach complex. No cæcum. Placenta deciduate, dome-like, composed of an aggregation of numerous discoidal lobes. Strictly arboreal in habits, vegetable feeders, and limited geographically to the forest regions of South and Central America. Two genera, *Bradypus* and *Cholœpus*. See SLOTH.

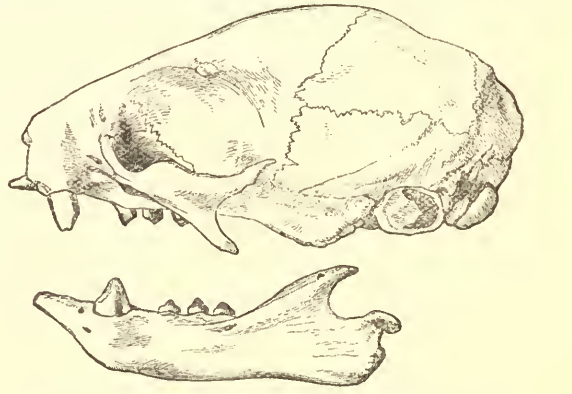

FIG. 34.—Skull of Two-toed Sloth (*Cholœpus didactylus*). From *Proc. Zool. Soc.*, 1871, p. 432.

Family MEGATHERIIDÆ.

The members of this family are all extinct. Their characters, so far as is known from the well-preserved remains of many species found abundantly in deposits of Pleistocene age in

[1] In some few Armadillos the suture between the premaxilla and maxilla passes behind the first upper tooth, but in all the other known members of the order all the teeth are implanted in the maxilla.

[2] See *Proceedings of the Zoological Society* of London, 1882, p. 358.

both North and South America, were intermediate between those of the existing *Bradypodidæ* and the *Myrmecophagidæ*, combining the head and dentition of the former with the structure of the vertebral column, limbs, and tail of the latter. Almost all the known species are of comparatively gigantic size, the smallest, *Cœlodon escrivanensis*, exceeding the largest existing Anteater, and the Megatherium being larger than a Rhinoceros. The dentition is usually $\frac{5}{4}$ on each

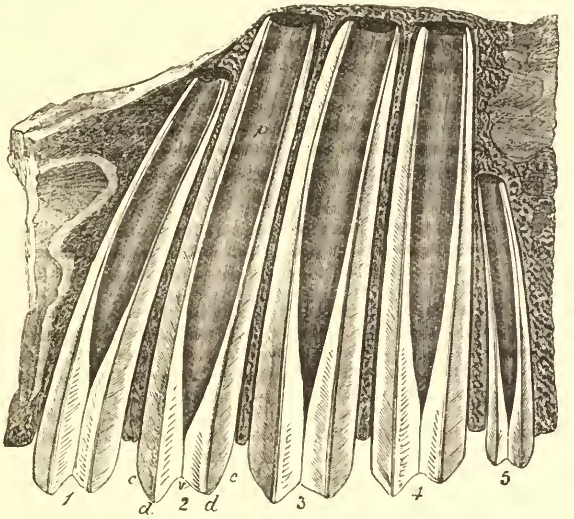

FIG. 35.—Section of Upper Molar Teeth of *Megatherium*. ×½. From Owen.

side, as in the Sloths, but in *Cœlodon* $\frac{4}{3}$. This genus, and in a still more marked degree *Megatherium*, differ from all the others in the details of the structure of the teeth. They are very deeply implanted, of prismatic form (quadrate in transverse section); and the component tissues—hard dentine (fig. 35, *d*), softer vaso-dentine (*v*), and cementum (*c*)—are so arranged that, as the tooth wears, the surface always presents a pair of transverse ridges, thus producing a triturating apparatus comparable to the "bilophodont" molar of *Dinotherium*, *Tapirus*, *Manatus*, *Macropus*, and others, though produced in a different manner. In all the other genera the teeth are more or less cylindrical, though sometimes laterally compressed or even longitudinally grooved on the sides, and on the grinding surface the prominent ridge of hard dentine follows the external contour, and is surrounded only by a thin layer of cementum, as in the existing Sloths. The genera of which the remains are best known are *Mylodon* (fig. 37), *Lestodon*, *Scelidotherium*, *Gryphotherium*, and *Megalonyx*. In the last-named the anterior tooth of both upper and lower jaws is large and removed by a considerable interval from the others. The osteological characters of these genera have been fully described in the works of Cuvier, Owen, Burmeister, Leidy, Gervais, Reinhardt, and others.

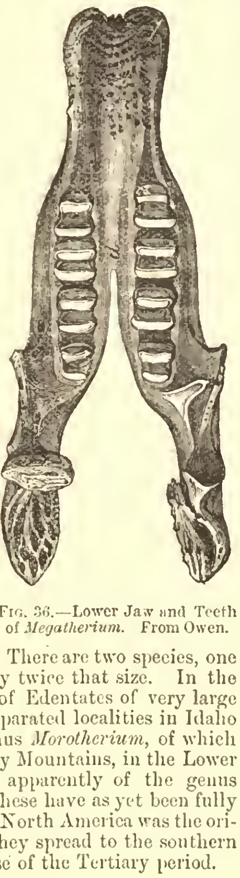
FIG. 36.—Lower Jaw and Teeth of *Megatherium*. From Owen.

No Eocene Edentates have yet been found in America. In the Miocene of the Pacific coast of North America some remains have been discovered, assigned by Marsh to the genus *Moropus*, the type of a distinct family, the *Moropidæ*. There are two species, one about as large as a Tapir, and one nearly twice that size. In the Lower Pliocene, well-preserved remains of Edentates of very large size have been found at several widely separated localities in Idaho and California. These belong to the genus *Morotherium*, of which two species are known. East of the Rocky Mountains, in the Lower Pliocene of Nebraska, a large species apparently of the genus *Moropus* has been discovered. None of these have as yet been fully described or figured. Marsh believes that North America was the original home of the Edentates, and that they spread to the southern portion of the continent towards the close of the Tertiary period.

Family MYRMECOPHAGIDÆ.

Externally clothed with hair. No teeth. Head elongated. Mouth tubular, with a small terminal aperture, through which the long, vermiform tongue, covered with the viscid secretion of the enormous submaxillary glands, is rapidly protruded in feeding, and withdrawn again with the adhering particles of aliment, which are then sucked into the pharynx. In the manus, the third toe is greatly developed, and has a long falcate claw; the others are reduced or suppressed. The pes has four or five subequal digits with claws. Posterior dorsal and lumbar vertebræ with additional interlocking zygapophyses. Tail long, sometimes prehensile. Placenta dome-like or discoidal. The animals of this family are the "Anteaters" *par excellence*. They feed exclusively on animal substances, mostly insects. One species is terrestrial, the others arboreal; none burrow in the ground. They are all inhabitants of the Neotropical region.

Myrmecophaga.—Skull greatly elongated and narrow, its upper surface smooth and cylindriform. Anteriorly the face is produced into a long, tubular rostrum, rounded above and flattened below, and with terminal nares, and composed of the mesethmoid ossified for more than half its length, the vomer, the maxillæ, and the long and narrow nasal bones, the premaxillæ being extremely short and confined to the margin of the anterior nares. The zygomatic arch is incomplete, the styliform malar only articulating with the maxilla in front, and not reaching to the very short zygomatic process of the squamosal. The lacrymal foramen is in front of the margin of the orbit. There are no post-orbital processes to the frontals or any other demarcation between the orbits and the temporal fossæ. Palate ex-

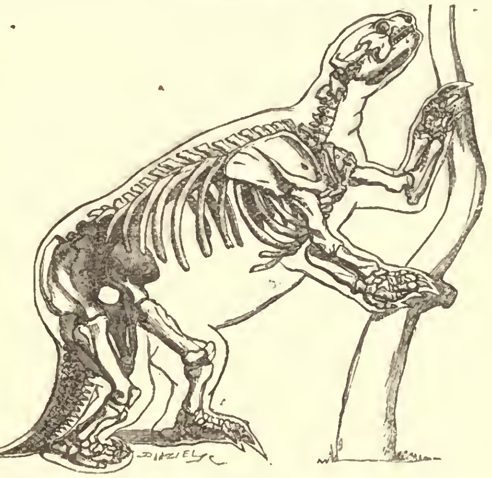
FIG. 37.—Skeleton of *Mylodon robustus* (Pleistocene, South America). From Owen.

tremely elongated, and produced backwards as far as the level of the external auditory meatus by the meeting in the middle line of the largely developed pterygoids. The glenoid fossa a shallow oval facet, with its long diameter from before backwards. Mandible very long and slender, with an exceedingly short symphysis, no distinct coronoid process, and a slightly elevated, elongated, flattened, condylar articular surface. Vertebræ: C 7, D 15–16, L 3–2, S 6, C 31. Clavicles rudimentary. In the manus, the first digit is very slender, the second also slender, with compressed phalanges of nearly equal length. The third digit is immensely developed; though its proximal phalanx is extremely short, its ungual phalanx is so long that the entire length of the digit exceeds that of the second. The fourth has a long and rather slender metacarpal, and three phalanges diminishing in size, the ungual phalanx being very small. The fifth has the metacarpal nearly as long, but not so stout as the fourth, and followed by two small phalanges, the last rudimentary and conical. Claws are developed upon all but the fifth. In walking the toes are kept strongly flexed, and have their points turned upwards and inwards, the weight being supported upon a callous pad over the end of the fifth digit, and by the dorsal surfaces of the third and fourth digits. The hind feet are short and rather broad, with five subequal claws, the fourth rather longest, the first shortest; the whole sole is placed on the ground in walking. Body rather compressed, clothed with long, coarse hair. Tail about as long as the body, and covered with very long hair; not prehensile. Ears small, oval, erect. Eyes very small. Stomach consisting of a subglobular, thin-walled, cardiac portion, and a muscular pyloric gizzard with dense epithelial lining. No ileo-colic valve, and a short wide ill-defined cæcum. Mammæ two, pectoral.

There is one species, *M. jubata*, the Great Anteater, or Ant Bear, measuring 4 feet in length without the tail, and upwards of 2 feet in height at the shoulder. Its prevailing colour is grey, with a broad black band, bordered with white, commencing on the chest, and passing obliquely over the shoulder, diminishing gradually in breadth as it approaches the loins, where it ends in a point.

It is extensively distributed in the tropical parts of South and Central America, frequenting low swampy savannas, along the banks of rivers, and the depths of the humid forests, but is nowhere abundant. Its food consists mainly of termites, to obtain which it opens their nests with its powerful sharp anterior claws, and as the insects swarm to the damaged part of their dwelling, it draws them into its mouth by means of its long, flexible, rapidly-moving tongue covered with glutinous saliva. The Great Anteater is quite terrestrial in its habits, being never known to climb trees, nor does it burrow underground like the Armadillos. Though generally an inoffensive animal, when attacked it can defend itself vigorously and effectively with its sabre-like anterior claws. The female bears but a single young at a birth.

Tamandua.—This genus closely resembles the last in anatomical structure, but the head is much less elongated, the fur is short and bristly, the tail, tapering, prehensile, with the under side throughout and the whole of the terminal portion naked and scaly. The stomach is similar to that of *Myrmecophaga*, but with the muscular pyloric gizzard not quite so strongly developed. There is a distinct

FIG. 38.—Tamandua Anteater (*Tamandua tetradactyla*). From *Proc. Zool. Soc.*, 1871, pl. xliii.

ileo-colic valve and short globular cæcum. The fore foot has a very large claw on the third toe, moderate-sized claws on the second and fourth, a very minute one on the first, and none on the fifth, which is entirely concealed within the skin. The hind foot has five subequal claws. Vertebræ: C 7, D 17, L 2, S 5, C 37. There are very rudimentary clavicles.

The Tamandua (*T. tetradactyla*) is much smaller than the Great Anteater, and differs essentially from it in its habits, being mainly arboreal. It is an inhabitant of the dense primeval forests of South and Central America. As different individuals vary much in their coloration, it is possible that there may be more than one species. The usual colour is yellowish-white, with a broad black lateral band, covering nearly the whole of the side of the body.

Cycloturus.—The skull is much shorter even than in *Tamandua*, and is arched considerably in the longitudinal direction. It differs from that of the other members of the family mainly in the long canal for the posterior nares not being closed by bone below, as the greater part of the palatines and the pterygoids do not meet in the middle line. The mandible has a prominent, narrow, recurved coronoid and a well-developed angular process; it is strongly decurved in front. Vertebræ: C 7, D 16, L 2, S 4, C 40. Ribs remarkably broad and flat. Clavicles well developed. Manus remarkably modified. The third digit is greatly developed at the expense of all the others; it has a stout short metacarpal and but two phalanges, of which the most distal is large, compressed, pointed, and much curved, and bears a very strong hook-like claw. The second digit has the same number of phalanges, and bears a claw, but is very much more slender than the third. The fourth is represented only by the metacarpal, and one nailless phalanx, the first and fifth only by very rudimentary metacarpals. The pes is also completely modified into a climbing organ. The hallux is rudimentary, consisting of a metatarsal and one phalanx, concealed beneath the skin, but the other four toes are subequal and much curved, with long pointed compressed claws. The tuber calcanei is directed towards the plantar surface, and parallel with it and extending to about double its length is a greatly elongated sesamoid ossicle. These together support a prominent calcarine cushion to which the nails are opposed in climbing. Stomach pyriform, with muscular walls, but no distinct gizzard-like portion, as in the foregoing genera. The commencement of the colon provided with two small cæca, resembling those of many Birds, narrow at the base, and rather dilated at their terminal blind ends, and communicating with the general cavity by very minute apertures. Tail longer than the body, tapering, bare on the under surface, and very prehensile. Fur soft and silky.

This genus has also but one species certainly known, the Little or Two-toed Anteater (*C. didactylus*), an animal not larger than a Rat, of a general yellowish colour, and exclusively arboreal in its habits. It is a native of the hottest parts of South and Central America.

Family DASYPODIDÆ.

The greater part of the skin strongly ossified. On the back and sides the union of numerous quadrate or polygonal scutes forms a hard shield, usually consisting of an anterior (scapular) and posterior (pelvic) solid portion (which overhang on each side the parts of the body they respectively cover, forming chambers into which the limbs are withdrawn), and a variable number of rings between, connected by soft flexible skin so as to allow of curvature of the body. The top of the head has also a similar shield (cephalic), and the tail is usually encased in bony rings or plates. The outer or exposed surfaces of the limbs are protected by irregular bony scutes, not united at their margins; but the skin of the inner surface of the limbs and under side of the body is soft and more or less clothed with hair. Hairs also in many species project through apertures between the bony scutes of the back. The ossified dermal plates are everywhere covered by a layer of horny epidermis. Teeth numerous, simple, of persistent growth, and usually monophyodont, but in one genus (*Tatusia*) a succession of teeth has been observed. Zygomatic arch of skull complete. Cervical vertebræ with extremely short, broad, and depressed bodies. The atlas free, but the second and third, and often several of the others, ankylosed together both by their bodies and arches. Lumbar vertebræ with accessory zygomatic processes, and very large metapophyses, supporting the bony carapace. Clavicles well developed. A third trochanter on the femur. Tibia and fibula ankylosed at their distal extremities. Fore feet with strongly developed, curved claws, adapted for digging and scratching, three, four, or five in number. Hind feet plantigrade, with five toes, all provided with nails. Tongue long, pointed, and extensile, though to a less degree than in the Anteaters. Submaxillary glands largely developed. Stomach simple. Placenta discoidal, deciduate.

The animals of this family are commonly called Armadillos, a word of Spanish origin, having reference to their armour-like covering. The existing species are all of small or moderate size. They are mostly, though not universally, nocturnal in their habits. They are omnivorous, feeding on roots, insects, worms, reptiles, and carrion. They are harmless and inoffensive creatures, offering no resistance when caught, their principal means of escape from their enemies being the extraordinary rapidity with which they can burrow in the ground, and the tenacity with which they retain their hold in their subterranean retreats. Notwithstanding the shortness of their limbs they can run with great rapidity. Most of the species are esteemed good eating by the natives of the countries in which they live. They are all inhabitants of the open plains or the forests of the tropical and temperate parts of South America, with the exception of one species (*Tatusia peba*), which ranges as far north as Texas. Of the existing genera, *Chlamydophorus* stands apart from the rest in the formation of its external covering; but in all other respects *Tatusia* is the most aberrant form, exhibiting a different type of structure of the fore feet, which in all the others shows modifications, though in very varying degrees, of the same type.

Subfamily **Chlamydophorinæ.**—In most anatomical characters, especially the structure of the fore foot, this little group resembles the *Dasypodinæ*, but it differs remarkably from all other known Armadillos, living or extinct, in the peculiar modification of the dermal armour.

Chlamydophorus.—Teeth $\frac{8}{8-9}$, subcylindrical, somewhat compressed, moderate in size, smaller at each end (especially in front) than at the middle of the series. Skull broad and rounded behind, pointed in front. Muzzle subcylindrical and depressed. A conspicuous rounded, rough prominence on the frontal bone, just before each orbit. Tympanic prolonged into a tubular auditory meatus, curving upwards round the base of the zygoma. Vertebræ: C 7, D 11, L 3, S 10, C 15. Upper part of head and trunk covered with four-sided horny plates (with very small thin ossifications beneath), forming a shield, free, and overhanging the sides of the trunk, and attached only along the middle line of the back. The plates are arranged in a series of distinct transverse bands, about twenty in number between the occiput and the posterior truncated end, and not divided into solid thoracic and pelvic shields with movable bands between. The hinder end of the body is abruptly truncated and covered by a vertically-placed, strong, solid, bony shield, of an oval (transversely extended) form, covered by thin epidermic plates. This shield is firmly ankylosed by five bony processes to the hinder part of the pelvis. Through a notch in the middle of its lower border the tail passes out. The latter is rather short, cylindrical in its proximal half, and expanded and depressed or spatulate in its terminal portion, and covered with horny plates. The dorsal surfaces of the fore and hind feet are also covered with horny plates. The remainder of the limbs and under surface and sides of the body beneath the overlapping lateral parts of the dorsal shield are clothed with rather long, very soft silky hair. Eyes and ears very small, and concealed by the hair. Extremities short. Feet large, each with five well-developed claws, those on the fore feet very long, stout, and subcompressed, the structure of the digits being essentially the same as those of *Xenurus* and *Priodon.* Nipples two, pectoral. Visceral anatomy closely resembling that of *Dasypus*, the cæcum being broad, short, and bifid.

C. truncatus.—The Pichiciago, a small burrowing animal, about 5 inches long, inhabits the sandy plains of the western part of the Argentine Republic, especially the vicinity of Mendoza. Its horny covering is of a pinkish colour, and its silky hair snow white. It is rare, and its habits but little known. A second species, *C. retusa*, from Bolivia, has been described by Burmeister. It is of rather larger size, and has the dorsal shield attached to the skin of the back, as far as its edge, instead of only along the median line.

Subfamily **Dasypodinæ.**—Fore feet usually with all five digits developed and with nails, though the first and fifth may be suppressed. The first and second long and slender, with the normal number and relative length of phalanges. The others stout, with short broad metacarpals, and with phalanges greatly reduced in length and generally in number by coalescence. The ungual phalanx of the third very large, that of the others gradually diminishing to the fifth. *Dasypus*, as now restricted, has the most normal form of manus, but the modifications so markedly developed in all the others (and culminating in *Tolypeutes*) are foreshadowed, as it were, in it. Ears wide apart. Mammæ one pair, pectoral.

Dasypus.—Teeth $\frac{9}{10}$ or $\frac{8}{9}$, of which the anterior in the upper jaw is usually implanted in the premaxillary bone. The series of teeth extends posteriorly some distance behind the anterior root of the zygoma, almost level with the hinder edge of the palate. They are large, subcylindrical, slightly compressed, diminishing in size towards each end of the series; the anterior two in the mandible much smaller, and more compressed than the others. Cranial portion of the skull broad and depressed. Facial portion triangular, broad in front and much depressed. Auditory bulla completely ossified, perforated on the inner side by the carotid canal, and continued externally into an elongated bony meatus auditorius, with its aperture directed upwards and backwards. (In all the remaining genera of *Dasypodinæ* the tympanic bone is a mere half ring, loosely attached to the cranium.) Mandible with a high ascending ramus, broad transversely-placed condyle, and high slender coronoid process. Vertebræ: C 7, D 11–12, L 3, S 8, C 17–18. Head broad and flat above. Muzzle obtusely pointed. Ears of moderate size or rather small, placed laterally, far apart. Body broad and depressed. Carapace with six or seven movable bands between the scapular and pelvic shields. Tail shorter than the body, tapering, covered with plates forming distinct rings near the base. Fore feet with five toes; the first much more slender than the others, and with a smaller ungual phalanx and nail; the second, though the longest, also slender. The third, fourth, and fifth gradually diminishing in length, all armed with very strong, slightly curved, compressed claws, sloping away from an elevated rounded inner border to a sharp, outer, and inferior edge. The hind foot is rather short, with all five toes armed with stout, compressed, slightly curved, obtusely pointed claws,—the third the longest, the second nearly equal to it, the fourth the next, the first and fifth shorter and nearly equal.

To this genus belongs one of the best-known species of the group, the Six-banded Armadillo or Encoubert (*D. sexcinctus*) of Brazil and Paraguay. A very similar species, *D. villosus*, the Hairy Armadillo, replaces it south of the Rio Plata. There are also two very small species, *D. vellerosus* and *D. minutus*, from the Argentine Republic and North Patagonia. The latter differs from the other three in having no tooth implanted in the premaxillary bone.

Xenurus.—Teeth $\frac{9}{9}$ or $\frac{8}{8}$, of moderate size and subcylindrical. The most posterior placed a little way behind the anterior root of the zygoma, but far from the hinder margin of the palate. Cranium somewhat elongated, much constricted behind the orbits, and immediately in front of the constriction considerably dilated. Mandible slender; coronoid process very small and sharp-pointed, sometimes obsolete. Vertebræ: C 7, D 12–13, L 5, S 10, C 18. Head broad behind. Ears rather large and rounded, wide apart. Movable bands of carapace 12–13. Tail considerably shorter than the body, and slender, covered with nearly naked skin, with but a few small, scattered, dermal bony plates, chiefly on the under surface and near the apex. On the fore feet the first and second toes are long and slender, with small claws and the normal number of phalanges; the other toes have but two phalanges; the third has an immense falcate claw; the fourth and fifth similar but smaller claws. The hind feet are comparatively small, with five toes, with small, triangular, blunt nails; the third longest, the first shortest. The best known species of this genus, the Tatouay or Cabassou, *X. unicinctus*, is, after *Priodon gigas*, the largest of the group. It is found, though not abundantly, in Surinam, Brazil, and Paraguay. Others, *X. hispidus* and *lugubris*, have been described, but little is as yet known of them.

Priodon.—Teeth variable in number, and generally differing on the two sides of each jaw, usually from 20 to 25 on each side above and below, so that as many as 100 may be present altogether, but as life advances the anterior teeth fall out, and all traces of their alveoli disappear. The series extends as far back as the hinder edge of the anterior root of the zygoma. They are all very small; in the anterior half of each series they are strongly compressed, having flat sides and a straight free edge; the posterior teeth are more cylindrical, with flat, truncated, free surfaces. Vertebræ: C 7, D 12, L 3, S 10, C 23. Head small, elongated, conical. Ears moderate, ovate. Carapace with 12–13 movable bands. Tail nearly equal to the body in length, gradually tapering, closely covered with quadrangular scales, arranged in a quincunx pattern. Fore feet with five toes, formed on the same plan as those of *Xenurus*, but with the claw of the third of still greater size, and that of the others, especially the fifth, proportionately reduced. Hind foot short and rounded, with five very short toes, with short, broad, flat obtuse nails. The only known species, the Great Armadillo (*P. gigas*), is by far the largest of existing members of the family, measuring rather more than 3 feet from the tip of the nose to the root of the tail, the tail being about 20 inches long. It inhabits the forests of Surinam and Brazil. The powerful falcate claws of its fore feet enable it to dig with great facility. Its food consists chiefly of termites and other insects, but it is said to attack and uproot newly-made graves for the purpose of devouring the flesh of the bodies contained in them.

Tolypeutes.—Teeth $\frac{9}{9}$ or $\frac{8}{9}$, rather large in proportion to the size of the skull, the hinder end of the series reaching nearly to the posterior margin of the palate. Vertebræ: C 7, D 11, L 3, S 12, C 13. Ears placed low on the sides of the head, rather large, broadly ovate. Carapace with its scapular and pelvic shields very free at the sides of the body, forming large chambers into which the limbs can be readily withdrawn. Only three movable bands. Tail short, conical, covered with large bony tubercles. The fore feet formed on the same type as the last, but the peculiarities carried out to a still greater extent. The claw of the third toe is very long and falcate, the first and fifth greatly reduced and sometimes wanting. On the hind foot the three middle toes have broad, flat, subequal nails, forming together a kind of tripartite hoof; the first and fifth much shorter and with more compressed nails.

The Armadillos of this genus have the power of rolling themselves up into a perfect ball, the shield on the top of the head and the tuberculated dorsal surface of the tail exactly fitting into and filling up the apertures left by the notches at either end of the carapace. This appears to be their usual means of defence when frightened or surprised, as they do not burrow like the other species. They run very quickly, with a very peculiar gait, only the tips of the claws of the fore feet touching the ground. Three species are described:—*T. tricinctus*, the Apar; *T. conurus*, the Matico; and *T. muriei.*

Subfamily **Tatusiinæ.**—This contains but one genus, *Tatusia.*—Teeth $\frac{8}{8}$ or $\frac{7}{7}$, very small, subcylindrical. The first and second subcompressed, the last considerably smaller than the others. They present the remarkable peculiarity (unique among Edentates, so far as

FIG. 39.—*Glyptodon clavipes* (Pleistocene, South America). From Owen.

is yet known) of all being, with the exception of the last, preceded by two-rooted milk teeth, which are not changed until the animal has nearly attained its full size. Vertebræ: C 7, D 9–11, L 5, S 8, C 20–27. Head narrow, with a long, narrow, subcylindrical, obliquely-truncated snout. Ears rather large, ovate, and erect, placed close together on the occiput. Carapace with seven to nine distinct movable bands. Body generally elongated and narrow. Tail moderate or long, gradually tapering; its dermal plates forming very distinct rings for the greater part of its length. Fore feet with four visible toes, and a concealed clawless rudiment of the fifth. Claws all long, slightly curved, and very slender, the third and fourth subequal and alike, the first and fourth much shorter. Hind feet with five toes, all armed with strong, slightly-curved, conical, obtusely-pointed nails. The third longest, then the second and fourth; the first and fifth much shorter than the others.

This genus differs from all the other Armadillos in having a pair of inguinal mammæ, in addition to the usual pectoral pair, and in producing a large number (four to ten) of young at a birth, all the others having usually but one or two.

The Peba Armadillo, *T. septemcincta*, is a well-known species, having an extensive range from Texas to Paraguay. It is replaced in the more southern regions of South America by a smaller species, with shorter tail, the Mulita (*T. hybrida*), so called from the resemblance of its head and ears to those of a mule. *T. kappleri* is a large species or variety from Surinam.[1]

Fossil remains of *Dasypodidæ* have been found by Lund and others in the caves of Brazil in deposits of Pleistocene age. Some are attributable to existing genera, but others are assigned to distinct modifications of the type called *Euryodon*, *Chlamydotherium*, *Eutatus*, &c. In the same region, but still more abundantly in the fluviatile deposits which cover the country in the neighbourhood of Buenos Ayres, are found the remains of one of the most remarkable forms of mammals yet discovered, the Glyptodons, or *Hoplophoridæ* (fig. 39). They differ from the existing *Dasypodidæ* in their large size, and in having the carapace composed of a solid piece (formed by the union of a multitude of bony dermal scutes) without any movable rings, and in having also a ventral piece or plastron. The facial portion of the skull is very short. A long process of the maxillary bone descends from the anterior part of the zygomatic arch. The ascending ramus of the mandible is remarkably high. The teeth are $\frac{8}{8}$ in all known species, all much alike, having two deep grooves or flutings on each side, so as to divide them into three nearly distinct lobes (fig. 40). The vertebral column is almost entirely ankylosed into a solid tube, but there is a complex joint at the base of the neck, to allow the head being retracted within the carapace. The limbs are very strong, and the feet short and broad, resembling externally those of an elephant or tortoise. Many species of the family have been described and figured, especially by Burmeister (in the *Annales del Museo publico de Buenos Aires*), by whom five genera are recognized, which are thus characterized:—

FIG. 40.—Teeth of Glyptodon. From Owen.

I. Four toes only on the posterior feet.
 A. Four toes on the anterior feet, the pollex being absent.
  a. Cuirass thin but inflexible.
   1. *Hoplophorus*:—*H. euphractus*, *H. ornatus*, *H. elegans*, *H. pumilio*.
  b. The cuirass stronger, with clefts between the scutes at the lower antero-lateral border, allowing of a certain amount of flexibility.
   2. *Panochthus*:—*P. tuberculatus*, *P. bullifer*.
 B. Both pollex and fifth digit of the manus absent.
   3. *Dœdicurus*:—*D. giganteus*.

II. Five perfect toes on the posterior feet, and four on the anterior, the fifth digit of which is absent.
 A. Tail elongated, with the rings of the base smooth, and the cuirassed apex cylindrical or tubular.
   4. *Glyptodon*:—*G. clavipes*, *G. reticulatus*.
 B. Tail short, the rings tuberculated, the point round and short.
   5. *Schistopleurum*:—*S. elongatum*, *S. asperum*, *S. læve*.

Family MANIDÆ.

Covered externally (except the under surface of the body and inside of the limbs) with large imbricated horny scales, with scattered hairs growing in the intervals. No teeth. Tongue long, vermiform, and protractile. No accessory articular processes to the lumbar vertebræ, but the anterior zygapophyses largely developed and very concave, completely embracing the semicylindrical surfaces of the posterior zygapophyses. Limbs short, with five complete digits on each foot. Scaphoid and lunar bone of carpus united. Uterus bicornuate. Placenta diffused and non-deciduate. The species are mainly terrestrial and fossorial, though one is partially arboreal. All belong to the Ethiopian and Oriental regions of the Old World.

Manis.—Skull somewhat of the form of an elongated cone, with the small end turned forwards; very smooth and free from crests and ridges. No distinction between the orbits and temporal fossæ. The zygomatic arch usually incomplete, owing to the absence of the malar bone. No distinct lacrymal bone. Palate long and narrow. The pterygoids extend backwards as far as the tympanics, but do not meet in the middle line below. Tympanic ankylosed to the surrounding bones, and more or less bullate, but not produced into a tubular auditory meatus. Rami of mandible very slender and straight, without any angle or coronoid process. From near the anterior extremity of the upper edge a sharp, conical, tooth-like process projects upwards and outwards. No clavicles. No third trochanter to the femur. Ungual phalanges bifid at their terminations. Caudal vertebræ with very long strong transverse processes and numerous chevron bones. Tongue long, vermiform, flattened towards the tip. The retractor or sterno-glossal muscles arise from the hinder extremity of the immensely prolonged ensiform cartilage of the sternum. Stomach with thick, muscular walls and lining membrane, and with a special gland near the middle of the great curvature, consisting of a mass of complex secreting follicles, the ducts of which terminate in a common orifice. No cæcum. A gall-bladder. Head small, depressed, narrow, pointed in front, with a very small mouth-opening. Eyes and pinna of ear very small. Body elongated, narrow. Tail more or less elongated, convex above, flat underneath. The whole of the upper surface of the head, the upper surface and sides of the body, the whole of the tail, and the outer sides of the extremities covered with large, overlapping, horny scales, with usually a few stiff hairs growing between and projecting beyond them. The sides and under surface of the head, the under surface of the body, and the inner sides of the limbs without scales but with a rather scanty covering of hair. Limbs short. In walking the dorsal surface and outer sides of the phalanges of the two outer digits of the front feet alone rest on the ground, the points of the nails turning upwards and inwards. The third toe the longest, with a powerful compressed curved claw, the second and fourth with similar but smaller claws, that of the pollex often almost rudimentary. Hind feet plantigrade, with hallux very short, and four other toes subequal, with moderate, curved, subcompressed nails.

The animals of this genus, called Pangolins or Scaly Anteaters, are all of small or moderate size, terrestrial and burrowing, and feed mainly on termites. One small African species climbs trees. They can roll themselves up in a ball when in danger. Their peculiar elongated form, short limbs, long, gradually-tapering tail, and scaly covering give them on a superficial inspection more the appearance of reptiles than of mammals. The species are not numerous, but may be grouped into three sections. (1) *Manis* proper. Tail considerably exceeding in length both head and body. Scales not covering the dorsal surface of the manus. On fore feet the first toe exceedingly small, but with a distinct short nail; second, fourth, and fifth subequal, with moderate compressed claws; third greatly exceeding the others, with a much larger falcate claw. Two species, both from West Africa: *M. longicaudata* (vertebræ: C 7, D 13, L 5, S 3, C 46), and *M. tricuspis* (vertebræ: C 7, D 13, L 6, S 3, C 44). (2) All the others have the scaly covering of the fore limbs extending to the claws, and the tail not exceeding the length of the head and body. On the fore feet the first and fifth toes are equal and very small, the second and fourth equal and longer, the third longest, but not so disproportionately so as in the other section. The tails of most of these are broad at the base and taper towards the extremity. They constitute the genus *Pholidotus* of Gray, and include *M. gigantea*, West Africa, the largest species of the group, of which the head and body measure 2 feet 6 inches, and the tail the same. Vertebræ: C 7, D 13, L 6, S 4, C 28. *M. pentadactyla*, *M. aurita*, and *M. javanica*, all of the Oriental region. (3) One very distinct species, *M. temminckii*, from South and East Africa, with the tail nearly as broad as the body for the whole of its length, and rounded at the end, constitutes the genus *Smutsia* of Gray.

Family ORYCTEROPODIDÆ.

External surface scantily covered with bristle-like hairs. Teeth numerous, and of peculiar and complex structure, being traversed by a number of parallel vertical pulp-canals. Lumbar vertebræ with no accessory zygapophyses. Femur with a third trochanter. Fore feet without pollex, but all the other digits well developed, with strong moderate-sized nails, suited to digging, the plantar surfaces of which rest on the ground in walking. Hind feet with five subequal toes. Mouth elongated and tubular. Tongue subvermiform. Placenta broadly zonular. Feed on animal substances. Terrestrial and fossorial in habits. Limited to the Ethiopian region.

Orycteropus.—The total number of teeth appears to be from

[1] A single imperfect skin, brought from the province of Ceara in Brazil, indicates a very remarkable form of Armadillo, named by A. Milne-Edwards *Scleropleura brunetti* (*Ann. Sc. Nat.*, xvi. p. 8, 1872). The dermal plates are said to be much less developed than in other members of the family, and confined to the sides, all the median portion of the back being clothed with a flexible hairy skin. The head is broad and short, the ears small and far apart. The tail is long, and almost entirely devoid of scutes. The feet are unknown.

eight to ten in each side of the upper, and eight in the lower jaw; but they are never all in place at one time, as the small anterior teeth are shed before the series is completed behind. In the adult they number usually five on each side above and below, of which the first two are simple and compressed, the next two larger and longitudinally grooved at the sides, the most posterior simple and cylindrical. The structure of all these teeth is quite peculiar among mammals, though resembling that of some fishes. Their summits are rounded before they are worn; their bases do not taper to a root, but are evenly truncated and continually growing. Each tooth is made up of an aggregation of parallel dental systems, having a slender pulp cavity in the centre, from which the dentinal tubes radiate outwards, and being closely packed together each system assumes a polygonal outline as seen in transverse section. No evidence of any vertical succession of teeth has been discovered. Skull moderately elongated. The facial portion subcylindrical and slightly tapering. The zygoma complete and slender. The palate ends posteriorly in the thickened transverse border of the palatines, and is not continued back by the pterygoids. The tympanic is annular, and not ankylosed to the surrounding bones. The mandible is slender anteriorly, but rises high posteriorly, with a slender recurved coronoid, and an ascending pointed process on the hinder edge below the condyle, which is small, oval, and looks forwards as much as upwards. Vertebræ: C 7, D 13, L 8, S 6, C 25. The large number of lumbar vertebræ is peculiar among Edentates. Tongue less vermiform than in *Myrmecophaga*, being thick and fleshy at the base, and gradually tapering to the apex. The salivary apparatus is developed much in the same manner as in that genus, but the duct of the submaxillary gland has no reservoir. The stomach consists of a large subglobular cardiac portion, with a very thick, soft, and corrugated lining membrane, and a smaller muscular, pyloric part, with a comparatively thin and smooth lining. There is a very distinct ileo-cæcal valve, and a considerable-sized cæcum; also a gall-bladder. No pollex to the fore foot. All the other usual toes well developed, with strong, subcompressed nails, flatter on the hind foot. Head elongated, with a tubular snout, terminal nostrils, and small mouth-opening. Ears large, pointed, erect. Tail nearly as long as the body, cylindrical, very thick at the base, tapering to the extremity.

The best known species is the Cape Anteater (*O. capensis*), or "Aard-Vark" (Earth Pig) of the Dutch colonists, from South Africa, an animal not altogether unlike a Pig in size and general appearance. It lives in burrows in the ground, and feeds chiefly on ants and other insects. A second species, or well-marked local variety, *O. æthiopicus*, inhabits the north-eastern parts of Africa.

Extinct Edentata of the Old World.

Certain remains, chiefly of bones of the limbs, found in France and Greece, and assigned to genera called *Macotherium* and *Ancylotherium*, united provisionally in the family *Macrotheriidæ*, indicate the existence of animals of large size inhabiting Europe during the Middle Tertiary epoch, the characters of which appear to indicate a generalized Edentate form or something intermediate between the *Edentata* and *Ungulata*. In the structure of the phalanges they most resembled the *Manidæ*, but there is some evidence that they possessed teeth. Some fragments from the Eocene of Paris are still more doubtfully assigned by Gervais to the order.

Bibliography of Edentata.—No general work on the order has been published but that of Rapp (*Anat. Untersuchungen über die Edentaten*, 2d ed., 1852), now nearly out of date. Among numerous memoirs on special groups the following may be cited:—*Myrmecophagidæ*:—R. Owen, "Anatomy of Great Anteater," *Trans. Zool. Soc.*, vol. iv.; G. Pouchet, *Mém. sur le Grand Fourmilier*, 1871; W. A. Forbes, "Anat. of Great Anteater," *Proc. Zool. Soc.*, 1882, p. 287. *Megatheriidæ*:—R. Owen, *Extinct Gigantic Sloth* (*Mylodon Robustus*), 1842; Id., "On the Megatherium," *Philos. Trans.*, 1851–56; J. Leidy, "Extinct Sloth-tribe of North America," *Smithsonian Contrib. to Knowledge*, vii., 1855; H. Burmeister, *Description de la République Argentine*, t. iii. Mammifères, 1879,—which contains full references to various memoirs by Owen, Gervais, Reinhardt, and others. *Glyptodontidæ*:—Owen, *Catalogue of Fossil Mammals, Mus. Roy. Coll. Surgeons*, 1845; T. H. Huxley, "Osteol. of Glyptodon," *Phil. Trans.*, 1865; H. Burmeister, *Annales del Museo Publico de Buenos Ayres*, and *Descript. de la République Argentine*, 1879. *Dasypodidæ*:—J. Murie, "Anatomy of *Tolypeutes*," *Trans. Linn. Soc.*, vol. xxx., 1874; A. H. Garrod, *Proc. Zool. Soc.*, 1878. For placentation of Edentates see W. Turner, *Trans. Roy. Soc. Edin.*, xxvii. (1873) p. 72, and *Jour. Anat. and Physiol.*, vols. viii. and x.; A. Milne-Edwards, *Ann. Sciences Nat.* [6] viii. p. 1; and for brain, P. Gervais, "Formes cérébrales des Edentés," *Nouv. Arch. du Muséum*, tom. v.; W. Turner, *Jour. Anatomy*, i. 313 (1867).

Order SIRENIA.

The purely aquatic habits and Fish-like form of the animals of this order caused them to be formerly confounded with the *Cetacea*, but a more intimate knowledge of their structure has shown that they really belong to a widely different type of the class.

The head is rounded and not disproportionate in size as compared with the trunk, from which it is scarcely separated by any externally visible constriction or neck. Nostrils valvular, separate, and placed above the fore part of the obtuse, truncated muzzle. Eyes very small, with imperfectly formed eyelids, capable, however, of contraction, and with a well-developed nictitating membrane. Ear without any pinna. Mouth of small or moderate size, with tumid lips beset with stiff bristles. General form of the body depressed fusiform. No dorsal fin. Tail flattened and horizontally expanded. Fore limbs paddle-shaped, the digits being enveloped in a common cutaneous covering, though sometimes rudiments of nails are present. No trace of hind limbs. External surface covered with a tough, finely wrinkled, or very rugous skin, naked, or with fine hairs sparsely scattered over it.

The skeleton is remarkable for the massiveness and density of most of the bones of which it is composed, especially the skull and ribs, which must add to the specific gravity of these slow-moving animals, and aid in keeping them to the bottom of the shallow waters in which they dwell, while feeding on aquatic vegetables. The skull presents many peculiarities, among which may be indicated the large size and backward position of the anterior narial aperture, a further modification of that met with in the Tapirs among Ungulates, and presenting some approach to that so characteristic of the *Cetacea*. The nasal bones are generally absent in the recent forms, or are only found in a most rudimentary condition, attached to the edge of the frontals, far away from the middle line; but in some at least of the extinct species these bones, though small in size, are normal in situation and relations. In very few other respects does the skull present any resemblance to that of the *Cetacea*. In the spinal column none of the vertebræ are united together to form a sacrum, and the flat ends of the bodies do not ossify separately, so as to form disk-like epiphyses in the young state, as in nearly all other mammals. The anterior caudal vertebræ have well-developed chevron bones. In one genus (*Manatus*) there are only six cervical vertebræ. There are no clavicles. The humerus has a small but distinct trochlear articulation at the elbow-joint. The two bones of the forearm are about equally developed, and generally ankylosed together at both extremities. The carpus is short and broad, and the digits five in number, with moderately elongated and flattened phalanges, which are never increased in number beyond the limit usual in the *Mammalia*. The pelvis is extremely rudimentary, consisting of a pair of bones suspended at some distance from the vertebral column. In no existing species is there any trace of a hind limb, but in the extinct *Halitherium* an acetabular depression and rudimentary femur have been discovered.

Two kinds of teeth, incisors and molars, separated by a wide interval, are generally present. The former may be developed into tusks in the upper jaw, or may be quite rudimentary. The molars vary much in character. In one genus (*Rytina*) no teeth of any kind are present, at least in the adult. In all, the anterior part of the palate, and a corresponding surface on the prolonged symphysis of the lower jaw, are covered with rough horny plates of peculiar structure, which doubtless assist in mastication. The tongue is small and fixed in position, with a surface resembling that of the plates just spoken of. The salivary glands are largely developed. The stomach is compound, being divided by a valvular constriction into two principal cavities, the first of which is provided with a singular glandular pouch near the cardiac end, and the second usually with a pair of elongated, conical, cæcal sacs or diverticula. The intestinal canal is long, and with very muscular walls. There is a cæcum, either simple, conical, and with extremely thick walls, as in *Halicore*, or bifid, as in *Manatus*. The apex of the heart is deeply cleft between the ventricles. The principal arteries form very extensive and complex *retia mirabilia*. The lungs are remarkably long and narrow, as, owing to the very oblique position of the diaphragm, the thoracic cavity extends far back over the abdomen. The epiglottis and arytenoid cartilages of the larynx do not form a tubular prolongation as in the *Cetacea*. The brain is of comparatively small size, and the convolutions on the surface of the cerebrum few and shallow. The kidneys are simple. Testes abdominal. The uterus is bicornuate. The placenta (in the Dugong) is non-deciduate and diffuse, the villi being scattered generally over the surface of the chorion except at the poles. The umbilical vesicle disappears early. The mammæ are two, and pectoral or rather post-axillary in position.

The *Sirenia* pass their whole life in the water, being denizens of shallow bays, estuaries, lagoons, and large rivers, but unlike the *Cetacea* are not met with in the high seas, far away from the shore. Their food consists entirely of aquatic plants, either marine algæ or freshwater grasses, upon which they browse beneath the surface, as the terrestrial herbivorous mammals do upon the green pastures on shore. They are generally gregarious, slow and inactive in their movements, mild, inoffensive, and apparently unintelligent in disposition. Though occasionally found stranded by the tide or waves, there is no satisfactory evidence that they voluntarily leave the water to bask or feed on the shore. The habit of the Dugong of raising its round head out of water, and carrying its young under the fore fin, seems to have given rise, among the imaginative early voyagers in the Indian Ocean, to the legendary beings, half human and half fish, in allusion to which the name *Sirenia* was bestowed by Illiger on the order, though certainly the face of a Dugong, when closely inspected, does not bear the slightest resemblance to that of the mermaid of romance. The species now existing are very few, and there is reason to believe that the time is not far distant when they will all become extinct. One species, *Rhytina stelleri*, of the North Pacific, was totally exterminated through the agency of man during the last century; and the others, being valuable for their flesh as food, for their hides, and especially for the oil obtained from the thick layer of fat which lies immediately beneath their skin, rapidly diminish in numbers as civilized populations occupy the regions forming their natural habitat. The surviving species are confined to the tropical regions of the shores of both sides of the Atlantic and the great rivers which empty themselves into that ocean, and to the coasts of the Indian Ocean from the Red Sea to North Australia. In the Miocene and early Pliocene epoch Sirenians abounded in the seas of Europe, and their remains have been found in deposits of corresponding periods of North America. Evidence has also been discovered of the existence of an animal of the group in the seas at the bottom of which the Eocene nummulitic limestone mountain ranges of Egypt were deposited.

The existing genera present such well-marked distinguishing characters that, if they alone were known, they might be placed in separate families; but, as in so many similar cases, our knowledge of the extinct forms, imperfect as it is, goes far to bridge over the distinction between them.

Manatus.—Incisors $\frac{2}{2}$, rudimentary, concealed beneath the horny oral plates, and disappearing before maturity. Molars $\frac{11}{11}$, but rarely more than $\frac{6}{6}$ present at one time; the anterior teeth falling before the posterior come into use; similar in characters from beginning to end of the series; with square, enamelled crowns, the grinding surface raised into tuberculated transverse ridges. The upper teeth with two ridges and three roots, the lower teeth with an additional (posterior) ridge or talon and two roots. The cervical vertebræ present the remarkable anomaly of being reduced to six in number, the usual vertebral formula being C 6, D 15–18, L and C 25–29. Rostrum of the skull, formed by the union of the premaxillæ in front of the anterior narial aperture, shorter than the length of the aperture and scarcely deflected from the basi-cranial axis. Tail entire, rounded or shovel-shaped. Rudimentary nails on the fore limbs. Cæcum bifid. Habitat the shores of, and the great rivers which empty themselves into, the Atlantic within the tropics. The American and African forms are generally considered to be distinct species (*M. australis* and *M. senegalensis*), though they differ but little from each other in anatomical characters and in habits. They are rather fluviatile than marine, ascending large rivers almost to their sources. See MANATEE.

Halicore.—In the upper jaw a pair of large, nearly straight, tusk-like incisors, directed downwards and forwards, partially coated with enamel. In the male they have persistent pulps, and bevelled cutting edges, which project a short distance from the mouth, but in the female, though they remain through life in the alveolar cavity, they are not exserted, and, the pulp cavity being filled with osteodentine, they soon cease to grow (as in the female Narwhal). In the young there is also a second small deciduous incisor on each side above. At this age there are also beneath the horny plate which covers the anterior portion of the mandible four pairs of slender conical teeth lodged in wide alveolar depressions. These become absorbed before the animal reaches maturity. The molars are usually $\frac{5}{5}$, sometimes $\frac{6}{6}$, altogether, but not all in place at once, as the first falls before the last rises above the gum; they are more or less cylindrical in section, except the last, which is compressed and grooved laterally, without distinction into crown and root, increasing in size from before backwards, with persistent pulps and no enamel. The summits of the crowns are tuberculated before wearing, afterwards flattened or slightly concave. Skull with rostrum formed by the union of the premaxillæ in front of the narial aperture, longer than the aperture itself, bending downwards at a right angle with the basi-cranial axis, and enclosing the sockets of the large incisor tusks. Anterior part of the lower jaw bent down in a corresponding manner. Vertebræ: C 7, D 18–19, L and C 30. Tail broadly notched in the middle line, and with two pointed lateral lobes. No nails on the fore limbs. Cæcum single.

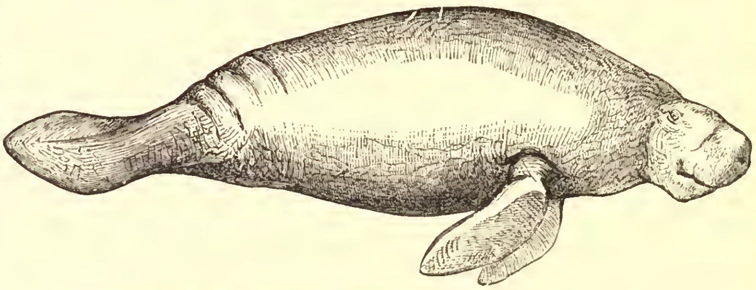

FIG. 41.—American Manatee (*Manatus australis*), from life. *Proc. Zool. Soc.*, 1881, p. 457.

The Dugongs are more distinctly marine in their habits than the Manatees, feeding chiefly on sea-water algæ. They inhabit the shallow bays and creeks of the Red Sea, east coast of Africa, Ceylon, islands of the Bay of Bengal and the Indo-Malayan Archipelago (including the Philippines), and the north coast of Australia, ranging from Barrow Reefs on the west to Moreton Bay on the east. Though the distinctive characters are not very obvious, they have been divided into three species, according to the localities which they respectively inhabit:—*H. tabernaculi* from the Red Sea, *H. dugong* from the Indian seas, and *H. australis* from Australia. The last-named has lately been the object of a regular "fishery," chiefly on account of its oil, which is peculiarly clear, limpid, and free from disagreeable smell, and is said to have the same medical properties as cod-liver oil. Although often stated in books to attain the length of 20 feet when adult, there does not appear to be any evidence from actual specimens in museums that Dugongs ever reach half that size, 8 feet being the common length of adult animals.

Rhytina.—No teeth, their place being supplied functionally by the dense, strongly-ridged, horny oral plates. Premaxillary rostrum about as long as the anterior narial aperture, and moderately deflected. Vertebræ: C 7, D 19, L and C 34–37. Head very small in proportion to the body. Tail with two lateral pointed lobes. Pectoral limbs small and truncated. Skin naked and covered with a very thick, hard, rugged bark-like epidermis. Stomach without cæcal appendages to the pyloric cavity. Cæcum simple.

Only one species of this genus is known, *R. stelleri*, the Northern Sea-cow, by far the largest animal of the order, attaining the length of 20 to 25 feet. It was formerly an inhabitant of the shores of two small islands in the North Pacific, Behring's and the adjacent Copper Island, on the former of which it was discovered by the ill-fated navigator whose name the island bears, when, with his accomplished companion, the German naturalist Steller, he was wrecked upon it in 1741. Twenty-seven years afterwards (1768), as is commonly supposed, the last of the race was killed,[1] and its very existence would have been unknown to science but for the interesting account of its anatomy and habits left by Steller, and the few more or less perfect skeletons which have recently rewarded the researches carried on in the frozen soil of the islands around which it dwelt. There is no evidence at present of its having inhabited any other coasts than those of the islands just named, though it can hardly be supposed that its range was always so restricted. When first discovered it was extremely numerous in the shallow bays round Behring's Island, finding abundant nutriment in the large laminariæ growing in the sea. Its extirpation is entirely due to the Russian hunters and traders who followed upon the track of the explorers, and who, upon Steller's suggestion, lived upon the flesh of the great Sea-cows. Its restricted distribution, large size, inactive habits, fearlessness of man, and even its affectionate disposition towards its own kind when wounded or in distress, all contributed to accelerate its final extinction.

Extinct Sirenia.

The Miocene and early Pliocene seas of Europe abounded in Sirenians, to which the generic name of *Halitherium* was given by Kaup. They had large tusk-like incisors in the upper jaw, as in the existing Dugongs, though not so greatly developed. Their molar teeth were $\frac{5}{5}$ or $\frac{6}{6}$, anteriorly simple and single-rooted, posteriorly those above with three and those below with two roots, and with enamelled and tuberculated or ridged crowns, in all which respects they more resemble those of the Manatee than of the Dugong. The anterior molars were deciduous. Some species at least had nasal bones, short, broad, but normal in position, whereas in all the existing genera these bones are quite rudimentary. Another and still more important evidence of conformity to the general mammalian type is the better development of the pelvic bone, and the presence of a small styliform femur articulated to the acetabulum, although no traces of any other part of the limb have been discovered. These ancient Sirenians were thus, in dental, cranial, and other osteological characters, less specialized than are either of the existing species, and, if the intermediate links could be discovered, might well be looked upon as ancestral forms from which the latter have been derived, but at present the transitional conditions have not been detected. So far as is yet known, when changes in the physical conditions of the European seas rendered them unfitted to be the habitation of Sirenians, the Halitherium type still prevailed. If the existing Dugongs and Manatees are descended from it, their evolution must have taken place during the Pliocene and Pleistocene epochs, the one in seas to the east, the other to the west of the African continent, which has long formed a barrier to their intercommunication. Halitherium remains have been found in many parts of Germany, especially near Darmstadt, also in France, Italy, Belgium, Malta, the isthmus of Suez, &c. Until lately none were known from England, probably owing to the absence of beds of an age corresponding to those in which they are found on the European continent; but recently a skull and several teeth have been detected among the rolled debris of Miocene formations, out of which the Red Crag of Suffolk is partially composed. The species are not yet satisfactorily characterized. Some of them appear to have attained a larger size than the existing Manatee or Dugong. One of these from the Pliocene of Italy and France, having but $\frac{5}{5}$ molar teeth, has been separated generically under the name of *Felsinotherium* by Capellini, by whom it has been fully described. A portion of a skull found in Belgium has been named *Crassitherium* by Van Beneden; and some compressed teeth, somewhat similar to but larger than those of the Dugong, discovered in the department of Lot-et-Garonne, France, gave origin to the genus *Rytiodus* of E. Lartet. Of this more complete remains have recently been described by Delfortrie. The rostrum is more elongated than in *Halitherium*, but the skull is otherwise very similar, as are the molar teeth. The incisors are very large, exserted, strongly compressed, almost sabre-like, rounded on the upper or anterior surface, sharp below, concave on the external and convex on the inner side, and transversely striated.

Pachyacanthus of Brandt, from the Vienna basin, is also, according to Van Beneden, another form of *Sirenia*, of which, however, the skull is not known. In various Miocene and perhaps Eocene marine formations of the United States of America remains of Sirenians have been found, but mostly in such a fragmentary condition that they afford at present little evidence of the early history of the group in that country. A more satisfactory discovery is that of a nearly complete skull and some bones from a limestone Tertiary formation in Jamaica. It is of smaller size than the Manatee, and as far as the teeth are concerned, of a still more generalized character than *Halitherium*, the dentition being apparently $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{5}{5}$, $m\ \frac{3}{3} = 48$. The incisors are small, not developed into tusks; the canines (wanting in all existing Sirenians) are rather larger than the incisors, judging by the sockets; and the molars are bilophodont, and covered with enamel. It has been described by Professor Owen under the name of *Prorastomus sirenoides*. Unfortunately we have no knowledge of the geological antiquity of the formation in which it was embedded. Lastly must be mentioned the *Eotherium egyptiacum*, Owen, founded on the cast of a brain, with a small quantity of surrounding bone, discovered in the nummulitic limestone of Eocene age of the Mokattam Hills, near Cairo. The brain is narrower than in *Manatus*, and resembles that of *Halitherium*. This is of interest as the most ancient known evidence of any Sirenian whose age has been geologically determined.

The few facts as yet collected relating to the former history of the *Sirenia* leave us as much in the dark as to the origin and affinities of this peculiar group of animals as we were when we only knew the living members. They lend no countenance to their association with the *Cetacea*, and on the other hand their supposed affinity with the *Ungulata*, so much favoured by modern zoologists, receives no very material support from them.

Bibliography of Sirenia.—J. F. Brandt, *Symbolæ Sirenologicæ*, St Petersburg, 3 fasciculi, 1846-61-68,—an exhaustive account of the anatomy, affinities, and literature of the group, with copious illustrations of the osteology of *Rhytina*. *Anatomy of Dugong*:—Everard Home, *Phil. Trans.*, 1820, p. 315; Owen, *Proc. Zool. Soc.*, 1838, p. 29. *Manatee*:—Vrolik, *Bijdr. tot de Dierkunde*, 1851; Murie, *Trans. Zool. Soc. Lond.*, vol. viii. p. 127, 1870, and vol. xi. p. 19, 1880; Garrod, *ibid.*, vol. x. p. 137, 1875. *Extinct Sirenia*:—Gervais, *Journal de Zoologie*, tom. i. p. 332, 1872.

Order CETACEA.

This is perhaps the most distinctly circumscribed and natural of all the larger groups into which the class is divided.

The external form is Fish-like, the body being fusiform, passing anteriorly into the head without any distinct constriction or neck, and posteriorly tapering off gradually towards the extremity of the tail, which is provided with a pair of lateral, pointed expansions of skin supported by dense fibrous tissue, called "flukes," forming together a horizontally placed triangular propelling organ, notched in the middle line behind.

The head is generally large, in some species attaining to even more than one-third of the entire length of the animal, and the aperture of the mouth is always wide, and bounded by stiff immobile lips. The fore limbs are reduced to the condition of flattened ovoid paddles, encased in a continuous integument, showing no external sign of division into fore arm and manus, or of separate digits, and without any trace of nails. There are no signs of hind limbs visible externally. The general surface of the skin is smooth and glistening, and devoid of hair, although in many species there are a few fine bristles in the neighbourhood of the mouth, which may persist through life or be present only in the young state. Immediately beneath the skin, and intimately connected with it, is a thick layer of fat, held together by a dense mesh of areolar tissue, constituting the "blubber," which serves the purpose of the hairy covering of other mammals in retaining the heat of the body. In nearly all species a compressed median dorsal tegumentary fin is present. The eye is small, and is not provided with a nictitating membrane or true lacrymal apparatus. The external auditory meatus is a very minute aperture in the skin situated at a short distance behind the eye, and there is no vestige of a pinna. The nostrils open separately or by a single crescentic valvular aperture, not at the extremity of the snout, but near the vertex.

The bones generally are spongy in texture, the cavities being filled with oil. In the vertebral column, the cervical region is remarkably short and immobile, and the vertebræ, originally always seven in number, are in many species more or less fused together into a solid mass. The odontoid process of the axis, when that bone is free, is usually very obtuse, or even obsolete. None of the vertebræ are united

[1] Nordenskiöld, during his recent voyage in the "Vega," obtained some information from natives of Behring's Island which led him to believe that a few individuals may have survived to a much later date, even to 1854.

together to form a sacrum. The lumbar and caudal vertebræ are numerous and large, and, as their arches are not connected by any articular processes (zygapophyses), they are capable of a very free motion in all directions. The epiphyses at the ends of the vertebral bodies are very distinct flattened disks, not uniting until after the animal has attained its full dimensions.[1] There are largely developed chevron bones, the presence of which indicates the distinction between the caudal and lumbar vertebræ.

The skull is modified in a very peculiar manner. The brain-case is short, broad, and high, almost spherical in fact. The supra-occipital bone rises upwards and forwards from the foramen magnum, to meet the frontals at the vertex, completely excluding the parietals from the upper region of the cranium. The frontals are expanded laterally to form the roof of the orbits. The anterior narial aperture opens upwards, and has in front of it a

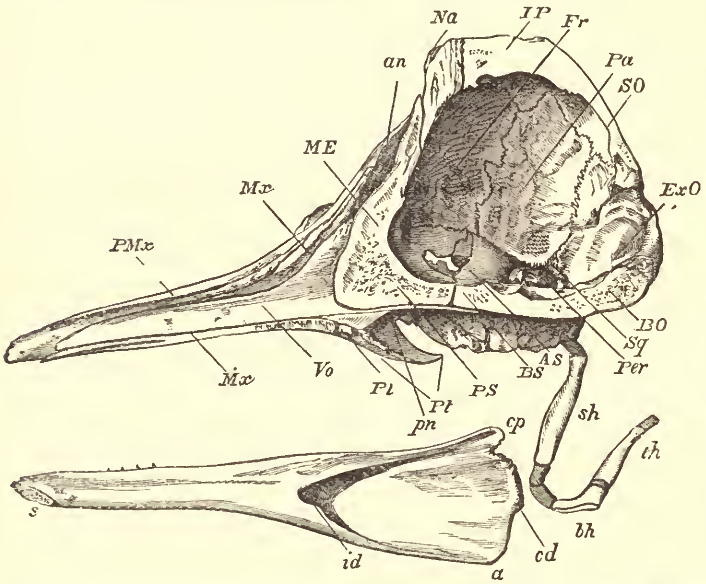

FIG. 42.—A Section of the Skull of a Young Dolphin (*Globicephalus melas*). ×⅛. *PMx*, premaxilla; *Mx*, maxilla; *ME*, ossified portion of the mesethmoid; *an*, anterior nares; *Na*, nasal; *IP*, inter-parietal; *Fr*, frontal; *Pa*, parietal; *SO*, supra-occipital; *ExO*, ex-occipital; *BO*, basi-occipital; *Sq*, squamosal; *Per*, periotic; *AS*, alisphenoid; *PS*, presphenoid; *Pt*, pterygoid; *pn*, posterior nares; *Pl*, palatine; *Vo*, Vomer; *s*, symphysis of mandible; *id*, inferior dental canal; *cp*, coronoid process of mandible; *cd*, condyle; *a*, angle; *sh*, stylo-hyal; *bh*, basi-hyal; *th*, thyro-hyal. From *Osteology of Mammalia*.

more or less horizontally prolonged rostrum, formed of the maxillæ, premaxillæ, vomer, and mesethmoid cartilage, extending forwards to form the upper jaw or roof of the mouth.

There are no clavicles. The humerus is freely movable on the scapula at the shoulder-joint, but beyond this the articulations of the limb are imperfect, flattened ends of the bones coming in contact with each other, with fibrous tissue interposed, allowing of scarcely any motion. The radius and ulna are distinct, and about equally developed, and much flattened, as are all the bones of the manus. There are four, or more commonly five, digits, and the number of the phalanges of the second and third digits always exceeds the normal number in mammals, sometimes very considerably; they present the exceptional character of having epiphyses at both ends.[2] The pelvis is represented by a pair of small styliform bones placed longitudinally, suspended below and at some distance from the vertebral column at the commencement of the caudal region. These appear to represent the ischia, as the crura of the corpora cavernosa are attached to them. In some species, to the outer surface of these are fixed other small bones or cartilages, the rudiments of the hind limb.

Teeth are generally present, but exceedingly variable in number. In the existing species, they are of simple, uniform character, all having conical or compressed crowns and single roots, and are never preceded by milk teeth. They are therefore homodont and monophyodont. In one group, the Mystacocetes, the teeth are absent (except in the fœtal condition), and the palate is provided with numerous transversely placed horny laminæ or "baleen." The salivary glands are rudimentary or absent. The stomach is multilocular. The intestinal canal simple, and only in some species provided with a small cæcum. The liver is very little fissured, and there is no gall-bladder. The vascular system is greatly complicated by arterial and venous plexuses, or *retia mirabilia*. The larynx is of peculiar shape, the arytenoid cartilages and the epiglottis being much elongated, and together forming a tubular prolongation, which projects into the posterior nares, and when embraced by the soft palate forms a continuous passage between the nostrils and the trachea, as in the Ungulates, but in a more perfect manner. The brain is large relatively to the size of the animal, very round in form, and with its surface divided by sulci into very numerous and complex convolutions. The kidneys are deeply lobulated. The testes are abdominal. There are no vesiculæ seminales, nor os penis. The uterus is bicornuate, the placenta non-deciduate and diffuse. The mammæ are two in number, and the nipples placed in depressions on each side of the vulva. The principal ducts of the gland are dilated during lactation into large reservoirs, into which the milk collects, and from which it is injected by the action of a compressor muscle into the mouth of the young animal, by which means the process of sucking under water is greatly facilitated and expedited.

The animals of the order *Cetacea* abound in all known seas, and some species are inhabitants of the larger rivers of South America and Asia. Their organization necessitates their passing their life entirely in the water, as on land they are absolutely helpless. They have, however, to rise very frequently to the surface for the purpose of respiration; and, in relation to the constant upward and downward movement in the water thus necessitated, their principal instrument of motion, the tail, is expanded horizontally, quite unlike that of a Fish, whose movements are mainly in straightforward or lateral directions. The position of the respiratory orifice or nostril on the highest part of the head is very important for this mode of life, as it is the only part of the body the exposure of which above the surface is absolutely necessary. Of the numerous erroneous ideas connected with natural history, few are so widespread and still so firmly believed, notwithstanding repeated expositions of its falsity, as that the *Cetacea* spout out through their blowholes water taken in at the mouth. The fact is, the "spouting," or more properly "blowing," of the Whale is nothing more than the ordinary act of expiration, which, taking place at longer intervals than inland animals, is performed with a greater amount of emphasis. The moment the animal rises to the surface it forcibly expels from its lungs the air taken in at the last inspiration, which of course is highly charged with watery vapour in consequence of the natural respiratory changes. This, rapidly condensing in the cold atmosphere in which the phenomenon is generally observed, forms a column of steam or spray, which has been erroneously taken for

[1] This is an important distinction from the *Sirenia*, but a character common to nearly all other mammals. It is doubtful whether there is any foundation for the statement that these epiphyses remain ununited for an exceptionally long period in the *Cetacea*.

[2] A character repeated in some of the Seals.

water. It also often happens, especially when the surface of the ocean is agitated into waves, that the animal commences its expiratory puff before the orifice has quite cleared the top of the water, some of which may thus be driven upwards with the blast, tending to complete the illusion. In hunting Whales the harpoon often pierces the lungs or air passages of the unfortunate victim, and then fountains of blood may be forced high in the air through the blowholes, as commonly depicted in scenes of Arctic adventure; but this is nothing more (allowance being made for the Whale's peculiar mode of breathing) than what always follows severe wounds of the respiratory organs of other mammals.

All the *Cetacea* are predaceous, subsisting on living animal food of some kind. One genus alone (*Orca*) eats other warm-blooded animals, as seals, and even members of its own order, both large and small. Many feed on fish, others on small floating crustaceans, pteropods, and medusæ, while the principal staple of the food of many is constituted by the various species of cephalopods, *Loligo* and other *Teuthidæ*, which must abound in some seas in vast numbers, as they form almost the entire support of some of the largest members of the order. In size the *Cetacea* vary much, some of the smaller Dolphins scarcely exceeding 4 feet in length, while others are the most colossal of all animals. It is true that most statements of their bulk found in general and even zoological literature are greatly exaggerated, but even when reduced to their actual dimensions (which will be mentioned under the respective genera) some of the existing Whales exceed in size that of any animal living either at present or in former times of which we have any certain evidence. With some exceptions, the *Cetacea* generally are timid inoffensive animals, active in their movements, and very affectionate in their disposition towards one another, especially the mother towards the young, of which there is usually but one, or at most two, at a time. They are generally gregarious, swimming in herds or "schools" (so termed by the whalers) sometimes amounting to many thousands in number; though some species have hitherto only been met with either singly or in pairs.

Relations of the different Cetacea to each other and to other Mammals.—As before said, the *Cetacea* form a perfectly well-defined group, sharply separated from all other mammals, and with no outlying or doubtful forms at present known. Among the existing members of the order, there are two very distinct types, the Toothed Whales or *Odontoceti* and the Baleen Whales or *Mystacoceti*, which present as many marked distinguishing structural characters as are found between many other divisions of the *Mammalia* which are reckoned as orders. The extinct *Zeuglodon*, so far as its characters are known, does not fall into either of these groups, but is in some respects an annectant form, and therefore must be placed, provisionally at least, in a third group by itself.

The Mystacocetes appear at first sight to be the most specialized and aberrant of the existing *Cetacea*, as indicated by the absence of teeth, the presence of baleen, and the form and size of the mouth; but, as we see in other groups, dental characters, and all such as relate to the prehension of food generally, are essentially adaptive and consequently plastic or prone to variation, and hence cannot well be relied upon as tests of affinity. In another character, also adaptive, the laxity of the connexion of the ribs with the vertebral column and with the sternum, and the reduction of that bone in size, allowing great freedom of expansion of the thoracic cavity for prolonged immersion beneath the water, the Mystacocetes have passed beyond the Odontocetes in specialization. On the other hand, the greater symmetry of the skull, the more anterior position of the external nostrils and their double external orifice, the form of the nasal bones, the presence of a distinctly developed olfactory organ, the mode of attachment of the periotic bone to the cranium, the presence of a cæcum and the regular arrangement of the alimentary canal, the more normal characters of the manus and the better development of the muscles attached to it, and the presence, in many species at least, of parts representing not only the bones but the muscles and ligaments of a hind limb,[1] all show less deviation from the ordinary mammalian type than is presented by the Odontocetes. Taking all these characters into consideration, it does not appear reasonable to suppose that either type has been derived from the other, at all events in the form in which we see it now, but rather that they are parallel groups, both modified in different fashions from common ancestors.

Among the Mystacocetes, in the especially distinguishing characters of the division, the *Balænopteræ* are less specialized than the *Balænæ*, which in the greater size of the head, the length and compression of the rostrum, the development of the baleen, and shortness of the cervical region are exaggerated forms of the type, and yet they retain more fully some primitive characters, as the better development of the hind limb, the pentadactylous manus, and the absence of a dorsal fin. Both forms are found distinct in a fossil state as far back as the early Pliocene age, but generally represented by smaller species than those now existing. The Mystacocetes of the Miocene seas were, so far as we know at present, only *Balænopteræ*, some of which (*Cetotherium*) were, in the elongated flattened form of the nasal bones, the greater distance between the occipital and frontal bone at the top of the head, and the greater length of the cervical vertebræ, more generalized than those now existing. In the shape of the mandible also, Van Beneden, to whose researches we are chiefly indebted for a knowledge of these forms, discerns some approximation to the Odontocetes.

Among the last-named group there are several distinct types, of which that represented by *Platanista*, although in some respects singularly modified, has been considered to present on the whole approximations towards the more normal and general type of mammalian structure. It is therefore interesting to find a similar form well represented among the earliest fossil remains of Cetaceans in Europe. Almost all the other members of the suborder range themselves under the two principal heads of Ziphioids (or Physeteroids) and Delphinoids. The former is an ancient and once abounding type, of which the Sperm Whale (*Physeter*) is a highly specialized form. Among the latter, *Globicephalus* is a modified form as regards the structure of its anterior extremity, and *Monodon* as regards its dentition, while *Delphinus* with its various minor subdivisions may be regarded as the dominating type of Cetaceans at the present day, abundant in slightly differentiated species and abundant in individuals. They are in this respect to the rest of the order much as the hollow-horned Ruminants are to the Ungulates.

The earliest Cetaceans of whose organization we have anything like complete evidence are the Zeuglodons of the Eocene period,[2] which approach in the structure of skull and teeth to a more generalized mammalian type than either of the existing suborders. The smallness of the cerebral cavity compared with the jaws and the rest of the skull they share with the primitive forms of many other types. The forward

[1] These have recently been described in detail by Professor Struthers in the *Journal of Anatomy and Physiology*, 1881.

[2] The cervical vertebra of *Palæocetus*, supposed to be from the Cambridge Greensand, and a single caudal vertebra lately found in the Upper Eocene at Roydon in Hampshire, may for the present be omitted from consideration, as too inconclusive in the nature of the evidence they afford as to the history of the group.

position of the narial aperture and the length and flatness of the nasal bones, which distinguish them from all existing forms, we must also suppose to be a character at one time common to all Cetaceans, though now retained (but to a less degree) only by the Mystacocetes. Even *Squalodon*, which in its heterodont dentition so much resembles *Zeuglodon* as to have been placed by some zoologists in the same genus, entirely differs from it, and conforms with the ordinary Dolphins in its essential cranial characters.

The origin of the *Cetacea* is at present involved in much obscurity. They present no signs of closer affinity to any of the lower classes of vertebrates than do many other members of their own class. Indeed in all that essentially distinguishes a mammal from the oviparous vertebrates, whether in the osseous, nervous, reproductive, or any other system, they are as truly mammalian as any other group. Any supposed marks of inferiority, as absence of limb structure, of hairy covering, of lacrymal apparatus, &c., are obviously modifications (or degradations, as they may be termed) in adaptation to their special mode of life. The characters of the teeth of *Zeuglodon* and other extinct forms, and also of the fœtal Mystacocetes, clearly indicate that they have been derived from mammals in which the heterodont type of dentition was fully established. The steps by which a land mammal may have been modified into a purely aquatic one are clearly indicated by the stages which still survive among the *Carnivora*, in the *Otariæ*, and in the true Seals. A further change in the same direction would produce an animal somewhat resembling a Dolphin, and it has been thought that this may have been the route by which the Cetacean form has been developed. There are, however, great difficulties in the way of this view. If the hind limbs had ever been developed into the very efficient aquatic propelling organs they present in the Seals, it is not easy to imagine how they could have become completely atrophied and their function transferred to the tail. It is more likely that the Whales were derived from animals with long tails, which were used in swimming, eventually with such effect that the hind limbs became no longer necessary. The powerful tail, with its lateral cutaneous flanges, of an American species of Otter (*Pteronura sandbachii*) may give an idea of this member in the primitive Cetaceans. But the structure of the *Cetacea* is, in so many essential characters, so unlike that of the *Carnivora* that the probabilities are against these orders being nearly related. Even in the skull of the Zeuglodon, which has been cited as presenting a great resemblance to that of a Seal, quite as many likenesses may be traced to one of the primitive Pig-like Ungulates (except in the purely adaptive character of the form of the teeth), while the elongated larynx,[1] complex stomach, simple liver, reproductive organs both male and female, and fœtal membranes of the existing *Cetacea* are far more like those of that group than of the *Carnivora*. Indeed it appears probable that the old popular idea which affixed the name of "Sea-Hog"[2] to the Porpoise contains a larger element of truth than the speculations of many accomplished zoologists of modern times. The fact that *Platanista*, which, as mentioned above, appears to retain more of the primitive characteristics of the group than any other existing form, and also the somewhat related *Inia* from South America, are both to the present day exclusively fluviatile, may point to the freshwater origin of the whole group, in which case their otherwise rather inexplicable absence from the seas of the Cretaceous period would be accounted for.

[1] There is much resemblance in the larynx of the Hippopotamus, but none in that of the Seal, to the same organ in the *Cetacea*.

[2] German, *Meerschwein*, whence the French *Marsouin*. "Porpoise" is said to be derived from "*Porc-poisson*."

Suborder *MYSTACOCETI*,
the Balænoidea, *or Whalebone Whales.*

Teeth never functionally developed, but always disappearing before the close of intra-uterine life. Palate provided with plates of baleen or "whalebone." Skull symmetrical. Nasal bones forming a roof to the anterior nasal passages, which are directed upwards and forwards. Maxilla produced in front of, but not over, the orbital process of the frontal. Lacrymal bones small and distinct from the jugal. Tympanic bone ankylosed with the periotic, which is attached to the base of the cranium by two strong diverging processes. Olfactory organ distinctly developed. Rami of mandible arched outwards, their anterior ends meeting at an angle, and connected by fibrous tissue without any true symphysis. All the ribs at their upper extremity articulating only with the transverse processes of the vertebræ; their capitular processes when present not articulating directly with the bodies of the vertebræ. Sternum composed of a single piece, and articulating only with a single pair of ribs. No ossified sternal ribs. External openings of nostrils distinct from each other, longitudinal. A short conical cæcum.

These animals have, when in the fœtal state, numerous, minute, calcified teeth lying in the dental groove of both upper and lower jaws. They are best developed about the middle of fœtal life, after which period they are absorbed, and no trace of them remains at the time of birth.[3] The baleen or whalebone does not make its appearance until after birth. It consists of a series of flattened horny plates, between three and four hundred in number, on each side of the palate, with a bare interval along the middle line. They are placed transversely to the long axis of the palate, with very short intervals between them. Each plate or blade is somewhat triangular in form, with the base attached to the palate and the apex hanging downwards. The outer edge of the blade is hard and smooth, but the inner edge and apex fray out into long bristly fibres, so that the roof of the whale's mouth looks as if covered with hair, as described by Aristotle. At the inner edge of each principal blade are two or three much smaller or subsidiary blades. The principal blades are longest near the middle of the series, and gradually diminish towards the front and back of the mouth. The horny plates grow from a dense fibrous and highly vascular matrix, which covers the palatal surface of the maxillæ, and which sends out lamellar processes, one of which penetrates the base of each blade. Moreover, the free edge of these processes is covered with very long vascular thread-like papillæ, one of which forms the central axis of each of the hair-like epidermic fibres of which the blade is mainly composed. A tranverse section of fresh whalebone shows that it is made up of numbers of these soft vascular papillæ, circular in outline, each surrounded by concentrically arranged epidermic cells, the whole bound together by other epidermic cells, that constitute the smooth cortical (so-called "enamel") surface of the blade, which, disintegrating at the free edge, allows the individual fibres to become loose and assume the hair-like appearance before spoken of. These fibres differ from hairs in not being formed in depressed follicles in the enderon, but rather resemble the fibres composing the horn of the Rhinoceros. The whalebone in fact consists of nothing more than modified papillæ of the buccal mucous membrane, with an excessive and cornified epithelial development. The blades are supported, and bound together for a certain distance from their base, by a mass of less hardened epithelium, secreted by the surface of the palatal membrane or matrix of the whalebone in the intervals of the lamellar processes. This is the "intermediate substance" of Hunter, the "gum" of the whalers. Baleen varies much in colour in different species. In some it is almost jet black, in others slate colour, horn colour, yellow, or even creamy-white. In some the blades are variegated with longitudinal stripes of different hues. It differs also greatly in other respects, being short, thick, coarse, and stiff in some, and greatly elongated and highly elastic in those species in which it has attained its fullest development. Its function is to strain the water from the small marine molluscs, crustaceans, or fish upon which the whales subsist. In feeding they fill the immense mouth with water containing shoals of these small creatures, and then, on their closing the jaws and raising the tongue, so as to diminish the cavity of the mouth, the water streams out through the narrow intervals between the hairy fringe of the whalebone blades, and escapes through the lips, leaving the living prey to be swallowed.[4]

Our knowledge of the different structural modifications at-

[3] These were discovered in the Greenland Whale by Geoffroy St Hilaire, whose observations were confirmed and extended to other genera by Eschricht. They have lately been very fully described in *Balænoptera rostrata* by Julin (*Archives de Biologie*, i., 1880).

[4] For the structure of whalebone, see Hunter, "Observations on the Structure and Economy of Whales," *Phil. Trans.*, 1787; Eschricht and Reinhardt, *On the Greenland Right Whale*, English translation by the Ray Society, 1866, pp. 67–78; and W. Turner, in *Trans. Roy. Soc. Edin.*, 1870.

tained by members of this important group of mammals, though largely increased of late years, is still imperfect. Formerly they were all divided into Right Whales (*Balæna*) and Rorquals or Fin-whales (*Balænoptera*), the latter distinguished by their smaller heads, elongated and slender form, free cervical vertebræ, tetradactylous manus, and the presence of very conspicuous longitudinal furrows or folds in the skin of the throat and chest, and of a small adipose dorsal fin. Recent discoveries have, however, brought to light several forms holding a somewhat intermediate position, and presenting combinations of characters not found in either of the larger known sections. According to our present knowledge the group is naturally divided into five very distinct genera. As these will be more fully described in the article WHALE, it will be sufficient at present to indicate their principal characteristics.

Balæna.—Skin of throat smooth, not furrowed. No dorsal fin. Cervical vertebræ united into a single mass. Pectoral limb short, broad, and pentadactylous. Head very large. Baleen very long and narrow, highly elastic and black. Scapula high, with a distinct coracoid and coronoid process. This genus contains the well-known Greenland Right Whale (*B. mysticetus*) of the Arctic seas, the whalebone and oil of which are so much valued in commerce, and also other whales, distinguished from this by having heads somewhat smaller in proportion to the body, with shorter baleen, and a larger number of vertebræ. These inhabit the temperate seas of both northern and southern hemispheres, and have been divided by zoologists into several species in accordance with their geographical distribution,—*B. biscayensis* of the North Atlantic, *B. japonica* of the North Pacific, *B. australis* of the South Atlantic, and *B. antipodarum* and *novæ-zelandiæ* of the South Pacific; but the differential characters by which they have been separated—external as well as anatomical—are so slight and so liable to individual variation that it is not improbable that when they are better known they will all come to be regarded as forming but a single species.

Neobalæna.—Known chiefly at present by the characters of the skeleton and baleen, which are very different from those of all other whales, but said to combine absence of plications of the throat with the presence of a dorsal fin. The cervical vertebræ are united. The manus small, narrow, and tetradactylous, wanting the pollex. The ribs remarkably expanded and flattened. The scapula very low and broad, with completely developed acromion and coracoid processes. Baleen very long, slender, elastic, and white. A single at present very rare species, *N. marginata*, from the Australian and New Zealand seas, is the smallest of the Whalebone Whales, being not more than 20 feet in length.

Rachianectes.—This combines the small head, elongated form, and narrow pectoral fin of *Balænoptera* with the smooth skin of the throat and absence of the dorsal fin of *Balæna*. The baleen is the shortest and coarsest of any of the group. Its osteology is imperfectly known. One species, *R. glaucus*, the Grey Whale of the North Pacific.

Megaptera.—Head of moderate size. Baleen plates short and broad. Cervical vertebræ free. Scapula with acromion and coracoid process absent or rudimentary. Skin of throat plicated. Dorsal fin low. Pectoral limb tetradactylous, very long and narrow, attaining about one-fourth of the length of the entire animal, the metacarpus and phalanges being greatly developed, and the latter very numerous. Animals of this genus, called "Humpbacks" by the whalers, are found in almost all seas. They have been divided into many species, but no satisfactory characters have yet been pointed out by which these can be distinguished from one another.

Balænoptera.—Head small and flat, and pointed in front. Body long and slender. Skin of throat plicated. A small falcate dorsal fin. Baleen short and coarse. Cervical vertebræ free. Scapula low and broad, with a large acromion and coracoid process. Pectoral limb tetradactylous, small, narrow, and pointed. This genus contains the various species of Rorquals, Fin-whales, Fin-backs, Finners, or Razor-backs, as they are variously called, some of which are found in almost every sea. Among them are the most gigantic of all animals, *B. sibbaldii*, which attains the length of 80 feet, and the small *B. rostrata*, which does not exceed 30. There are certainly four quite distinct modifications of this genus, represented by the two just mentioned, and by *B. musculus* and *B. borealis*, all inhabitants of British seas, but the question whether almost identical forms found in the Southern and Pacific Oceans are to be regarded as specifically identical or as distinct awaits the result of future researches.

SUBORDER *ARCHÆOCETI.*

This group is formed to include certain extinct Cetaceans, which are at present only known by more or less fragmentary portions of their skeleton and teeth, and whose position and affinities are therefore still subject to doubt.

In the anterior part of both jaws the teeth are simple, conical, or slightly compressed, and sharp-pointed. The first three in the upper jaw are distinctly implanted in the premaxillary bone, and so may be reckoned as incisors. The tooth which succeeds, or the canine, is also simple and conical, but it does not exceed the others in size. This is followed by five teeth with two distinct roots, and compressed, pointed crowns, with denticulated cutting edges. The dentition is therefore $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, p and $m\,\frac{5}{5} = 36$, resembling that of some Seals.[1] General form of the skull elongated and much depressed. Brain cavity very small, and the skull between it and the orbits elongated and narrow. Temporal fossæ very large. A strong sagittal crest. Rostrum long and narrow, differing from that of other Cetaceans in the large extent to which the premaxillæ form the sides of the anterior extremity. Nasal bones elongated, flat, and narrow, the opening of the anterior nares being over the middle of the elongated compressed rostrum. All the cervical vertebræ free. The characters of the dorsal vertebræ, and mode of articulation of the ribs, appear to have resembled those of *Platanista* rather than *Balæna*, *Physeter*, or *Delphinus*. Lumbar vertebræ with elongated bodies. Characters of the limbs not known with certainty.[2]

All the known fossil remains belonging to the animals of this group may be referred, provisionally at least, to the genus *Zeuglodon*, so named because the first section of a molar tooth examined was taken from the base of the crown, where it was beginning to divide into the two roots, and looked like two single teeth "linked or yoked together." This name was substituted by Owen for the earlier one *Basilosaurus* of Harlan, with the consent of that author, on the mammalian nature of the animal being demonstrated.[3] The latter name is, however, still generally retained by American zoologists. The remains have hitherto been found chiefly in the Eocene formations of the States of Alabama, Louisiana, Mississippi, and Arkansas, and have been assigned to several species. A portion of a skull is recorded from the Barton Clay (Eocene) of Hampshire, England.

SUBORDER *ODONTOCETI,* *the* DELPHINOIDEA, *or Toothed Whales.*

Calcified teeth always present after birth; generally numerous, but sometimes a very limited number (in a few cases none) are functionally developed. No baleen. Upper surface of the skull more or less asymmetrical. Nasal bones in the form of nodules or flattened plates, applied closely to the frontals, and not forming any part of the roof to the narial passage, which is directed upwards and backwards. Olfactory organ rudimentary or absent. Hinder end of the maxilla expanded and covering the greater part of the orbital plate of the frontal bone. Lacrymal bone either inseparable from the jugal, or, when distinct, very large, and forming part of the roof of the orbit. Tympanic bone not ankylosed with the periotic, which is usually only attached to the rest of the skull by ligament. Rami of mandible nearly straight, much expanded in height posteriorly, with a wide funnel-shaped aperture to the dental canal, and coming in contact in front by a flat surface of variable length, but always constituting a true symphysis. Several of the anterior ribs with well-developed capitular processes, which articulate with the bodies of the vertebræ. Sternum almost always composed of several pieces, placed one behind the other, with which several pairs of ribs are always connected by the intervention of well-developed cartilaginous or ossified sternal ribs. External respiratory aperture single, the two nostrils uniting before they reach the surface, usually in the form of a transverse subcrescentic valvular aperture, situated on the top of the head. Manus always pentadactylous, though the first and fifth digits are usually very little developed. No cæcum, except in *Platanista*.

Family PHYSETERIDÆ.

No functional teeth in the upper jaw. Mandibular teeth various, often much reduced in number. Bones of the cranium raised so as to form an elevated prominence or crest behind the nares. Pterygoid bones thick, produced backwards, meeting in the middle line, and not involuted to form the outer wall of the post-palatine air-sinuses, but simply hollowed on their outer side. Transverse processes of the arches of the dorsal vertebræ, to which the tubercles of the ribs are attached, ceasing abruptly near the end of the series, and replaced by processes on the body at a much lower level, and not on a line, or serially homologous with them, but serially homologous anteriorly with the heads of the ribs, and posteriorly with the transverse processes of the lumbar vertebræ. (In some genera, as *Physeter*, the two processes, upper and lower on each side, are both present and well developed in the same vertebra in the region of transition. In others, as *Ziphius* and *Berardius*, they are not both developed on any single vertebra.) Costal cartilages not ossified.

Subfamily **Physeterinæ.**—Numerous teeth in the mandible, which are not set in distinct bony alveoli, but in a long groove

[1] An appearance in one specimen has been described by C. G. Carus as indicating a vertical succession of the teeth, but the evidence upon which this rests is by no means satisfactory, and appears to admit of another explanation.

[2] A mutilated humerus of *Zeuglodon cetoides* has given rise to many conjectures, appearing to some anatomists to indicate Seal-like freedom of motion at the elbow-joint, while to others its characters appear to be truly Cetacean.

[3] See *Trans. Geol. Soc. Lond.*, ser. ii., vol. vi. p. 67.

imperfectly divided by partial septa, and held in place by the strong, fibrous gum which surrounds them. No distinct lacrymal bone. Cranium strikingly asymmetrical in the region of the narial apertures, in consequence of the left opening greatly exceeding the right in size.

Physeter.—Upper teeth apparently of uncertain number, rudimentary and functionless, being embedded in the gum. Lower jaw with from 20 to 25 teeth on each side, stout, conical, recurved, and pointed at the apex until they are worn, without enamel. Upper surface of the cranium concave; its posterior and lateral edges raised into a very high and greatly compressed semicircular crest or wall. Zygomatic processes of malar bones thick and massive. Rostrum greatly elongated, broad at the base and gradually tapering to the apex. Upper edge of the mesethmoid forming a roughened irregular projection between the narial apertures, inclining to the left side. Mandible exceedingly long and narrow, the symphysis being more than half the length of the ramus. Vertebræ: C 7, D 11,

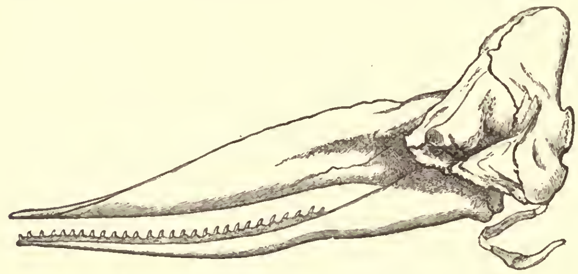

FIG. 43.—Skull of Sperm Whale (*Physeter macrocephalus*).

L 8, C 24; total 50. Atlas free; all the other cervical vertebræ united by their bodies and spines into a single mass. Eleventh pair of ribs rudimentary. Head about one-third the length of the body; very massive, high and truncated, and rather compressed in front; owing its huge size and remarkable form mainly to the great accumulation of a peculiarly modified form of adipose tissue filling the large hollow on the upper surface of the cranium and overlying the rostrum. The single blowhole is longitudinal, slightly sigmoid, and placed at the upper and anterior extremity of the head to the left side of the middle line. The opening of the mouth is on the under side of the head, considerably behind the end of the snout. Pectoral fin short, broad, and truncated. Dorsal fin a mere low protuberance.

There is no certain evidence that more than one species of this genus exists. This is the Cachalot or Sperm Whale, *P. macrocephalus*, one of the most colossal of animals, quite equalling, if not exceeding, the Greenland Whale in bulk. The length of the full-grown male is from 55 to 60 feet, but the female is stated not to reach more than half that size. It feeds chiefly on cephalopods and fish, and is one of the most extensively distributed of Cetaceans, being met with, usually in herds or "schools," in almost all tropical or subtropical seas, but not occurring, except accidentally, in the polar regions. Those that appear occasionally on the British coasts are solitary stragglers, usually, if not always, old males. The oil contained in the great cavity above the skull, when refined, yields "spermaceti," and the thick covering of blubber which everywhere envelops the body produces the valuable "sperm oil" of commerce; hence this animal has long been the subject of a regular chase, by which its numbers have been greatly diminished. The substance called "ambergris," largely used in perfumery, is a concretion formed in the intestine of the Sperm Whale, and is found floating on the surface of the seas which they inhabit. Its genuineness is attested by the presence of the debris of the horny beaks of the cephalopods on which the Whales feed.

Kogia.—Teeth of the upper jaw absent or reduced to a rudimentary pair in front; in lower jaw 9 to 12 on each side, rather long, slender, pointed, and curved, with a coating of enamel. Upper surface of the cranium concave, with thick, raised, posterior and lateral margins, massive and rounded at their anterior terminations above the orbits. Upper edge of the mesethmoid forming a prominent sinuous ridge, constituting a kind of longitudinal septum to the base of the great supra-cranial cavity. Rostrum not longer than the cranial portion of the skull, broad at the base, and rapidly tapering to the apex. Zygomatic process of the malar styliform. Mandible with symphysis less than half the length of the entire ramus. Vertebræ: C 7, D 13 or 14, L and C 30; total 50 or 51. All the cervical vertebræ united by their bodies and arches. External characters not well known, but, judging by the somewhat conflicting accounts of those that have had an opportunity of observing them, the head is about one-sixth of the length of the body, and obtusely pointed in front; the mouth small and placed far below the apex of the snout; the spiracle crescentic, and placed obliquely on the top of the head anteriorly to the eyes, and to the left of the middle line; the pectoral fins are obtusely falcate; and there is a triangular dorsal fin.

The history of this genus is a good illustration of the difficulties in which the study of the *Cetacea* has been involved by the superficial manner in which it has been investigated. The first known example, a skull from the Cape of Good Hope in the Paris Museum, was described by Blainville under the name of *Physeter breviceps*. This was afterwards with good reason generically separated by Gray. Until within a very few years ago only five other individuals had been met with, each of which had been described under a different specific name (viz., *grayi*, *macleayi*, *simus*, *floweri*, and *potsii*), and which are arranged by Gray in two distinct genera. The most careful examination of the description given of these specimens, or of the now numerous osteological remains available, fails to detect any differences beyond those which may be attributed to age or sex; and hence, according to our present knowledge, these six supposed species must all be included under one name, *K. breviceps*, an animal which appears to attain the length of 10 feet when adult, and has been met with at various distant localities in the Southern Ocean, and also off the coast of Madras and in the North Pacific.

Subfamily **Ziphiinæ.**—Teeth of the mandible quite rudimentary and concealed in the gum, except one, or very rarely two, pairs which may be largely developed, especially in the male sex. A distinct lacrymal bone. Externally the mouth is produced into a slender rostrum or beak, from above which the rounded eminence formed by a cushion of fat resting on the cranium in front of the blowhole rises somewhat abruptly. Spiracle or blowhole single, crescentic, median, as in the *Delphinidæ*. Pectoral fin small, ovate, the five digits all moderately well developed. A small obtusely falcate dorsal fin situated considerably behind the middle of the back. Longitudinal grooves on each side of the skin of the throat, diverging posteriorly, and nearly meeting in front. In external characters and habits the animals of this group closely resemble each other. They appear to be almost exclusively feeders on various species of cephalopods, and occur either singly, in pairs, or in small herds. By their dental and osteological characters they are easily separated into four distinct genera.

Hyperoodon.—A small conical pointed tooth at the apex of each ramus of the mandible, concealed by the gum during life. Skull with the upper ends of the premaxillæ rising suddenly behind the nares to the vertex and expanded laterally, their outer edges curving backwards and their anterior surfaces arching forwards and overhanging the nares; the right larger than the left. Nasal bones lying in the hollow between the upper extremities of the premaxillæ, strongly concave in the middle line and in front; their outer edges, especially that of the right, expanded over the front of the inner

FIG. 44.—*Hyperoodon rostratus.* From a specimen taken off the coast of Scotland, 1882.

border of the maxilla. Very high longitudinal crests on the maxillæ at the base of the rostrum, extending backwards almost to the nares, approaching each other in the middle line above; sometimes compressed and sometimes so massive that their inner edges come almost in contact. Anteorbital notch distinct. Mesethmoid but slightly ossified. Vertebræ: C 7, D 9, L 10, C 19; total 45. All the cervical vertebræ united. Upper surface of the head in front of the blowhole very prominent and rounded, rising abruptly from above the small, distinct snout.

Two species are known, *H. rostratus*, the common Hyperoodon or Bottle-nose, and *H. latifrons*, both inhabitants of the North Atlantic, and attaining when adult respectively the length of 24 and 30 feet.

Ziphius.—A single conical tooth of moderate size on each side of the mandible close to the anterior extremity, and directed forwards and upwards. Skull with the premaxillæ immediately in front and at the sides of the nares expanded, hollowed, and with elevated lateral margins, the posterior ends rising to the vertex and curving forwards, the right being considerably more developed than the left; the conjoint nasals forming a strongly pronounced symmetrical eminence at the top of the cranium, projecting forwards over the nares, flat above, most prominent and rounded in the middle line in front, and separated by a notch on each side from the premaxillæ. Anteorbital notch not distinct. Rostrum (seen from above) triangular, gradually tapering from the base to the apex; upper and outer edges of maxillæ at base of rostrum raised into low roughened tuberosities. Mesethmoid cartilage densely ossified in adult age, and coalescing with the surrounding bones of the rostrum. Vertebræ: C 7, D 10, L 10, C 22; total 49. The three anterior cervical vertebræ united, the rest free.

The type of this genus is *Z. cavirostris* of Cuvier, founded upon an imperfect skull picked up in 1804 on the Mediterranean coast of France, and described and figured in the *Ossemens Fossiles* under the impression that it was that of an extinct species. Many other individuals have, however, been subsequently met with in various parts of the world, from the Shetland Islands to New Zealand, all referable to the same genus if not to the same species; although, as is usual in such cases, they have mostly been described under different names. Teeth, apparently of allied forms, are abundantly found in the Suffolk and Antwerp Crags.

Mesoplodon.[1]—A much compressed and pointed tooth in each ramus of the mandible, variously situated, but generally at some distance behind the apex; its point directed upwards, and often somewhat backwards, occasionally developed to a great size. Skull with the region around the nares as in *Hyperoodon*, except that the nasals are narrow and more sunk between the upper ends of the

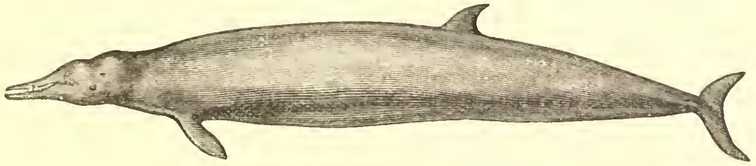

FIG. 45.—*Mesoplodon bidens.* From Reinhardt.

premaxillæ; like those of *Hyperoodon*, they are concave in the middle line in front and above. No maxillary tuberosities. Anteorbital notch not very distinct. Rostrum long and narrow. Mesethmoid in adult age ossified in its entire length, and coalescing with the surrounding bones. Vertebræ: C 7, D 10, L 10 or 11, C 19 or 20; total 46 to 48. Two or three anterior cervicals united, the rest usually free.

Though varying in form, the mandibular teeth of the different members of this genus agree in their essential structure, having a small and pointed enamel-covered crown, composed of true dentine, which, instead of surmounting a root of the ordinary character, is raised upon a solid mass of osteodentine, the continuous growth of which greatly alters the form and general appearance of the organ as age advances, as seen most strikingly in the case of *M. layardi*, where the long, narrow, flat, strap-like teeth, curving inwards at their extremities, actually meet over the rostrum, and must greatly interfere with the movements of the jaw. In one species (*M. grayi*) a row of minute, conical, pointed teeth, like those of ordinary Dolphins, 17 to 19 in number, are present even in the adults, on each side of the middle part of the upper jaw, but embedded by their roots only in the gum, and not in bony alveoli. This fact, with the frequent presence of rudimentary teeth in other species of this and the last genus in both upper and lower jaws, suggests the idea that the Ziphioids are derived from ancestral forms having teeth of normal character in both jaws, but whose dentition

FIG. 46.—Skull of *Mesoplodon densirostris.*

has become greatly specialized. The existing species of this genus are widely distributed in both northern and southern hemispheres, but most frequent in the latter. The best established are *M. bidens*, *M. europæus*, *M. densirostris*, *M. layardi*, *M. grayi*, and *M. hectori*; but there is still much to be learned with regard to their distinctive characters and geographical distribution. They were abundant in the Later Miocene and Pliocene age, as attested by the frequency with which the most imperishable and easily recognized portion of their structure, the long, cylindrical rostrum of the skull, of more than ivory denseness, is found among the rolled and waterworn fragments of animal remains which compose the well-known "bone-bed" at the base of the Red Crags of Suffolk. Numerous generic distinctions have been founded upon slight modifications of the form of these rostra, such as *Choneziphius*, *Placoziphius*, *Belemnoziphius*, &c., but these can only be considered as provisional until further knowledge is obtained of the structure of the animals to which they belonged.

[1] For the very complicated synonymy of this genus, see *Trans. Zool. Soc.*, vol. viii. p. 208.

Berardius.—Two moderate-sized, compressed, pointed teeth on each side of the symphysis of the mandible, with their apices directed forwards, the anterior being the larger of the two and close to the apex. Upper ends of the premaxillæ nearly symmetrical, moderately elevated, very slightly expanded, and not curved forward over the nares. Nasals broad, massive, and rounded, of nearly equal size, forming the vertex of the skull, flattened in front, most prominent in the middle line. Anteorbital notch distinct. Rostrum long and narrow. Mesethmoid only partially ossified. Small rugous eminences on the outer edge of the upper surface of the maxillæ at base of rostrum. Vertebræ: C 7, D 10, L 12, C 19; total 48. The three anterior cervicals ankylosed, the rest free and well developed.

The only known species, *B. arnouxi*, attains the length of 30 feet, and has hitherto only been met with in the seas around New Zealand.

Family SQUALODONTIDÆ.

Numerous extinct forms, chiefly known by teeth and fragments of crania, may be provisionally placed here, until more of their osteological characters shall be brought to light. They differ from all existing Cetaceans in having the teeth distinctly differentiated into groups, as in the *Archæoceti*, the posterior molars being two-rooted. The cranium, has, however, none of the distinguishing characteristics of the Zeuglodons, but essentially resembles that of the *Odontoceti*, especially in the position of the anterior nares and form of the nasal bones.

The best-known are associated in the genus *Squalodon*. Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, simple teeth of the molar series (premolars?) $\frac{4}{4}$, two-rooted molars $\frac{7}{7} = \frac{15}{15}$; total 60. The double-rooted molars differ from those of *Zeuglodon* in having the denticulations of the crown confined to the posterior border, or at all events much less developed on the front edge. Very little is known of the structure of these animals, beyond the skull and teeth, fragments of which have been found widely distributed throughout the marine Miocene and Early Pliocene formations of Europe, especially in the Vienna basin, many parts of France, and the Antwerp and Suffolk Crags. They have also been found in formations of corresponding age in North America and South Australia.

Family PLATANISTIDÆ.

Under this heading may be placed three very singular genera, which, though differing considerably from each other, have several points in common, and do not altogether come under the definition either of the *Physeteridæ* or the *Delphinidæ*, especially in the important character of the mode of articulation of the ribs with the dorsal vertebræ, as the tubercular and capitular articulations, distinct at the commencement of the series, gradually blend together, as they do in most ordinary mammals. The cervical vertebræ are all free. The lacrymal bone is not distinct from the malar. The jaws are long and narrow, with numerous teeth in both. The symphysis of the mandible exceeds half the length of the whole ramus. Externally the head is divided from the body by a slightly constricted neck. Pectoral limbs broad and truncated. Dorsal fin small or obsolete. Fluviatile or estuarine. There are three distinct genera, which might almost be made the types of families, but it is probably more convenient to keep them together.

Platanista.—Teeth about $\frac{30}{30}$ on each side, set near together, rather large, cylindrical, and sharp-pointed in the young; in old animals acquiring a large laterally compressed base, which in the posterior part of the series becomes irregularly divided into roots. As the conical enamel-covered crown wears away, the teeth of the young and old animals have a totally different appearance. The rostrum and dentigerous portion of the mandible are so narrow that

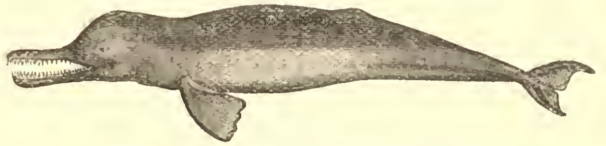

FIG. 47.—*Platanista gangetica.* From Anderson.

the teeth of the two sides are almost in contact. Maxillæ supporting very large, incurved, compressed bony crests, which overarch the nares and base of the rostrum, and almost meet in the middle line above. Orbits very small and eyes rudimentary, without crystalline lens. External respiratory aperture longitudinal, linear. Vertebræ: C 7, D 11, L 8, C 25; total 51. A small cæcum. No pelvic bones. Dorsal fin represented by a low ridge.

One species, *P. gangetica*, entirely fluviatile, being extensively distributed throughout nearly the whole of the river systems, not only of the Ganges, but of the Brahmaputra and Indus, ascending as high as there is water enough to swim in, but never passing out to sea. It is quite blind, and feeds on small fish and *Crustacea*, groping for them with its long snout in the muddy water at the bottom of the rivers. It attains the length of 8 feet.

Inia.—Teeth variable, from 26 to 33 on each side of each jaw; those at the posterior part with a distinct tubercle at the inner side of the base of the crown. Vertebræ: C 7, D 13, L 3, C 18; total 41. Transverse processes of lumbar vertebræ very broad. Sternum short and broad, and consisting of a single segment only. Dorsal fin a mere ridge. The long cylindrical rostrum externally furnished with scattered, stout, and crisp hairs. One species only is known, *I. geoffrensis*, about 8 feet in length, inhabiting the upper Amazon and its tributary streams.

Pontoporia.—Teeth 50 to 60 on each side of each jaw, with a cingulum at the base of the crown. Jaws very long and slender. Vertebræ: C 7, D 10, L 5, C 19; total 41. Transverse processes of the lumbar vertebræ extremely broad. Sternum elongated, composed of two segments, with four sternal ribs attached. Dorsal fin rather small, triangular, pointed. External respiratory aperture transverse,

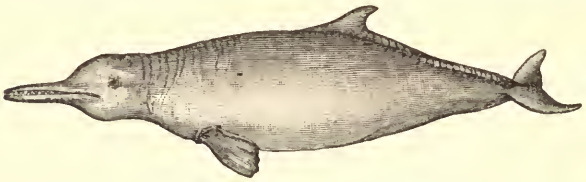

FIG. 48.—*Pontoporia blainvillii.* From Burmeister.

crescentic. This genus connects the last two forms with the true *Delphinidæ.* The only species, *P. blainvillii*, is one of the smallest of the whole order, not exceeding 5 feet in length. It has only been met with at the mouth of the Rio de la Plata, near Buenos Ayres, and there is at present no evidence that it ascends into the fresh waters of the river.

Family DELPHINIDÆ.

Teeth usually numerous in both jaws. Pterygoid bones short, thin, each involuted to form with a process of the palate bone the outer wall of the post-palatine air-sinus. Symphysis of mandible short, or moderate, never exceeding one-third of the length of the ramus. Lacrymal bone not distinct from the jugal. Transverse processes of the dorsal vertebræ gradually transferred from the arches to the bodies of the vertebræ without any sudden break, and becoming posteriorly continuous serially with the transverse processes of the lumbar vertebræ. Anterior ribs attached to the transverse process by the tubercle, and to the body of the vertebra by the head; the latter attachment lost in the posterior ribs. Sternal ribs firmly ossified. External respiratory aperture transverse, crescentic, with the horns of the crescent pointing forwards.

A very large group, closely united in essential characters but presenting great modifications in details. The different types are mostly so connected by intermediate or osculant forms that there are great difficulties in grouping them into natural subfamilies. Even the formation of well-defined genera is by no means satisfactory in all cases.

Monodon.—Besides some irregular rudimentary teeth, the entire dentition is reduced to a single pair of teeth which lie horizontally in the maxilla, and which in the female remain permanently concealed within the alveolus, so that this sex is practically toothless, while in the male (see fig. 49) the right tooth usually remains similarly concealed and abortive and the left is immensely developed, attaining a length equal to more than half that of the entire animal, projecting horizontally from the head in the form of a cylindrical, or slightly tapering, pointed tusk, without enamel, and with the surface marked by spiral grooves and ridges, running in a sinistral direction. (When, as occasionally happens, both tusks are developed, the spiral grooves have the same direction in each.) Vertebræ: C 7, D 11, L 6, C 26; total 50. Cervical region comparatively long, and all the vertebræ distinct, or with irregular unions towards the middle of the series, the atlas and axis being usually free. Manus small, short, and broad; second and third digits nearly equal, fourth slightly shorter. No dorsal fin.

One species, *M. monoceros*, the Narwhal or Sea-unicorn, so called on account of the remarkable single, horn-like tusk of the male, which often grows to a length of 7 or 8 feet. It inhabits the Arctic Ocean, where it is tolerably abundant and gregarious, feeding on various species of cephalopods, small fish, and crustaceans. It is rarely seen south of 65° N. lat.

Delphinapterus.—This genus is closely allied to the last in external form, as well as anatomical structure, differing only in the very different character of the dentition. Teeth from $\frac{8}{8}$ to $\frac{10}{10}$, occupying the anterior three-fourths of the rostrum and corresponding portion of the mandible, rather small, conical, and pointed when unworn, but usually become obliquely truncated, separated by intervals considerably wider than the diameter of the tooth, and implanted obliquely, the crowns inclining forwards especially in the upper jaw. Skull rather narrow and elongated, depressed. Premaxillæ convex in front of the nares. Rostrum about equal in length to the cranial portion of the skull, triangular, broad at the base, and gradually contracting towards the apex, when it is somewhat curved downwards. Vertebræ: C 7, D 11, L 9, C 23; total 50. Cervical vertebræ free. Manus broad, short, and rounded, all the digits being tolerably well developed, except the first. Anterior part of head rounded; no distinct snout. No dorsal fin, but a low ridge in its place.

One species, *D. leucas* (fig. 50), the Beluga, or White Whale, so called from its pure white colour, about 12 feet long, abundant in the Arctic seas, and extending as far south on the American coast as the river St Lawrence, which it ascends for a considerable distance. On rare occasions it has been seen on the coast of Scotland.

In all the remaining genera of *Delphinidæ* the cervical region of the vertebral column is very short, and the first two, and usually more, of the vertebræ are firmly united.

Phocæna.—Teeth $\frac{18}{18}$ to $\frac{25}{25}$, small, occupying nearly the whole length of the rostrum, with compressed, spade-shaped crowns, separated from the root by a constricted neck. Rostrum rather shorter than the cranium proper, broad at the base and tapering towards the apex. Premaxillæ raised into tuberosities in front of the nares. The frontal bones forming a somewhat square, elevated protuberance in the middle line of the skull behind the nares, rising altogether above the flattened nasals. Symphysis of mandible very short. Vertebræ: C 7, D 13, L 14, C 30; total 64 (subject to slight individual modifications). First to sixth cervical vertebræ, and sometimes the seventh also, coalesced. Manus of moderate size, oval, slightly falcate; second and third digits nearly equal in length; fourth and fifth well developed, but shorter. Head short, moderately rounded in front of the blowhole. Dorsal fin (in the typical species) near the middle of the back, triangular; its height considerably less than the length of the base; its anterior edge frequently furnished with one or more rows of conical horny tubercles.

The common Porpoise or Porpus, *P. communis*, is the best known of British Cetaceans (see PORPOISE). A species from Japan, *P. melas*, closely allied in osteological and dental characters, but which wants the dorsal fin, constitutes the genus *Neomeris* of Gray. It is entirely black in colour, and has but $\frac{18}{18}$ teeth, rather larger proportionally than those of *P. communis*, but of similar form.

Orcella.—Teeth $\frac{12}{12}$ to $\frac{14}{14}$, small, conical, pointed, rather closely set, and occupying nearly the whole length of the rostrum. Skull sub-globular, high. Rostrum nearly equal in length to the cranial portion of the skull, tapering. Manus of moderate size, not elongated, but somewhat pointed. All the bones of the digits broader than long, except the proximal phalanges of the index and third fingers. Head globular in front. Dorsal fin rather small, placed behind the middle of the body. Two species, both of small size—*O. brevirostris*, from the Bay of Bengal, and *O. fluminalis*, from the Irrawaddy river, from 300 to 900 miles from the sea. Our present knowledge of the anatomy, geographical distribution, and habits of these interesting Cetaceans is almost entirely due to the researches of Dr J. Anderson.[1]

FIG. 49.—Upper Surface of the Skull of Male Narwhal (*Monodon monoceros*), with the whole of both teeth exposed by removal of the upper wall of their alveolar cavities.

Orca.—Teeth about $\frac{12}{12}$, occupying nearly the whole length of the rostrum, very large and stout, with conical recurved crowns, and large roots, expanded laterally and flattened, or rather hollowed, on the anterior and posterior surfaces. Rostrum about equal in length to the cranial part of the skull, broad and flattened above, rounded in front; premaxillæ broad and rather concave in front of the

[1] *Anatomical and Zoological Researches, comprising an Account of the Zoological Results of the two Expeditions to Western Yunnan, in* 1868 *and* 1875 (1878).

nares, contracted at the middle of the rostrum, and expanding again towards the apex. Vertebræ: C 7, D 11–12, L 10, C 23; total 51 or 52. Bodies of the first and second and sometimes the third cervical vertebræ united; the rest free. Pectoral fin very large, ovate, nearly as broad as long. All the phalanges and metacarpals broader than long. General form of body robust. Face short and rounded. Dorsal fin near the middle of the back, very high and pointed.

The animals composing this genus are met with in almost all seas from Greenland to Tasmania, but the number of species is still very uncertain. They are readily known, when swimming in the water, by the high, erect, falcate dorsal fin, whence their common German name of *Schwert-fisch* (Sword-fish). By English sailors they are generally known as "Grampuses" or "Killers." They are

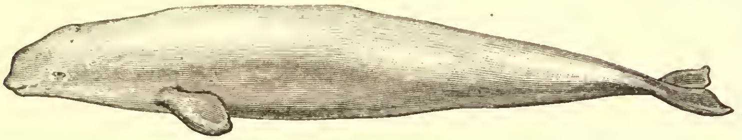

FIG. 50.—Beluga or White Whale (*Delphinapterus leucas*). From a specimen taken in the river St Lawrence, and exhibited in London, 1877.

distinguished from all their allies by their great strength and ferocity, being the only Cetaceans which habitually prey on warm-blooded animals, for, though fish form part of their food, they also attack and devour Seals, and various species of their own order, not only the smaller Porpoises and Dolphins, but even full-sized Whales, which last they combine in packs to hunt down and destroy, as Wolves do the larger Ruminants.

Pseudorca.—Teeth about $\frac{10}{10}$. Cranial and dental characters generally like those of *Orca*, except that the roots of the teeth are cylindrical. Vertebræ: C 7, D 10, L 9, C 24; total 50. First to sixth or seventh cervical vertebræ united. Bodies of the lumbar vertebræ distinguished from those of the preceding genera by being

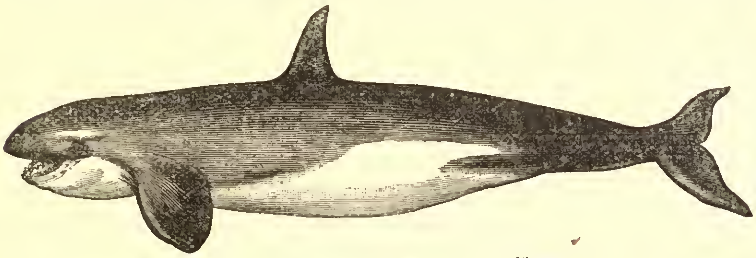

FIG. 51.—Grampus (*Orca gladiator*). From Hunter.

more elongated, the length being to the width as 3 to 2. Pectoral fin of moderate size, narrow, and pointed. Dorsal fin situated near the middle of the back, of moderate size, falcate. Head in front of the blowhole high, and compressed anteriorly, the snout truncated.

This genus was first known by the discovery of a skull in a subfossil state in a fen in Lincolnshire, named by Professor Owen *Phocæna crassidens*. Animals of apparently the same species were afterwards met with in small herds on the Danish coast, and fully described by Reinhardt. Others subsequently received from Tasmania were supposed at first to indicate a different species, but comparison of a larger series of specimens from these extremely distant localities fails to establish any characteristic difference, and indicates an immense range of distribution for a species apparently so rare. Its length is about 14 feet, and its colour entirely black.

Globiocephalus.—Teeth $\frac{8-12}{8-12}$, confined to the anterior half of the rostrum and corresponding part of the mandible, small, conical, curved, sharp-pointed when unworn, sometimes deciduous in old age. Skull broad and depressed. Rostrum and cranial portion about equal in length. Upper surface of rostrum broad and flat. Premaxillæ strongly concave in front of the nares, as wide at the middle of the rostrum as at the base or wider, and very nearly or completely concealing the maxillæ in the anterior half of this region. Vertebræ: C 7, D 11, L 12–14, C 28–29; total 58 or 59. Bodies of the anterior five or six cervical vertebræ united. Length of the bodies of the lumbar and anterior caudal vertebræ about equal to their width. Pectoral limb very long and narrow, the second digit the longest, and having as many as 12 or 13 phalanges, the third shorter (with 9 phalanges), the first, fourth, and fifth very short. Fore part of the head very round, in consequence of the great development of a cushion of fat, placed on the rostrum of the skull in front of the blowhole. Dorsal fin low and triangular, the length of its base considerably exceeding its vertical height.

The type of this well-marked genus is *G. melas*, the Pilot Whale, Ca'ing Whale, or Grindhval of the Faroe islanders, which attains the length of 20 feet, and is of nearly uniform black colour, except the middle of the under surface, which is lighter. They are extremely gregarious, and, unlike the Killers, are mild and inoffensive in disposition, feeding principally on cephalopods. Their eminently sociable character constantly leads to their destruction, as when attacked they instinctively rush together and blindly follow the leaders of the herd. In this way many hundreds at a time are frequently driven ashore and killed, when a herd enters one of the bays or fiords of the Faroe Islands or north of Scotland. Animals of this well-marked genus are found in nearly all seas, and their specific distinctions are not yet made out. Specimens from the Australian coasts, where they are generally called "Blackfish," are quite indistinguishable, either by external or osteological characters, from those of the North Atlantic.

Grampus.—Teeth none in the upper jaw; in the mandible few (3 to 7 on each side), and confined to the region of the symphysis. Vertebræ: C 7, D 12, L 19, C 30; total 68. General external characters much as in *Globiocephalus*, but the fore part of the head less rounded, and the pectoral fin less elongated.

But one species, *G. griseus*, is certainly known, about 13 feet long, and remarkable for its great variability of colour. It has been found, though rarely, in the North Atlantic and Mediterranean. A skull from the Cape of Good Hope, which differs slightly from that of the above, has been described under the name of *G. richardsoni*.

Delphinus.—Teeth very numerous in both jaws, more than $\frac{20}{20}$, occupying nearly the whole length of the rostrum, small, close-set, conical, pointed, slightly curved. Rostrum more or less elongated, and pointed in front, usually considerably longer than the cranial portion of the skull. Vertebræ: C 7, D 12–14, L and C variable; total 51 to 90. Pectoral fin of moderate size, narrow, pointed, somewhat falcate. First digit rudimentary, the second longest, third nearly equal, fourth and fifth extremely short. Externally the head shows a distinct beak or pointed snout, marked off from the antenarial adipose elevation by a V-shaped groove. Dorsal fin rather large, triangular or falcate, rarely wanting.

This is a large and heterogeneous genus, which probably ought to be divided, but, until more is known of the structure of many of the species than is at present attainable from the scanty materials in our collections, it is impossible to frame a system of subdivision upon a scientific basis. It seems preferable therefore, instead of introducing new names into zoology for groups founded upon trifling differences in the length or width of the rostrum of the skull or the number of the teeth, which may or may not be correlated with other more important structural modifications, to keep provisionally at least the Linnæan term *Delphinus* for what remains of the family, after eliminating the well-characterized genera previously described.

The true Dolphins, Bottle-noses, or, as they are more commonly called by seafaring people, "Porpoises," are found in considerable abundance in all seas, and some species are habitually inhabitants of large rivers, as the Amazon. They are all among the smaller members of the order, none exceeding 10 feet in length. Their food is chiefly fish, for the capture of which their long narrow beaks, armed with numerous sharp-pointed teeth, are well adapted, but some appear also to devour crustaceans and molluscs. They are mostly gregarious, and the agility and grace of their movements in the water are constant themes of admiration to the spectators of the scene when a "school of Porpoises" is observed playing round the bows of a vessel at sea. The type of the genus

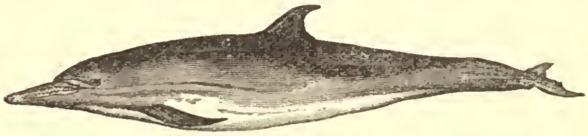

FIG. 52.—Common Dolphin (*Delphinus delphis*). From Reinhardt.

is the Common Dolphin of the Mediterranean (*D. delphis*, fig. 52), also found in the Atlantic, and of which a closely allied if not identical form is met with in the Australian seas (*D. forsteri*) and in the North Pacific (*D. bairdii*). The Tursio (*D. tursio*) is another British species of larger size and heavier build, with larger and less numerous teeth; this and several allied forms probably constitute a natural subgroup. The White-beaked and White-sided Dolphins (*D. albirostris* and *leucopleurus*) of the North Atlantic, and several others from the South and Pacific Seas, with comparatively broad and short rostrum to the skull and very numerous (80 to 90) vertebræ, constitute the genus *Lagenorhynchus* of Gray. Others, with long narrow rostrum, are associated under the name of *Steno*, one of which from the Chinese seas (*D. sinensis*) has but 51 vertebræ. This last is of a pure milk-white colour, but most of the species are variegated with glossy black, various shades of grey, and white, the latter chiefly on the under parts of the body. One species (*D. peronii*) from the South Seas is remarkable for the absence of dorsal fin. It constitutes the genus *Leucorhamphus* of Lilljeborg, and *Delphinapterus* of other authors; this last name, however, was originally bestowed on the Beluga, and should be retained for it.

Bibliography of Cetacea.—D. F. Eschricht, *Untersuchungen über die Nordischen Wallthiere*, 1849, contains a copious bibliography of the group up to the date of publication. Since that time numerous monographs on special families and genera have been published, and a large illustrated general work, *Ostéographie des Cétacés*, by P. J. Van Beneden and P. Gervais, 1868-79. See also J. F. Brandt, "Untersuchungen über die Fossilen und Subfossilen Cetaceen Europa's," in *Mém. de l'Acad. Imp. de St. Pétersbourg*, 7th ser. t. xx., 1873; and C. M. Scammon, *Marine Mammals of the N. W. Coast of North America*, 1874.

Order INSECTIVORA.

Terrestrial, rarely arboreal or natatorial, diphyodont, heterodont, placental mammals of small size, with plantigrade or semiplantigrade, generally pentadactyle, unguiculate feet; with clavicles (except in *Potamogale*); with more than two incisors in the mandible, and with enamel-coated molars having tuberculated crowns and well-developed roots. The body is clothed with fur, or protected by an armature of spines; the testes are inguinal or placed near the kidneys, and are not received into a scrotum, the penis is pendent or suspended from the wall of the abdomen; the uterus is two-horned and with or without a distinct corpus uteri, the placenta discoidal and deciduate; and the smooth cerebral hemispheres do not extend backwards over the cerebellum.

Representatives of this order are found throughout the temperate and tropical parts of both hemispheres (except South America and Australia), and exhibit much variety both in organization and in habit. The greater number are cursorial, but some (*Talpa*, *Chrysochloris*, *Oryzorictes*) are fossorial, some (*Potamogale*, *Nectogale*, *Myogale*) natatorial, and some (*Tupaiidæ*) arboreal, while the species of one genus (*Galeopithecus*) glide through the air like Flying Squirrels; to the great majority, however, the term insectivorous is applicable, the aberrant *Galeopithecus* being alone phytophagous also, while *Potamogale* is said to feed on fish, and the different species of Moles live chiefly on worms. Notwithstanding the homogeneous nature of their food, much variety prevails in the form and number of their teeth, as will be seen when we come to consider the classification of the species. In many the division into incisors, canines, premolars, and molars may be readily traced, but in others, forming the great majority of the species, such as the Shrews, this is accomplished with difficulty. The dentition of the *Insectivora* may, however, be considered typical, since from it may be derived, by modification, that of any known species of diphyodont placental *Mammalia*. This typical dentition is especially noticeable in the genus *Gymnura*, where the dental formula is—$i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $pm\ \frac{4}{4}$, $m\ \frac{3}{3}$; total 44 teeth. So also, in their general organization, these animals appear to have departed so little from what must have been the original mammalian type that, were it not for the apparently advanced character of their placentation, they might easily be considered the scarcely modified descendants of the ancestors of all other orders of diphyodont placental mammals. Their study, therefore, affords the best introduction to that of this division especially.

In most *Insectivora* the cranial cavity is of small relative size, and in none is the brain case elevated to any considerable extent above the face-line. The facial part of the skull is generally much produced, and the premaxillary and nasal bones well developed. The zygomatic arch is usually slender or deficient, the latter being the case in most of the species, and post-orbital processes of the frontals are found only in *Galeopithecidæ*, *Tupaiidæ*, and *Macroscelidæ*. The number of dorsal vertebræ varies from 13 in *Tupaia* to 19 in *Centetes*, of lumbar from 3 in *Chrysochloris* to 6 in *Talpa* and *Sorex*, and of caudal from the rudimentary vertebræ of *Centetes* to the 40 or more well-developed ones of *Microgale*. Not less variable are the characters of the vertebræ: the spinous processes may be very long in one species and short in another, though belonging to the same genus; in the *Soricidæ* and in *Myogale* the neural arches of the cervical vertebræ are very slender; in *Soricidæ* also and in *Gymnura* the four anterior vertebræ develop large single hypapophyses, and in *Galeopithecus* the body of each supports posteriorly a pair of hypapophysial tubercles. In *Erinaceus*, *Myogale*, and *Talpa* small oval ossicles are found on the inferior surfaces of the lumbar interspaces. In *Erinaceus*, owing to the thickness of the cord in the cervical region and its abrupt termination, the diameter of the neural canal in the cervical and first two dorsal vertebræ greatly exceeds that of any of the succeeding vertebræ. The sternum is variable, but generally narrow, bilobate in front, and divided into segments. The shoulder-girdle presents remarkable adaptive modifications, most expressed in *Talpa* (see MOLE), having relation to the use of the fore limbs in burrowing; in the Golden Moles (*Chrysochloris*), however (*vide infra*), the forearm and manus alone become specially modified. In *Galeopithecus* and *Macroscelides* the forearm bones are distally united; in all other known *Insectivora* the radius and ulna are distinct. The manus has generally five digits, but in *Rhynchocyon* and in one species of *Oryzorictes* the pollex is wanting. In the true Moles (see MOLE) it is extremely modified. The femur has, in most species, a prominent ridge below the greater trochanter presenting the characters of a third trochanter. In *Galeopithecus*, *Tupaia*, *Centetes*, *Hemicentetes*, *Ericulus*, and *Solenodon* the tibia and fibula are distinct, in all other genera more or less united together. The pes consists usually of five digits (rarely four by reduction of the hallux), and in some, as in the leaping species (*Macroscelides*, *Rhynchocyon*), the tarsal bones are greatly elongated. The form of the pelvis, and especially that of the symphysis pubis, varies within certain limits, which have been proposed by Leche as a basis for the classification of the families. Thus in *Galeopithecidæ*, *Tupaiidæ*, and *Macroscelidæ* there is a long symphysis, as in Rodents; in *Erinaceidæ*, *Centetidæ*, and *Potamogalidæ* it is short; and in *Soricidæ*, *Talpidæ*, and *Chrysochloridæ* there is none.

Space does not admit of even attempting a sketch of the interesting modifications of the muscular system, which will be found fully described in the present writer's *Monograph*, referred to in the bibliography. As to the nervous system, it may be noticed that the brain throughout the species presents a low type of organization: in none do the cerebral hemispheres present any trace of convolutions, nor do they extend backwards so as to cover the cerebellum; the olfactory lobes are large and project in front; and the corpus callosum is short and thin. In the Hedgehogs (*Erinaceus*) the spinal column ends abruptly opposite the third or fourth dorsal vertebra in a slender filament; the dorsal and lumbar nerves, given off in front of this point, are carried backwards in two compressed bundles occupying the suddenly narrowed spinal canal as far as the sacrum.

Owing to the similarity in the character of the food, the truly insectivorous species, forming more than nine-tenths of the order, present little variety in the structure of the digestive organs. Except in *Galeopithecus* (*vide infra*) the stomach is a simple, thin-walled sac; in some, as in *Centetes* and allied genera, the pyloric and œsophageal openings are very close together; the intestinal canal has much the same calibre throughout, and varies from three (in the Shrews) to twelve times (in the Hedgehogs) the length of the head and body. In the arboreal genera, *Galeopithecus* and *Tupaia*, and in the allied *Macroscelidæ*, all of which probably feed on vegetable substances as well, most of the species possess a cæcum. The liver is deeply divided into lobes, the right and left lateral being cut off by deep fissures; both the caudate and Spigelian lobes are generally well developed, and the gall-bladder, usually large and globular, is placed on the middle of the posterior surface of the right central lobe.

In most of the species (*Soricidæ*, *Centetidæ*, *Chrysochloridæ*) the penis is capable of being more or less completely retracted within the fold of integument surrounding the anus; in some (*Galeopithecidæ*, *Talpidæ*) it is pendent in front of the anus, while in others (*Macroscelidæ*, *Erinaceidæ*, *Solenodontidæ*) it is carried forwards and suspended from the abdominal wall. In *Centetinæ* and *Chrysochloris* the testes lie immediately behind the kidneys, in others more or less within the pelvis. During the rut they become greatly enlarged, forming protrusions in the inguinal region. Except in *Rhynchocyon* the uterine cornua are long and open into a short corpus uteri, which in many species (*Soricidæ*, *Talpidæ*, *Centetidæ*, *Chrysochloridæ*) is not separated from the vagina by a distinct os uteri. With the exception of *Galeopithecus* all *Insectivora* appear to be multiparous, the number of fœtuses varying from two to eight in *Erinaceus*, and from twelve to twenty-one in *Centetes*. The position of the mammary glands and the number of the teats vary greatly. In *Galeopithecus* there are two pairs of axillary teats, in *Solenodon* a single pair post-inguinal, but in most species they range from the thorax to the abdomen, varying from two pairs in *Gymnura* to twelve in *Centetes*. In *Chrysochloris* the thoracic and inguinal teats are lodged in deep cup-shaped depressions.

Odoriferous glands exist in many species. In most Shrews they occur on the sides of the body at a short distance behind the axilla, and their exudation is probably protective, as few carnivorous animals will eat their dead bodies. In both species of *Gymnura* and in *Potamogale* large pouches are situated on either side of the rectum, and discharge their secretions by ducts, opening in the first-named genus in front of and in the latter within the margin of the anus. In *Centetes* racemose glands similarly situated discharge by pores opening at the bottom of deep pits placed at either side of the anus.

The integument is thin, but in many species lined with well-developed muscles, which are probably more developed in the Hedgehogs (*Erinaceidæ*) than in any other mammal; in this family and in *Centetidæ* most of the species are protected by spines implanted in the panniculus carnosus, and more or less replacing the fur of the upper surface of the body.

The *Insectivora* are divisible into two very distinct suborders, of which the first includes a single genus only.

SUBORDER I. *Dermoptera*.

Upper and lower incisors compressed, multicuspidate, the lower deeply pectinate; anterior and posterior limbs connected by a broad integumentary expansion forming a parachute. Family I. *Galeopithecidæ*.

SUBORDER II. *Insectivora Vera*.

Upper and lower incisors conical, unicuspidate or with basal cusps only, the lower not pectinate; limbs free, formed for terrestrial progression.

I. Upper true molars broad, multicuspidate, with more or less well-defined W-shaped crowns.
  A. Symphysis pubis long; intestinal canal generally with a cæcum; cerebral cavity comparatively large.
    a. Orbital ring encircled by bone; metatarsus moderate; arboreal. Family II. *Tupaiidæ*.
    b. Orbital ring not encircled by bone; metatarsus greatly elongated; terrestrial. Family III. *Macroscelidæ*.
  B. Symphysis pubis short or none; intestinal canal without cæcum; cerebral cavity small; skull without post-orbital processes.
    a. First and second upper molars with a central fifth cusp.
      a'. Tympanics annular, not forming bullæ. Family IV. *Erinaceidæ*.
    b. No central fifth cusp; crowns of the upper molars W-shaped.
      a'. Tympanics annular, not forming bullæ; no zygomatic arches. Family V. *Soricidæ*.
      b'. Tympanics forming bullæ; zygomatic arches developed. Family VI. *Talpidæ*.
II. Upper true molars narrow, with V-shaped crowns.
      a'. Tympanics annular, not forming bullæ; zygomatic arches imperfect.
        a''. No clavicles. Family VII. *Potamogalidæ*.
        b''. Clavicles well developed.
          a'''. Skull constricted between the orbits; penis suspended. Family VIII. *Solenodontidæ*.
          b'''. Skull not constricted; penis pendent, retractible. Family IX. *Centetidæ*.
      b'. Tympanics forming bullæ; zygomatic arches well-developed. Family X. *Chrysochloridæ*.

Family GALEOPITHECIDÆ.

The characters of the family are those of the suborder *Dermoptera*, to which may be added that the orbit is nearly surrounded by bone, the zygomatic arches are well developed, the tympanics form bullæ osseæ, the ulna is distally united with the radius, the tibia and fibula are distinct, the pubic symphysis is long, the penis is pendent, the testes are received into inguinal pouches, the mammæ are axillary, the uterus is two-horned, and there is a large cæcum.

Galeopithecus ($i\ \frac{2}{3}$, $c\ \frac{1}{1}$, $pm\ \frac{2}{2}$, $m\ \frac{3}{3}$; second upper incisors and canines with two roots), with two species—*G. volans* and *G. philippinensis*. The former, the Flying Lemur of Linnæus, distinguished from the latter by the form of the upper incisors, has a total length of nearly 2 feet. The long and slender limbs are connected by a broad integumentary expansion extending outwards from the sides

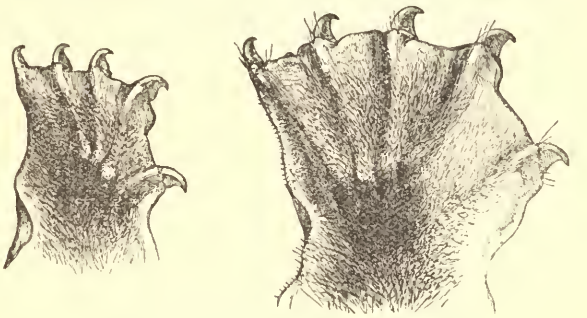

FIG. 53.—Feet of *Galeopithecus philippinensis*.

of the neck and body, and forming also a web between the fingers and toes as far as the base of the claws (fig. 53); the hind limbs are further connected by a similar expansion passing outwards along the back of the feet to the base of the claws, and, inwardly, involving the long tail to the tip, forming a true interfemoral membrane, as in the Bats.

The species of this family live in the forests of the Malay Peninsula, Sumatra, Borneo, and the Philippine Islands, where they feed chiefly on the leaves of trees, and probably also on insects. Their habits are nocturnal, and during the daytime they cling to the trunks or limbs of trees head downwards in a state of repose. With the approach of night their season of activity commences, when they may be occasionally seen gliding from tree to tree supported on their cutaneous parachute, and they have been noticed as capable of traversing in this way a space of 70 yards with a descent of only about one in five.

Galeopithecus was referred by some of the older zoologists and anatomists to the Bats, and by others (and even in lately published works) to the Lemurs, but Professor Peters's view (in which most subsequent writers agree) that it belongs to neither of these orders, and must be considered an aberrant Insectivore, appears to be undoubtedly the correct one. Besides differing from the Bats altogether in the form of the anterior limbs and of the double-rooted outer incisors and canines, it also contrasts strongly with them in the presence of a large sacculated cæcum, and in the great length of the colon, which is so remarkably short in all the *Chiroptera*. From the Lemurs, on the other hand, the form of the brain, the character of the teeth, the structure of the skull, and the deciduate discoidal placenta at once separate it.

Family TUPAIIDÆ.

Arboreal *Insectivora*, with comparatively large brain case, orbits encircled with bone, and well-developed zygomatic arches. The malar bone is perforated; the tympanics form bullæ; the pubic symphysis is long; the tibia and fibula are distinct, the metatarsus but little longer than the tarsus; the molars are broad, with

W-shaped cusps; and the intestinal canal has generally a short cæcum.

The animals included in this family are all arboreal, resembling Squirrels closely both in habits and in external form; they are divided into two genera having the same dental formula ($i\,\frac{2}{3}$, $c\,\frac{1}{1}$, $pm\,\frac{3}{3}$, $m\,\frac{3}{3}$), but distinguished by the form of the skull. *Tupaia*, with nine species, is found in India, Burmah, the Malay Peninsula, Nicobars, Sumatra, Java, and Borneo. The species closely resemble one another, differing chiefly in size and in the colour and length of the fur. Nearly all have long bushy tails, which still further

Fig. 54.—Pentail (*Ptilocercus lowii*). $\times\frac{1}{2}$. From Gray, *Proc. Zool. Soc.*, 1848.

increase their resemblance to Squirrels. Their food consists of insects and fruit, which they usually seek for in the trees, but also occasionally on the ground. When feeding they often sit on their haunches, holding the food, after the manner of Squirrels, between their fore paws. *Ptilocercus* includes a single very interesting species, *Pt. lowii*, inhabiting Borneo, remarkable for its long tail, two-thirds naked, having the terminal third furnished with a double fringe of long hairs. Its habits are probably similar to those of the Tupaias, of which it may be further noticed that they alone among *Insectivora* are day-feeders.

Family Macroscelidæ.

Terrestrial *Insectivora*, with comparatively large brain case, well-developed zygomatic arches, and tympanic bullæ; but the orbits are not encircled by bone, the malar is imperforate, and there are generally no post-orbital processes. The pubic symphysis is long, the tibia and fibula united high up, the metatarsus much longer than the tarsus, the molars broad and quadricuspidate, and the intestinal canal has a large cæcum.

These leaping Insectivores are easily distinguished by the great length of their metatarsal bones. All the species are African, and are divisible into two genera:—

a. $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $pm\,\frac{3}{3}$, $m\,\frac{3}{3}$ or $\frac{3}{4}$; forearm bones united below. *Macroscelides.*

b. $i\,\frac{1}{3}$ (or $\frac{0}{3}$), $c\,\frac{1}{1}$, $pm\,\frac{3}{3}$, $m\,\frac{3}{3}$; forearm bones separate. *Rhynchocyon.*

Macroscelides includes ten species widely distributed throughout the African continent. All are closely related, resembling one another in general forms, and even in the colour of the fur. They fall into two groups distinguished by the presence or absence of a small lower fourth molar. *M. tetradactylus* (fig. 55), type of the subgenus *Petrodromus*, differs from all in the absence of the hallux. Of *Rhynchocyon* four closely allied species have been described, all from East Africa.

Family Erinaceidæ.

Terrestrial *Insectivora*, with a small brain case, without post-orbital processes, with slender (rarely imperfect) zygomatic arches, with a short pubic symphysis, and with the tibia and fibula united above. The tympanics are annular, not forming bullæ; the intestine has no cæcum; the penis is carried forwards, and suspended from the wall of the abdomen; and the upper true molars have each four principal cusps and a small central fifth cusp very characteristic of the family.

Subfamily I. **Gymnurinæ.**—Caudal vertebræ numerous; palate bones completely ossified; pelvis very narrow; fur without spines.

Gymnura, $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $pm\,\frac{4}{4}$, $m\,\frac{3}{3}$, with two species, *G. rafflesii* and *G. suilla*, from the Malay Peninsula and Indian Archipelago. The former has the appearance of a large Rat with a long head and projecting mobile snout; the latter, much smaller, with a short tail and small third upper premolar, has long been known under the name of *Hylomys suillus*, and classed with the *Tupaiidæ*. Both species present a very generalized type of dentition, in this respect occupying an almost central position in the order.

Fig. 55.—*Macroscelides* (*Petrodromus*) *tetradactylus*. $\times\frac{1}{2}$. From Peters, *Reise nach Mossambique.*

Subfamily II. **Erinaceinæ.**—Caudal vertebræ rudimentary; palate bones with defects of ossification; pelvis wide; fur with spines.

Erinaceus, $i\,\frac{3}{2}$, $c\,\frac{1}{1}$, $pm\,\frac{3}{2}$, $m\,\frac{3}{3}$, includes nineteen species (familiarly known as Hedgehogs) distributed throughout Europe, Africa, and the greater part of Asia, but they have not been found in Madagascar, Ceylon, Burmah, Siam, the Malay Peninsula and Archipelago, or Australia. All the species resemble one another

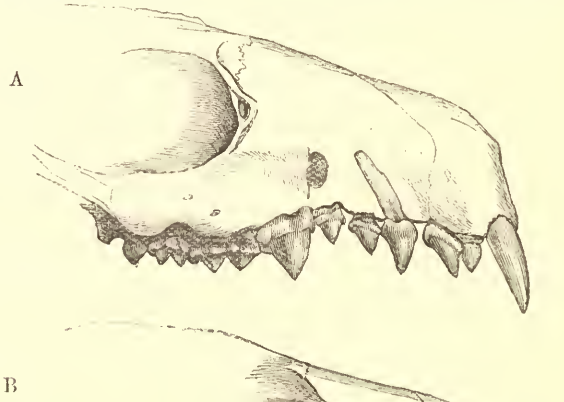

Fig. 56.—Facial parts of Skulls of (A) *Erinaceus europæus* and (B) *E. grayi*, much enlarged. Dobson, *Proc. Zool. Soc.*, 1881.

closely in the armature of spines which invests the upper surface and side of the body; and all possess the power of rolling themselves up into the form of a ball protected on all sides by strong spines, the dorsal integument being brought downwards and inwards over the head and tail, so as to include the limbs also, by the action of special muscles (for description see *Monograph of the*

Insectivora referred to in the bibliography). The common Hedgehog (*E. europæus*) is the most aberrant species, differing from all the rest in the peculiarly shaped and single-rooted third incisors and first upper premolars (fig. 56, A), and in its very coarse harsh fur. The dentition of the long-eared North Indian form, *E. grayi* (fig. 56, B), may be considered characteristic of all the other species, the only important differences being found in the variable size and position of the second upper premolar, which is very small, external, and deciduous in the Indian species *E. micropus* and *pictus*. The former species, limited to South India, is further distinguished by the absence of the malar bone. Of African species, *E. diadematus*, with long frontal spines, is probably the commonest, and *E. albiventris* has been made the type of a separate genus on account of the total absence of the hallux.

Family Soricidæ.

Terrestrial, rarely natatorial, *Insectivora*, with narrow elongated skulls, without post-orbital processes or zygomatic arches. The tympanics are annular, not forming bullæ; there is no symphysis pubis; the intestine has no cæcum; the tibia and fibula are united; and the molars have well-developed W-shaped cusps.

The dentition is very characteristic of the family; in all the upper front incisors are large, with a more or less prominent posterior basal cusp, and between these and the last premolar intervene a variable number of small incisors and premolars, among which the small canine can be distinguished only by its position immediately behind the premaxillary suture. The number of teeth in the mandible is always twelve, and the single pair of incisors are much extended horizontally forwards, the canine is the smallest tooth, and the single premolar is not much larger (see fig. 57).

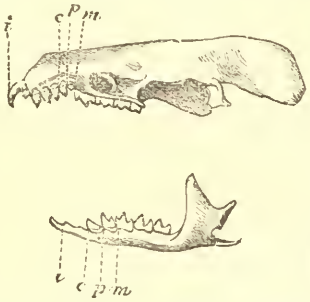

Fig. 57.—Skull and Dentition of *Sorex vermpicis*. Alston, *Proc. Zool. Soc.*, 1877.

The Shrews thus form a very compact family, which includes considerably more than half the known species of *Insectivora*, and of which the geographical distribution is coextensive with that of the order. They have been divided into several genera (so-called) and subgenera, depending chiefly on the number of the upper incisors and premolars, and on the colour of the teeth. The best arrangement appears to be that proposed by M. Alph. Milne-Edwards, as follows:—

A. Terrestrial; feet without a border composed of stiff hairs.
- *a.* Teeth white.
  - *a′*. 26 teeth.
    - *a″*. Tail very short, concealed. 1. *Anourosorex.*
    - *b″*. Tail moderately long. 2. *Diplomesodon.*
  - *b′*. 28–30 teeth. 3. *Crocidura.*
- *b.* Teeth more or less brown or red.
  - *a′*. Tail short; ears small. 4. *Blarina.*
  - *b′*. Tail and ears moderately long. 5. *Sorex.*

B. Amphibious; feet with a border of stiff hairs.
- *a.* Feet not webbed.
  - *a′*. 32 teeth; hairs of tail equal. 6. *Neosorex.*
  - *b′*. 30 teeth; tail fringed along middle edge. 7. *Crossopus.*
- *b.* Feet webbed. 8. *Nectogale.*

Anourosorex includes *A. squamipes*, a Mole-like species, with very short ears and tail, from Tibet. *Diplomesodon*, with one species, *D. pulchellus*, from the Kirghiz steppes, though agreeing in the number of teeth, is Shrew-like in external form. *Crocidura*, 28–30 teeth, with about seventy species divided into four subgenera, comprises the greater number of white-toothed Old-World Shrews, having a round tail thinly clothed with a few hairs of unequal length. *C. aranea* and *C. suaveolens* of the continent of Europe, and *C. indicus*, the Musk-Rat of India, are well-known examples. *Sorex*, the typical genus (see Shrew), also divided into four subgenera, with *Blarina*, includes all the species with brown teeth and angular uniformly hairy tail. *Neosorex* includes the New-World and *Crossopus* (see Shrew) the Old-World amphibious species, having a fringe of stiff hairs along the sides of the feet, and *Nectogale* a very remarkable species from Tibet, *N. elegans* (fig. 58), distinguished from all other Shrews by the webbed condition of the toes, and the presence of adhesive cushions on the under surface of the feet, which enable the animal to hold on to smooth stones at the bottom of rushing torrents.

Family Talpidæ.

Fossorial, rarely natatorial, *Insectivora*, distinguished from the *Soricidæ* by the presence of zygomatic arches and tympanic bullæ osseæ, and by the form of the teeth. The eyes are very small, in some species covered with skin; the ears are short and concealed by the fur; the fore limbs are generally more or less modified for digging; there is no symphysis pubis; the intestine has no cæcum; the tibia and fibula are united; and the unicuspidate upper and lower front incisors are not extended horizontally forwards.

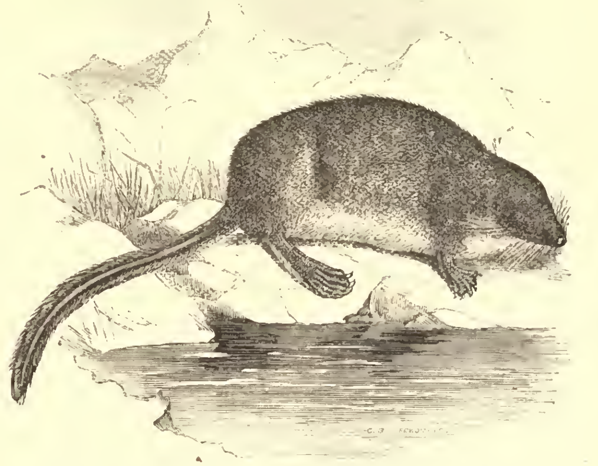

Fig. 58.—*Nectogale elegans*. A. Milne-Edwards, *Mammif. Tibet.*

This family, though thus easily distinguished, is, nevertheless, evidently closely related to the Shrews, with which such intermediate forms as those included in the genera *Urotrichus* and *Uropsilus* connect it. In striking contrast with the Shrews, however, the distribution of the Moles is limited to the temperate regions of Europe, Asia, and North America.

Subfamily I. **Myogalinæ.**—Clavicles and humeri moderately elongated; manus without os falciforme.

a. $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $pm\,\frac{4}{4}$, $m\,\frac{3}{3}$; feet webbed; natatorial. *Myogale.*
b. $i\,\frac{2}{1}$, $c\,\frac{1}{1}$, $pm\,\frac{3}{3}$, $m\,\frac{3}{3}$; feet narrow; terrestrial. *Uropsilus.*
c. $i\,\frac{2}{1}$, $c\,\frac{1}{1}$, $pm\,\frac{4}{3}$ or $\frac{3}{4}$, $m\,\frac{3}{3}$; feet wide; fossorial. *Urotrichus.*

Myogale includes two very remarkable species, *M. moschata* and *M. pyrenaica*. The former is by far the largest species of the family, its total length being about 16 inches. Its long proboscis-like snout projects far beyond the margin of the upper lip; the toes are webbed as far as the bases of the claws; and the long scaly tail is laterally flattened, forming a powerful instrument of propulsion when swimming. This species inhabits the banks of streams and lakes in south-east Russia, where its food consists of various aquatic insects. *M. pyrenaica*, living in a similar manner in the region of the Pyrenees, is very much smaller, has a round

Fig. 59.—*Myogale moschata*. × ¼.

tail, and a proportionally longer snout. *Urotrichus*, with *pm* $\frac{4}{3}$, and *Neürotrichus* (subg.), with *pm* $\frac{3}{4}$, are represented by two small Mole-like species, externally resembling one another closely, from Japan and North America respectively. Of *Uropsilus*, *U. soricipes*, from the borders of Tibet, is a very interesting species, having the external form of a Shrew but the skull of a Mole.

Subfamily II. **Talpinæ** (True Moles).—Clavicles and humeri very short and broad; manus with a large os falciforme.

A. Front upper incisors much larger than the second pair (New-World Moles).
- *a.* *i* $\frac{3}{2}$, *c* $\frac{1}{0}$, *pm* $\frac{3}{3}$, *m* $\frac{3}{3}$; extremity of nose simple. *Scalops.*
- *b.* *i* $\frac{3}{2}$, *c* $\frac{1}{1}$, *pm* $\frac{4}{4}$, *m* $\frac{3}{3}$; extremity of nose simple. *Scapanus.*
- *c.* *i* $\frac{3}{3}$, *c* $\frac{1}{1}$, *pm* $\frac{4}{4}$, *m* $\frac{3}{3}$; extremity of nose with appendages. *Condylura.*

B. Front upper incisors scarcely larger than the second pair (Old-World Moles).
- *d.* *i* $\frac{3}{2}$, *c* $\frac{1}{1}$, *pm* $\frac{4}{4}$, *m* $\frac{3}{3}$; manus as in *Urotrichus*. *Scaptonyx.*
- *e.* *i* $\frac{3}{3}$ or $\frac{3}{2}$, *c* $\frac{1}{1}$, *pm* $\frac{4}{4}$, *m* $\frac{3}{3}$; manus very broad. *Talpa.*

Scaptonyx, with a single species *S. fusicaudatus*, from west China, connects *Urotrichus* with the true Moles. *Talpa* includes seven species, of which the Common Mole is a familiar example. See MOLE.

Family POTAMOGALIDÆ.

Insectivora with a small brain case, without post orbital processes or zygomatic arches, and with annular tympanics not forming bullæ. There are no clavicles; the pubic bones are connected by a ligament, and there is no true symphysis; the intestine has no cæcum; the tibia and fibula are united low down; and the upper true molars have broadly V-shaped cusps presenting characters intermediate between those of the preceding and succeeding families.

FIG. 60.—*Potamogale velox.* × ¼. Allman, *Trans. Zool. Soc.*, vi., pl. i.

Potamogale, *i* $\frac{3}{3}$, *c* $\frac{1}{1}$, *pm* $\frac{3}{3}$, *m* $\frac{3}{3}$, with *P. velox*. This most interesting species inhabits the banks of streams in west equatorial Africa, and its whole structure indicates an aquatic life. It is nearly 2 feet in length, the tail measuring about half. The long cylindrical body is continued uninterruptedly into the thick laterally compressed tail, the legs are very short, and the toes are not webbed, progression through the water evidently depending wholly on the action of the powerful tail, while the limbs are folded inwards and backwards. The muzzle is broad and flat, and the nostrils are protected by valves. The fur is dark brown above, the extremities of the hairs on the back being of a metallic violet hue by reflected light, beneath whitish.

Geogale, *i* $\frac{2}{2}$, *c* $\frac{1}{1}$, *pm* $\frac{3}{2}$, *m* $\frac{3}{3}$, with *G. aurita*, a small Mouse-like species from Madagascar, agrees closely with *Potamogale* in the general form of the skull and teeth; the tibia and fibula are distinct, but it is not known whether a clavicle exists or not, and the material at present available is insufficient to definitely fix the natural position of the species.

Family SOLENODONTIDÆ.

Insectivora with a small brain case constricted between the orbits, and without post-orbital processes or zygomatic arches. The penis is carried forwards and suspended from the abdomen; the testes are received into perineal pouches; the mammary glands are post-inguinal; the uterine cornua end in cæcal sacs; the intestine has no cæcum; the tympanics are annular; the upper true molars have V-shaped crowns; the symphysis pubis is short; and the tibia and fibula are distinct.

Solenodon, *i* $\frac{3}{3}$, *c* $\frac{1}{1}$, *pm* $\frac{3}{3}$, *m* $\frac{3}{3}$, with *S. paradoxus* and *S. cubanus*, from Hayti and Cuba respectively, alone represents the family. These species, which differ chiefly in the colour and quality of the fur, have each a remarkably long cylindrical snout, a long naked tail, feet formed for running, and the body clothed with long, coarse fur.

The position of the mammæ quite behind on the buttocks is unique among *Insectivora*. The upper front incisors are much enlarged, and with the other incisors, canines, and premolars closely resemble those of *Myogale*; the second lower incisors are, as in

FIG. 61.—*Solenodon cubanus.* × ¼. Peters, *Abh. Akad. Berl.*

Potamogale, much larger than the anterior pair, and are deeply hollowed out internally. While thus apparently showing relationship with the *Talpidæ*, the form of the crowns of the molar teeth connects them with the next family.

Family CENTETIDÆ.

Insectivora with a small cylindrical brain case not constricted between the orbits, and without post-orbital processes or zygomatic arches. The penis is pendent and retractible within the fold of the integument surrounding the anus; the testes are abdominal; the mammary glands are thoracic and ventral; the uterine cornua are terminated by the Fallopian tubes; the intestine has no cæcum; the tympanics are annular; the molars have V-shaped crowns; the pubic symphysis is short, and the tibia and fibula separate or united. All the known species are limited to Madagascar.

Subfamily I. **Centetinæ**.—Tibia and fibula distinct; testes near kidneys; fur with spines.

FIG. 62.—Skull of *Centetes ecaudatus* (reduced).

Centetes, *i* $\frac{3}{3}$ or $\frac{2}{3}$, *c* $\frac{1}{1}$, *pm* $\frac{3}{3}$, *m* $\frac{3}{3}$ or $\frac{4}{3}$. The single species, *C. ecaudatus*, the well-known tailless Ground-Hog of Madagascar, attains a total length of from 12 to 16 inches, and is the largest known Insectivore. The adult males have exceedingly long canines, the extremities of the lower pair being received into pits in front of the upper canines. It is probably the most prolific of all mammals; as many as twenty-one young are said to have been brought forth at a birth. The young have strong white spines arranged in longitudinal lines along the back, but these are lost in the adult animal, which is provided only with a nuchal crest of long rigid hairs. *Hemicentetes*, *i* $\frac{3}{3}$, with *H. semispinosus* and *H. nigriceps*, is distinguished by the persistence of the third upper incisor, and by the form of the skull. The two species are very much smaller than *C. ecaudatus*, and the dorsal spines are retained in the adult state. *Ericulus*, *i* $\frac{2}{2}$, has *E. setosus*, a remarkable Hedgehog-like species having the whole upper surface and even the short tail densely covered with close-set spines. The facial bones are much shorter than in any of the preceding genera, and the upper front incisors are elongated as in *Erinaceus*. Judging from the slight development of the cutaneous muscles compared with those of the true

Hedgehogs, it is probable that complete involution, as in the latter animals, does not take place.

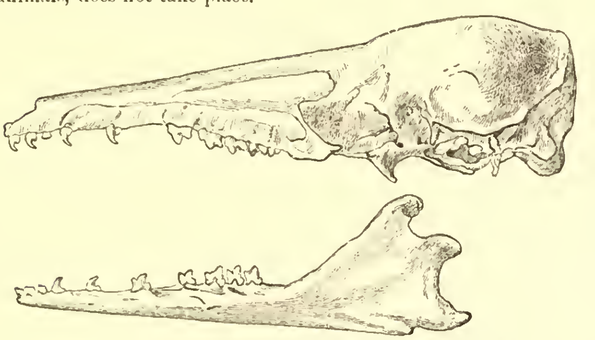

Fig. 63.—Skull of *Hemicentetes semispinosus*. × 2. Mivart, *Proc. Zool. Soc.*, 1871.

Subfamily II. **Oryzorictinæ.**—Tibia and fibula united; testes near urethra; fur without spines.

Microgale, $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $pm\ \frac{3}{3}$, $m\ \frac{3}{3}$, includes *M. longicaudata* and *M. cowani*, small Mouse-like species, the former with a tail double the length of the head and body; teeth like those of *C. ecaudatus*, but, owing to the comparatively much shorter muzzle, not separated by wide spaces, and the last premolar and molars with internal basal processes. *Oryzorictes* contains *O. hova* and *O. tetradactylus*, the latter distinguished by the presence of four digits only in the manus, the three inner having long laterally compressed fossorial claws. The general form of the head and body of the two species known is that of a Mole. They burrow in the rice-fields, and do much damage to the crops.

Family CHRYSOCHLORIDÆ.

Fossorial *Insectivora*, with conical skulls not constricted between the orbits, with well-developed zygomatic arches and tympanic bullæ, but without post-orbital processes. The eyes are covered by the hairy integument, the ears short and concealed by the fur; the internal generative organs and the crowns of the upper molar teeth are as in *Centetinæ*; the mammary teats are thoracic and inguinal, and placed in cup-shaped depressions; there is no pubic symphysis; and the tibia and fibula are united.

This family is evidently closely allied to *Centetidæ*, occupying the same relative position with respect to that family that *Talpidæ* does to *Soricidæ*. All the species are fossorial, and restricted to south Africa. In all the forearm and manus are similarly modified for digging, but in a manner very different from that observable in *Talpidæ* (see MOLE).

Fig. 64.—*Chrysochloris obtusirostris* (reduced).

Chrysochloris, $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $pm\ \frac{3}{3}$, $m\ \frac{3}{3}$ or $\frac{2}{2}$, embraces seven or eight species. Those with $m\ \frac{2}{2}$, with a basal talon to the lower grinders, and without a prominence in the temporal fossa, have been placed in a separate genus *Calcochloris* by Professor Mivart. Nearly all the species have the fur of the upper surface of a brilliant metallic lustre, varying from golden bronze to green and violet of different shades.

FOSSIL INSECTIVORA.

Of fossil *Insectivora* no undoubted traces have been found in deposits earlier than the Eocene. *Amphidozotherium*, allied to *Urotrichus*, and *Neogymnurus* and *Protalpa*, with relationships to *Gymnura* and *Talpa* respectively, have been described from the lacustrine Eocene beds of Quercy. Several genera with insectivorous affinities have been characterized by Cope and Marsh from remains found in the Eocene of Wyoming, but these have been relegated to distinct suborders of a new order *Bunodonta*, of which *Insectivora* is considered a suborder only. The Miocene deposits of the south of France and Germany have yielded fossil forms of *Erinaceidæ* (*Amphechinus*, *Galerix*, *Tetracus*), of *Soricidæ* (*Sorex*, *Mysarachne*, *Plesiosorex*), and of *Talpidæ* (*Dimylus*, *Galeospalax*, *Geotrypus*, *Hyporissus*, *Myogale*). Of the latter family *Galeospalax* has been characterized from the Pliocene of Norfolk; and remains of the common Hedgehog, and of some of the existing species of *Sorex*, have been found in various post-Tertiary deposits.

Bibliography of Insectivora.—Peters, *Reise nach Mossambique—Säugeth.*, 1852; Id., "Ueber die Classification der Insectivora," *Monatsb. Akad. Wissensch. Berlin*, 1865, and other papers; Mivart, "On the Osteology of the Insectivora," *Jour. Anat. and Phys.*, 1867, 1868, and *Proc. Zool. Soc.*, 1871; Gill, "Synopsis of Insectivorous Mammals," *Bull. Geol. and Geog. Survey, U.S.A.*, Washington, 1875 (includes a general bibliography of the order *Insectivora*); Dobson, *Monograph of the Insectivora, Systematic and Anatomical*, London, 1882.

ORDER CHIROPTERA.

Volant mammals, having their fore limbs specially modified for flight. The forearm consists of a rudimentary ulna, a long curved radius, and a carpus of six bones supporting a thumb and four greatly elongated fingers, between which, the sides of the body, and the hinder extremities a thin expansion of the integument (the wing-membrane) is spread out. The knee is directed backwards, owing to the rotation of the hind limb outwards by the wing-membrane; a peculiar elongated cartilaginous process (the calcaneum or calcar), rarely rudimentary or absent, arising from the inner side of the ankle-joint, is directed inwards, and supports part of the posterior margin of an accessory membrane of flight, extending from the tail or posterior extremity of the body to the hinder limbs (the inter-femoral membrane). The penis is pendent; the testes abdominal or inguinal; the mammary glands thoracic and generally post-axillary; the uterus simple or with more or less long cornua; the placenta discoidal and deciduate; and the smooth cerebral hemispheres do not extend backwards over the cerebellum. The dental series consists of four kinds of teeth—incisors, canines, premolars, and molars; and the dental formula never exceeds $i\ \frac{2}{3}$, $c\ \frac{1}{1}$, $pm\ \frac{3}{3}$, $m\ \frac{3}{3}$; total 38 teeth.

The animals comprised in this order are at once distinguished by the presence of true wings, and this peculiarity is accompanied by other modifications of bodily structure having special relation to aerial locomotion. Thus, in direct contrast to all other mammals, in which locomotion is chiefly effected by action from behind, and the hind limbs consequently greatly preponderate in size over the fore, in the *Chiroptera* the fore limbs, being the only agents in propelling the body forward during flight, immensely exceed the short and weak hinder extremities; the thorax, giving origin to the great muscles which sustain flight, and containing the proportionately (compared with other mammals) very large lungs and heart, is remarkably capacious, and the ribs are flattened and close together; the shoulder-girdle is also greatly developed in comparison with the weak pelvic bones.

Linnæus included the Bats among the *Primates*, mainly on account of the number of their upper incisors, supposed to be always four, the thoracic position of the mammæ, and the pendent condition of the penis. Many other zoologists, taking into consideration also the placental characters and the form of the uterus, have followed him; but it is evident that the situation of the mammæ is related to the necessarily central position of the young during flight, the shortness of the uterine cornua, observable in so many species, to the generally uniparous gestation requiring less room, while the discoid deciduate placenta is equally present in and characteristic of the *Insectivora*, many species of which have also the penis pendent. Then, all these reasons for maintaining the Bats in such an exalted position being disposed of, we find in the low organization of their brain another proof of their inferior position in the zoological scale, while furthermore, although they differ widely from all other mammals in external form, it is evident that this is but the result of special adaptation to aerial locomotion; and, taking into account their whole bodily structure, we are forced to admit with Professor Huxley that they may be regarded as exceedingly modified *Insectivora*.

So thoroughly, however, has this adaptation been carried out that of all animals the Bats are the least terrestrial, not one of them being equally well fitted, as most Birds and Insects are, for progression on the earth. This is due to the hind as well as the fore limbs being pressed into the service of aerial locomotion. The hind limb is so rotated outwards by the wing-membrane that, contrary to what obtains in all other vertebrates, the knee is directed backwards, and corresponds in position to its serial homologue the elbow. When placed on the ground, therefore, the animal rests on all fours, having the knees directed upwards like a grasshopper's, while, in order to bring the foot into a position for forward progression, it is rotated forwards and inwards on the ankle. Walking under these circumstances is at best only a species of shuffle, and that this is fully recognized by the animal is evidenced by its great anxiety to take to the wing, or, if this be impracticable, to ascend to some point where it can hitch itself up by the claws of the hind-legs in its usual position when at rest.

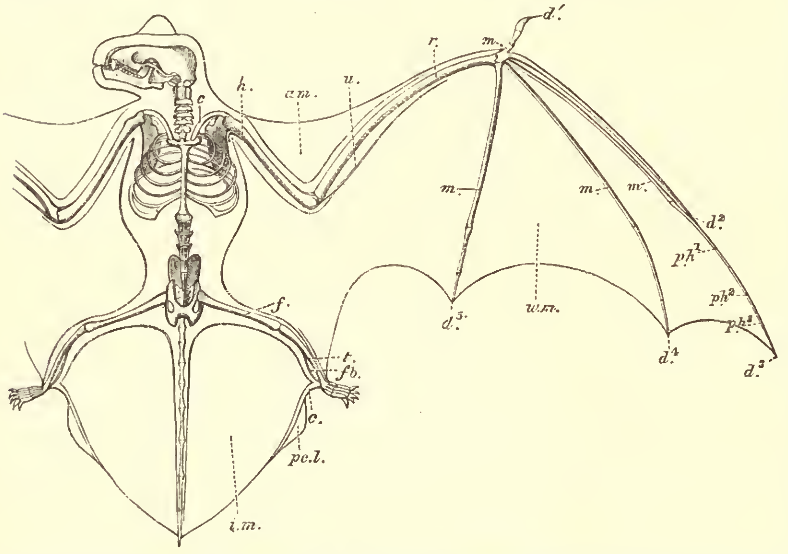

Fig. 65.—Skeleton and Volar Membranes of the Noctule Bat (*Vesperugo noctula*). × ½. *c*, clavicle; *h*, humerus; *r*, radius; *u*, ulna (rudimentary); d^1, first digit or pollex; d^2, d^3, d^4, d^5, other digits of the manus supporting *um*, the wing-membrane; *m*, *m*, metacarpal bones; ph^1, first phalanx; ph^2, second phalanx; ph^3, third phalanx; *am*, antebrachial membrane; *f*, femur; *t*, tibia; *fb*, fibula (rudimentary); *c*, calcaneum or calcar supporting *im*, the interfemoral membrane; *pcl*, post-calcaneal lobe.

The bones entering into the formation of the skeleton in *Chiroptera* are characterized by their slenderness, and by the great size of the medullary canals in those of the extremities. The vertebral column is short, and the vertebræ differ very slightly in number and form throughout the species. The general number of the dorso-lumbar vertebræ is 17, whereof 12 are dorsal; the cervical vertebræ are very broad, but short from before backwards (their breadth is due to the great transverse diameter of the spinal canal rendered necessary by the comparatively very large size of the spinal cord in this position, which, after giving off the nervous supply to the fore limbs and thorax, rapidly diminishes in size, and in the lumbo-sacral region is reduced to a fine thread). Except in the great frugivorous Bats (*Pteropodidæ*), the vertebræ, from the third cervical backwards, are devoid of spinous processes, a characteristic feature in the general osteology of the order. From the first thoracic to the last lumbar vertebra the spinal column forms a single curve backwards, which is most pronounced in the lumbar region. The bodies of the vertebræ are very slightly movable upon each other, and in old individuals appear to become partially ankylosed together. The caudal vertebræ are simple cylindrical bones without processes; their number and length is extremely variable even in closely allied species; and the anterior vertebræ are generally united to the ischial tuberosities. The development of these vertebræ, in fact, is intimately correlated to the habits of the animals, the long tail in the insectivorous species supporting and controlling the position of the large interfemoral membrane which appears not only to aid their rapid doubling motions when in pursuit of their insect prey by acting as a rudder on the air, but also to assist them in the capture and retention of the larger insects; in the frugivorous species, on the other hand, this is not required, and the tail is accordingly rudimentary or absent. In all Bats the presternum has a prominent keel for the attachment of the great pectoral muscles. In most species the ribs are much flattened, and in some partially ankylosed by their contiguous margins.

Great as is the variability of the shape of the skull in *Insectivora*, it is still greater in *Chiroptera*, and evidently depends upon the much wider differences in the nature of the food of different species requiring corresponding modifications of the manducatory apparatus, so that extreme modifications may be found in species of the same family, as in the case of the *Phyllostomidæ*. In some genera, however, as in *Miniopterus*, *Furia*, *Mormops* (*vide infra*), the peculiar shape of the skull cannot thus be accounted for. As in the *Insectivora*, post-orbital processes are developed in some species only, as in the *Pteropodidæ* and in a few *Nycteridæ* and *Emballonuridæ*; in *Pteropus leucopterus* alone does a process from the zygomatic arch meet the post-orbital so as to complete the orbital ring. Zygomatic arches, though slender, are present in all except in some of the species of *Phyllostomidæ*.

The milk teeth differ from those of all other mammals in that they in no respect resemble in form those of the permanent series. They are very slender, with acutely pointed recurved cusps, and are soon shed, but often coexist for a short time with the permanent teeth when the latter are considerably elevated above the gum. In the family *Rhinolophidæ* the milk teeth are absorbed before birth. The permanent teeth exhibit great variety in form, sometimes even in the same family, as in *Phyllostomidæ*, whilst in other families, as in *Rhinolophidæ*, the resemblance between the dentition of species otherwise differing in many important respects is most remarkable. In all, however, they are provided with well-developed roots, and their crowns are acutely tuberculate, with more or less well-defined W-shaped cusps, in the insectivorous species, as in *Insectivora*, or variously hollowed out or longitudinally grooved in the frugivorous, as in some species of *Phyllostomidæ* and in the *Pteropodidæ*.

As might be expected, the shoulder-girdle varies very slightly, having the same office to fulfil in all species. The clavicle is very long, strong, and curved; the scapulæ large, oval, triangular, with a long curved coracoid process. The humerus, though long, is scarcely two-thirds the length of the radius; the ulna is rudimentary; its proximal extremity, which articulates with but a small part of the humerus, is ankylosed with the radius; immediately beyond the joint it is reduced to a very slender splint-like bone, which extends about as far as the middle of the radius. In all species a detached sesamoid bone exists in the tendon of the triceps muscle, and is generally found in skeletons. The radius is very long, in some species as long as the head and body. The proximal row of the carpus consists of a single bone (the united scaphoid, lunar, and cuneiform bones), which, with the extremity of the radius, forms the radio-carpal joint; in the distal row the trapezium, trapezoid, and os magnum vary much in size in the different families; the unciform appears to be the most constant, and the pisiform is generally very small. It will be necessary to again refer to this subject when dealing with the diagnostic characters of the suborders.

The manus is, in all the species, composed of five digits. The first, fourth, and fifth consist each of a metacarpal bone and two osseous phalanges; in the second and third the number of phalanges is different in certain families. The first digit—the pollex—always terminates in a claw, which, with the proximal phalanx, is most developed in the frugivorous species. In most of the species of the frugivorous *Pteropodidæ* the second digit is also provided with a claw, but in all other Bats this and the remaining digits are unarmed. In the genus *Triænops* alone a very peculiar short bony process projects from the outer side of the proximal extremity of the terminal phalanx of the fourth digit. The relative development of the digits and their phalanges will be specially treated of under each family.

As might be expected from the small size of the posterior limbs, the pelvic girdle is very weak. The iliac bones are long and narrow. In most species the pubic bones of opposite sides are very loosely united in front in males; in females they are widely separated; in the family *Rhinolophidæ* alone do these bones form a symphysis. The eminentia ileo-pectinea develops in all species a long pectineal process, which in the subfamily *Phyllorhininæ* alone is continued forwards to the anterior extremity of the ilium (*vide infra*, p. 412), forming a preacetabular foramen which is unique among mammals. The acetabulum is small and directed outwards, and slightly upwards, and with this is related the peculiar position of the hind limb described above as one of the chief characteristics of the order. The femur is slender and cylindrical, with a small head and very short neck, and scarcely differs in form throughout the species. The bones of the leg and foot are more variable; in the subfamily *Molossinæ* alone is there a well-developed fibula; in all other species this bone is either very slender or cartilaginous and ligamentous in its upper third, or reduced to a small bony process above the heel, as in *Megaderma*, or altogether absent, as in *Nycteris*.

The foot consists of a very short tarsus, and of slender, laterally compressed toes, with much curved claws. The first digit is composed of a metacarpal bone, a proximal and an ungual phalanx, and is slightly shorter than the other four toes, which have each an additional phalanx, except in the subfamily *Phyllorhininæ* and in the anomalous genera *Thyroptera* and *Myxopoda*, where all the toes have the same number of phalanges as the first digit, and are equal to it in length. In the very remarkable genus *Cheiromeles* the first digit is thumb-like and separated from the others; and in the *Molossi* the first and fifth digits are much thicker than the intermediate toes.

The *muscular system*, as might be expected, exhibits few striking differences throughout the species. The most noticeable peculiarities in the myology of the order consist in the separated bands or slips into which the platysma is divided, and in the remarkable muscle termed occipito-pollicalis, which extends from the occipital bone to the base of the terminal phalanx of the pollex (see Macalister, "Myology of the *Chiroptera*," *Phil. Trans. Roy. Soc.*, 1872).

Although, as above mentioned, the brain presents a low type of organization, yet probably no animals possess so delicate sense of touch as the *Chiroptera*. It is undoubtedly this perceptive power which enabled the individuals deprived of sight, hearing, and smell, in Spallanzani's well-known experiments, to avoid the numerous threads hung across the rooms in which they were permitted to fly about. In the common Bats the tactile organs evidently exist, not only in the delicate vibrissæ which spring from the sides of the muzzle, but also in the highly sensitive and widely extended integumentary structures entering into the formation of the wing-membranes and ear-conchs, while in many other species, notably in the tropical Rhinolophine and Phyllostomine Bats, peculiar foliaceous cutaneous expansions surrounding the nasal apertures or extending backwards behind them are superadded (*vide infra*). These structures, collectively known as the "nose-leaf" (whence the term "leaf-nosed Bats"), have been shown by the present writer (who has traced their gradual development in different species) to be made up partly of the extended and thickened marginal integument of the nostrils, and partly of the highly differentiated glandular eminences occupying the sides of the muzzle, in which, in all the common Bats, the vibrissæ are implanted.

In all species of leaf-nosed Bats, and especially in the *Rhinolophidæ*, in which the nasal appendages reach their highest development, the superior maxillary division of the fifth nerve is of remarkably large calibre. The nasal branch of this nerve, which is given off immediately beyond the infra-orbital foramen, is by far the largest portion, the palpebral and labial branches consisting of a few slender nerve fibres only. This branch passes forwards and upwards on the sides of the superior maxillary bone, but soon spreads out into numerous filaments which pass into the muscles and integument above, and into the base of the nose-leaf. The nerve supply of the nose-leaf is further considerably augmented by the large nasal branch of the ophthalmic division of the fifth nerve.

While the many foliations, elevations, and depressions which vary the form of the nose-leaf also greatly increase the sensory surface so abundantly supplied by the fifth nerve, and in rapid flight intensify the vibrations conveyed to it, the great number of sweat and oil glands which enter into its structure perform an important function, analogous to that of the glands of the auditory canal in relation to the membrana tympani, in maintaining its surface in a highly sensitive condition.

The nasal appendages of *Chiroptera*, then, may be regarded as performing the office of an organ of a very exalted sense of touch standing in the same relation to the nasal branches of the sensory divisions of the fifth nerve as the aural apparatus to the auditory nerve; for, as the latter organ collects and transmits the waves of sound, so the former receives impressions arising from vibrations communicated to the air by approaching objects.

In no order of mammals is the ear-conch so greatly developed or so variable in form; in most of the insectivorous species the ears are longer than the head, while in some, as in the common Long-eared Bat (*Plecotus auritus*), their length nearly equals that of the head and body. The form of the conch is very characteristic in each of the families; in most the tragus is remarkably large, in some extending nearly to the outer margin of the conch; its office appears to be to cause undulations in the waves of sound, and so intensify and prolong them. It is worthy of notice that in the only family of insectivorous Bats wanting the tragus, the *Rhinolophidæ*, the auditory bullæ osseæ reach their greatest size, and the highly sensitive nasal appendages their highest development; also in the group *Molossi* the ear-conch is divided by a prominent keel; and the antitragus is remarkably large in those species in which the tragus is minute (see fig. 66, *a*). In the frugivorous Bats, as might be expected, the form of the ear-conch is very simple, and but slightly variable throughout the species.

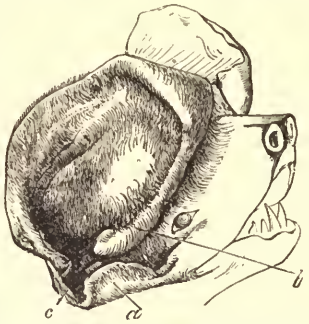

Fig. 66.—Head of *Molossus glaucinus*. Dobson, *Proc. Zool. Soc.*, 1876. *a*, antitragus; *b*, keel of the ear-conch; *c*, notch behind antitragus.

In all Bats the ears are extremely mobile, each moving independently at the will of the animal. This has been observed by the writer even in the frugivorous *Pteropodidæ*, in which the peculiar vibratory movements noticed by Mr Osburn in *Artibeus perspicillatus* may also be seen when the animals are alarmed.

The opening of the mouth is anterior in most species, but in many it is inferior, the extremity of the nose being more or less produced beyond the lower lip, so much so indeed in the small South-American species *Rynchonycteris naso* as to resemble that of the Shrews. The lips exhibit the greatest variety in form, which will be specially referred to under each family. The absence of a fringe of hairs is very characteristic of all fruit-eating Bats, and probably always distinguishes them from the insectivorous species, which they may resemble in the form of their teeth and in other respects.

The œsophagus is narrow in all species, and especially so in the sanguivorous *Desmodontes*. The stomach presents two principal types of structure, which correspond respectively to the two great divisions of the order, the *Megachiroptera* and the *Microchiroptera*; in the former (with the exception of *Harpyia*) the pyloric extremity is more or less elongated and folded upon itself, in the latter it is simple, as in *Insectivora vera*; a third exceptional type is met with in the sanguivorous *Desmodontes*, where the left or cardiac extremity is greatly elongated, forming a long narrow cæcum-like appendage. The intestine is comparatively short, varying from one and a half to four times the length of the head and body, being longest in the frugivorous, shortest in the insectivorous species. In *Rhinopoma microphyllum* and *Megaderma spasma* only has a very small cæcum been found.

The liver is characterized by the great size of the left lateral lobe, which occasionally equals half the size of the whole organ; the right and left lateral fissures are usually very deep; in *Megachiroptera* (*Harpyia* excepted) the Spigelian lobe is ill-defined or absent, and the caudate is generally very large, but in *Microchiroptera*, on the other hand, the Spigelian lobe is very large, while the caudate is small, in most species forming a ridge only. The gall-bladder is generally well developed and attached to the right central lobe, except in *Rhinolophidæ*, where it is connected with the left central.

In most species the hyoid bones are simple, consisting of a chain of slender, elongated, cylindrical bones connecting the small basi-hyoid with the cranium, while the pharynx is short, the larynx shallow with feebly developed vocal cords, and guarded by a short acutely-pointed epiglottis, which in some genera (*Harpyia*, *Vampyrus*, *e.g.*) is almost obsolete. In the *Epomophori*, however, we find a remarkable departure from the general type: the pharynx is long and very capacious, the aperture of the larynx far removed from the fauces, and, opposite to it, a canal, leading from the narial chambers, and extending along the back of the pharynx, opens; the laryngeal cavity is spacious and its walls are ossified; the hyoid bone is

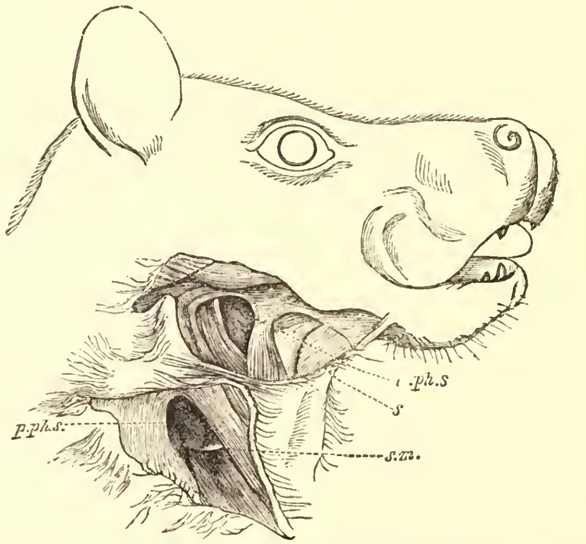

Fig. 67.—Head and Neck of *Epomophorus franqueti* (adult male, natural size). Dobson, *Proc. Zool. Soc.*, 1881. The anterior (*a.ph.s*) and posterior (*p.ph.s*) pharyngeal sacs are opened from without, the dotted lines indicating the points where they communicate with the pharynx; *s*, thin membranous septum in middle line between the anterior pharyngeal sacs of opposite sides; *s.m*, sterno-mastoid muscle separating the anterior from the posterior sac.

quite unconnected, except by muscle, with the cranium; the cerato-hyals and epi-hyals are cartilaginous and greatly expanded, entering into the formation of the walls of the pharynx, and, in the males of three species at least, supporting the orifices of a large pair of air-sacs communicating with the pharynx (see fig. 67).

In extent, peculiar modifications, and sensitiveness, the cutaneous system reaches its highest development in this order. As a sensory organ its chief modifications in connexion with the external ear, and with the nasal and labial appendages, have been described when referring to the nervous system. It remains therefore to consider its relative development as part of the organs of flight.

The extent and shape of the volar membranes depend mainly on the form of the bones of the anterior extremities, and on the presence or absence of the tail. Certain modifications of these membranes, however, are met with, which evidently do not depend on the skeleton, but are related to the habits of the animals, and to the manner in which the wing is folded in repose.

The volar membranes consist of—(1) the "antebrachial membrane," which extends from the point of the shoulder along the humerus and more or less of the forearm to the base of the thumb, the metacarpal bone of which is partially or wholly included in it; (2) the "wing-membrane," which is spread out between the greatly elongated fingers, and extends along the sides of the body to the posterior extremities, generally reaching to the feet; and (3) the "interfemoral membrane," the most variable of all, which is supported between the extremity of the body, the legs, and the calcanea (see fig. 65).

The antebrachial and wing membranes are most developed in those species which are fitted only for aerial locomotion, and which when at rest hang with the body enveloped in the wings; but in the family *Emballonuridæ*, especially in the subfamily *Molossinæ* (the species of which are, of all Bats, the best fitted for terrestrial progression), the antebrachial membrane is reduced to the smallest size, and is not developed along the forearm, leaving also the thumb quite free, and the wing-membrane is very narrow and folded in repose completely under the forearm. The relative development of the interfemoral membrane has been referred to above in describing the caudal vertebræ. Its small size in the frugivorous and sanguivorous species, which do not require it, to which, indeed, its presence would be actually injurious as impeding their motions when searching for food as they hang suspended by their feet, is easily understood. Odoriferous glands and pouches opening on the surface of the outer skin are developed in many species, but in most cases more so in males than in females, and so constitute very remarkable secondary sexual characters. They will be referred to when treating of the peculiarities of certain species. (See also the writer's paper "On Secondary Sexual Characters in *Chiroptera*," *Proc. Zool. Soc. Lond.*, 1873, pp. 241–252.)

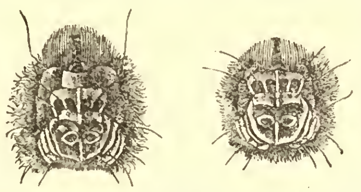

FIG. 68.—Frontal Sac and Nose-Leaf in Male and Female of *Phyllorhina larvata*. Dobson, *Proc. Zool. Soc.*, 1873.

Space does not admit of entering here upon a special description of the respiratory, circulatory, digestive, urinary, and generative organs, which will be found fully treated of in the works noted in the bibliography of the order below, and therefore with the above short account of the general structure of the species we proceed to consider their classification and geographical distribution.

The *Chiroptera* fall naturally into two subdivisions, which may be called suborders.

SUBORDER I. *MEGACHIROPTERA.*

Frugivorous Bats, generally of large size, having the crowns of the molar teeth smooth, marked with a longitudinal groove; with the bony palate continued behind the last molar narrowing slowly backwards; with three phalanges in the index finger, the third phalanx terminated generally by a claw; with the sides of the ear-conch forming a complete ring at the base; with the tail, when present, inferior to (not contained in) the interfemoral membrane; with the pyloric extremity of the stomach generally much elongated; and with the Spigelian lobe of the liver ill-defined or absent, while the caudate is well developed.

Frugivorous; limited to the tropical and subtropical parts of the Eastern Hemisphere.

Family PTEROPODIDÆ.

The characters of the single family are those of the suborder.

Epomophorus, $i\ \frac{2}{2}$ (or $\frac{1}{2}$), $c\ \frac{1}{1}$, $pm\ \frac{2}{3}$, $m\ \frac{1}{2}$; tail very short or none, when present quite free from the interfemoral membrane; second finger with a claw; premaxillary bones united in front. The six species include some of the most remarkable forms of fruit-eating Bats. They are strictly limited to the African continent south of the Sahara, and are readily distinguished by their remarkably large and long head and very expansible, often peculiarly folded, lips, and by the invariable white tuft of hair which adorns the margins of the ears; most of the species also are provided with peculiar glandular pouches, situated in the integument of the side of the neck near the point of the shoulder. These pouches are rudimentary or quite absent in females, thus presenting an interesting secondary sexual character. In the males they are lined with a glandular membrane, from which long coarse yellowish hairs arise, and, projecting from the mouth of the pouches, form conspicuous epaulet-like tufts on the shoulders, hence the generic name. Another and even still more remarkable secondary sexual character has been recently discovered by the writer in the males of *E. franqueti*, *comptus*, *pusillus*, and *monstrosus*. This consists in the presence of a pair of large air-sacs extending outwards on each side from the pharynx beneath the integument of the neck, in the position shown in fig. 67. These sacs are evidently capable of being greatly distended at the will of the animal, and their inflation probably occurs under the same circumstances that the wattles of male gallinaceous birds swell up, namely, when engaged in courting the females. Other remarkable conditions in which these Bats appear to differ from all other species, as in the peculiar structure of the hyoid bones and larynx, may be found described in detail in the writer's paper in the *Proceedings of the Zoological Society* for June 1881. These Bats appear to live principally on figs, the juicy contents of which their voluminous lips and capacious mouths enable them to swallow without loss.

Pteropus, $i\ \frac{2}{2}$, $c\ \frac{1}{1}$, $pm\ \frac{3}{3}$, $m\ \frac{2}{3}$, with forty-one species, includes more than half the *Pteropodidæ*. All are of large size, and the absence of a tail, the long pointed muzzle, and the woolly fur covering the neck render their recognition easy. They are the "Flying Foxes" of Europeans in India, and one of the species, *Pt. edulis*, inhabiting Java, measures 5 feet across the fully extended wings, and is the largest known species of the order. The species resemble one another closely in dentition, and are mainly distinguished by the form of the ears and quality of the fur. *Pt. scapulatus*, from north-east Australia, approaches the species of the second section of the family, the *Macroglossi*, in the remarkable narrowness of its molars and premolars.

FIG. 69.—Head of *Pteropus personatus*. Gray, *Proc. Zool. Soc.*, 1866.

The geographical range of the genus is very peculiar, extending from Madagascar and its islands through the Seychelles to India, Ceylon, Burmah, the Malay Archipelago, southern Japan, New Guinea, Australia, and Polynesia (except the Sandwich Islands, Ellice's Group, Gilbert's Group, Tokelau, and the Low Archipelago). Of the islands inhabited some are very small and remote from any continent, such as Savage Island in the South Pacific, and Rodriguez in the Indian Ocean. Although two species inhabit the Comoro Islands, which are scarcely 200 miles from the African coast, not a single species is found in Africa; yet in India, separated by thousands of miles of almost unbroken ocean, a species exceedingly closely allied to the common Madagascar "Flying Fox" is abundant. The Malay Archipelago and Australia are their headquarters, and in some places they occur in countless multitudes. Mr Macgillivray remarks of *Pt. conspicillatus*:—"On the wooded slope of a hill on Fitzroy Island I one day fell in with this Bat in prodigious numbers, looking while flying in the bright sunshine (so unusual for a nocturnal animal) like a large flock of rooks. On close approach a strong musky odour became apparent, and a loud incessant chattering was heard. Many of the branches were bending under their load of Bats, some in a state of inactivity, suspended by their hind claws, others scrambling along among the boughs, and taking to wing when disturbed." *Cynonycteris*, dentition as in *Pteropus*, but with a short tail, and the fur of the back of the neck not differing from that of the back, with nine species, extends into Africa, but has not been recorded from Australia or Polynesia; otherwise its distribution accords with that of *Pteropus*. *C. ægyptiaca* inhabits the chambers of the Great Pyramid and other deserted buildings in Egypt, and is probably the species so generally figured in Egyptian frescos. *Boneia*, with one species, *B. bidens*, from Borneo, differs from *Cynonycteris* in having two upper incisors only.

Cynopterus, $i\ \frac{2}{2}$ or $\frac{2}{1}$, $c\ \frac{1}{1}$, $pm\ \frac{3}{3}$, $m\ \frac{2}{2}$, muzzle shorter and grooved like *Pteropus* in front, tail and fur as in *Cynonycteris*, with seven species, is almost limited to the Oriental region. *C. marginatus* is very common in India, and extremely destructive to ripe fruit of every description. To a specimen of this Bat obtained by the writer at Calcutta uninjured was given a ripe banana, which, with the skin removed, weighed exactly 2 ounces. The animal immediately, as if famished with hunger, fell upon the fruit, seizing it between the thumbs and the index fingers, and took large mouthfuls out of it, opening the mouth to the fullest extent with extreme voracity. In the space of three hours the whole fruit was consumed. Next morning the Bat was killed, and found to weigh one ounce, half the weight of the food eaten in three hours. Indeed the animal when eating seemed to be a kind of living mill, the food passing from it almost as fast as devoured, and apparently unaltered, eating being, as it were, performed only for the pleasure of eating.

FIG. 70.—Head of *Harpyia major*. Dobson, *Proc. Zool. Soc.*, 1877.

Harpyia, $i\ \frac{1}{0}$, $c\ \frac{1}{1}$, $pm\ \frac{2}{3}$, $m\ \frac{2}{2}$, premaxillary bones well-developed and united in front, facial bones much elevated above the margin of the jaw, nostrils tubular, body and limbs as in *Cynopterus*, includes two species of very remarkable physiognomy (as may be seen from fig. 70), limited to the Austro-Malayan subregion.

Cephalotes, *i* $\frac{1}{1}$, *c* $\frac{1}{1}$, *pm* $\frac{2}{3}$, *m* $\frac{2}{3}$, premaxillary bones not united in front, nostrils simple, muzzle short, index finger without a claw, tail short, includes two species, having the same distribution as those of *Harpyia*; in both the wing-membrane arises from the centre line of the back, to which it is attached by a longitudinal very thin process of the integument; the wings are quite naked, but the back covered by them is well clothed with hair.

Notopteris, *i* $\frac{2}{1}$, *c* $\frac{1}{1}$, *pm* $\frac{2}{3}$, *m* $\frac{2}{2}$, index finger without a claw, wings from the spine, tail long. With this genus we enter the second division of the family, the *Macroglossi*, which have the facial part of the skull much produced, the molar teeth narrow, and scarcely raised above the gum, and the tongue exceedingly long, attenuated in the anterior third, and armed with long recurved papillæ near the tip. The single representative of the genus, *N. macdonaldii*, inhabits the Fiji Islands, Aneiteum Island, and New Guinea. It is at once distinguished from all other Bats of this family by the remarkable length of its tail, which is nearly as long as the forearm.

Eonycteris, *i* $\frac{2}{2}$, *c* $\frac{1}{1}$, *pm* $\frac{3}{3}$, *m* $\frac{2}{3}$, is also represented by a single species, *E. spelæa*, from the Farm Caves, Moulmein, Burmah, which has somewhat the appearance of a *Cynonycteris*, but the absence of a claw in the index finger and the presence of the characteristic tongue and teeth at once distinguish it.

Macroglossus and *Melonycteris*, each with a single species, are closely allied; the index finger in both has a claw, but the number of the teeth is the same as in *Eonycteris*. *Macroglossus minimus* is the smallest known species of the suborder; it is much smaller than the common Serotine Bat of Europe, and its forearm is scarcely longer than that of the Long-eared Bat. It is nearly as common in certain parts of India as *Cynopterus marginatus* (compared with which it is proportionally equally destructive to fruit), and extends eastward through the Malay Archipelago as far as New Ireland, where it is associated with *Melonycteris melanops*, distinguished from it by its larger size and by the total absence of the tail.

Suborder II. *MICROCHIROPTERA.*

Insectivorous (rarely frugivorous or sanguivorous) Bats, of comparatively small size, having the crowns of the molar teeth acutely tuberculated, marked by transverse grooves, with the bony palate narrowing abruptly, not continued backwards laterally behind the last molar; with one rudimentary phalanx (rarely two phalanges or none) in the index finger, which is never terminated by a claw; with the outer and inner sides of the ear-conch commencing inferiorly from separate points of origin; with the tail, when present, contained in the interfemoral membrane, or appearing upon its upper surface; with a simple stomach (except in *Desmodontes*); and with the Spigelian lobe of the liver very large, the caudate lobe generally small. Inhabiting the tropical and temperate regions of both hemispheres.

The Bats included in this suborder are mainly insectivorous, though some are frugivorous, and two species are known to be sanguivorous. They fall into five natural families, which may be arranged in two groups or alliances as follows:—

I. Tail contained within the interfemoral membrane; the middle pair of upper incisors never large, always separated from each other by a more or less wide space. I. *Vespertilionine Alliance.*

- *a.* Middle finger with two osseous phalanges only (except in *Myxopoda aurita*, *Thyroptera tricolor*, and *Mystacina tuberculata*).
  - *a'.* First phalanx of the middle finger extended (in repose) in a line with the metacarpal bone.
    - *a''.* Nostrils opening in a depression on the upper surface of the muzzle, surrounded by foliaceous cutaneous appendages.
      - *a'''.* Tragus none; premaxillary bones rudimentary, represented by thin osseous laminæ suspended from the nasal cartilages in the centre of the space between the canines. *Rhinolophidæ.*
      - *b'''.* Tragus distinct; premaxillary bones cartilaginous or small, separated by a space in front. *Nycteridæ.*
    - *b''.* Nostrils opening by simple crescentic or circular apertures at the extremity of the muzzle, not surrounded by distinct foliaceous cutaneous appendages; premaxillary bones small, lateral, separated by a wide space in front; tragus distinct. *Vespertilionidæ.*

II. Tail perforating the interfemoral membrane, and appearing on its upper surface, or produced considerably beyond the truncated membrane; the middle pair of upper incisors generally large and close together. II. *Emballonurine Alliance.*

  - *b'.* First phalanx of the middle finger folded (in repose) on the dorsal surface of the metacarpal bone (except in *Noctilio* and *Mystacina*).
    - *c''.* Nostrils opening by simple circular or valvular apertures at the extremity of the muzzle, not surrounded or margined by foliaceous cutaneous appendages; tragus distinct. *Emballonuridæ.*
- *b.* Middle finger with three well developed osseous phalanges; first phalanx of the middle finger short; nostrils in the front part of the cutaneous nasal appendages, or opening by simple apertures at the extremity of the muzzle; chin with warts or erect cutaneous ridges; premaxillary bones well-developed, united in front. *Phyllostomidæ.*

I. Vespertilionine Alliance.

Family Vespertilionidæ.

In the above synopsis of the families of *Microchiroptera* the *Vespertilionidæ* take the central position; and this is, indeed, the place really occupied by them in the suborder. This family includes the common simple-faced Bats of all countries, of which the well-known Pipistrelle and the Whiskered Bat (*Vespertilio mystacinus*) may be taken as familiar types, and its species number about 150, considerably more than one-third the total number of the known species of *Chiroptera*, estimated at slightly over 400 (see Introd. to Dobson's *Catal. Chiropt. Brit. Mus.*, 1878). Besides the characters of the family given in the synopsis, it may be added that the skull is of moderate size, the nasal and frontal bones not much extended laterally or vertically, nor furrowed by deep depressions; the number of incisors varies from $\frac{2}{3}$ to $\frac{1}{3}$, rarely (in *Antrozous* only) $\frac{1}{2}$, premolars $\frac{3}{3}$ or $\frac{2}{2}$ or $\frac{1}{2}$, rarely (in *Vesperugo noctivagans* of North America) $\frac{2}{3}$; the upper incisors are small, separated by a wide space in the centre, and placed in pairs or singly near the canines; the molars are well-developed, with acute W-shaped cusps. The family is distributed over the temperate and tropical regions of both hemispheres. The genera may be conveniently divided into four groups:—*Plecoti*, *Vespertiliones*, *Miniopteri*, and *Thyropteri*.

In the *Plecoti*, of which the common Long-eared Bat (*Plecotus auritus*) is the type, the crown of the head is but slightly raised above the face-line, the upper incisors are close to the canines, and the nostrils are margined behind by grooves on the upper surface of the muzzle, or by rudimentary nose-leaves; the ears also are generally very large and united. Of the five genera, *Plecotus*, *i* $\frac{2}{3}$, *pm* $\frac{2}{3}$, has two species:—one the common Long-eared European Bat referred to above; the other, *P. macrotis*, restricted to North America, is distinguished by the great size of the glandular prominences of the sides of the muzzle, which meet in the centre above and behind the nostrils. *Synotus*, *i* $\frac{2}{3}$, *pm* $\frac{2}{2}$, distinguished by dentition and by the outer margin of the ear being carried forwards above the mouth and in front of the eye, includes the European Barbastelle Bat, *S. barbastellus*, and *S. darjelingensis* from the Himalaya. *Otonycteris*, *i* $\frac{1}{3}$, *pm* $\frac{1}{2}$, connecting this group with the *Vespertiliones* through the tropical *Scotophili*, is represented by a single species, *O. hemprichii*, from North Africa and the Himalaya. The next two genera are distinguished by the presence of a rudimentary nose-leaf:—*Nyctophilus*, *i* $\frac{1}{3}$, *pm* $\frac{1}{2}$, with one species, *N. timoriensis*, from the Australian region; and *Antrozous*, *i* $\frac{1}{2}$, *pm* $\frac{1}{2}$, distinguished from all the family besides by having but two lower incisors, and from other *Plecoti* by the separate ears; the single species, *A. pallidus*, inhabits California.

The group *Vespertiliones*, with eight genera, includes nine-tenths of the species. Of these one-third are contained in the genus *Vesperugo*, which is divisible into six subgenera according to the number of premolars and incisors; the latter vary from $\frac{2}{3}$ to $\frac{1}{3}$ in the subgenera *Scotozous* and *Rhogeëssa*, and the premolars from $\frac{2}{2}$ to $\frac{1}{2}$ (in the subgenus *Lasionycteris* $\frac{2}{3}$). The Bats of this genus are generally easily distinguished by their comparatively thickly formed bodies, by their flat broad heads and obtuse muzzles, by their short, broad, and triangular, obtusely-pointed ears, by their obtuse and usually slightly incurved tragus, by their short legs, and by the presence in most species of a well-developed post-calcaneal lobule. This lobule (which is supported by a cartilaginous process derived from the calcaneum) may act as a kind of adhesive disk in securing the animal's grasp when climbing over smooth surfaces. *Vesperugo* probably contains the greatest number of individuals among the genera of *Chiroptera*, and, with the exception of *Vespertilio*, its species have also the widest geographical range, being in fact cosmopolitan; and one of the species, the well-known Serotine, *V.* (*Vesperus*) *serotinus*, is remarkable as the only species of Bat known to inhabit both the Old and the New World; one, *V. borealis*, has been found close to the limits of the Arctic Circle, and another, *V. magellanicus*, inhabits the cold and desolate shores of the Straits of Magellan, doubtless the Bat referred to by Mr Darwin in the *Naturalist's Voyage*. *Chalinolobus* agrees with *Vesperugo* in the dental formula, but is readily distinguished by the presence of a well-defined lobe projecting near the angle of the mouth from the lower lip, and by the unicuspidate upper inner incisors. The species fall into two subgenera:—*Chalinolobus*, *pm* $\frac{2}{2}$, with *C. tuberculatus* from New Zealand, Tasmania, and Australia, and three other species from Australia; and *Glauconycteris*, *pm* $\frac{1}{2}$, limited to southern and equatorial Africa, with *G. argentatus* and two other species, the Bats of this subgenus being especially remarkable for their peculiarly thin membranes traversed by very distinct reticulations and parallel lines. *Scotophilus*, *i* $\frac{1}{3}$, *pm* $\frac{1}{2}$, includes eight species, restricted to the tropical and subtropical regions of the eastern hemisphere, though widely distributed within these limits. The Bats of this genus, though difficult to define, and approaching certain of those of *Vesperugo* in many points, are distinguished especially by the single pair of unicuspidate upper incisors separated by a wide space and placed close to the canines, by the small transverse first lower premolar crushed in between the canine and second premolar, and, generally, by their conical nearly naked muzzles and remarkably thick leathery membranes. *Sc. temminckii* is probably the commonest species of Bat in India, and appears often on the wing even before the sun has touched the horizon, especially when the white ants are swarming, feeding eagerly upon them as they rise in the air. *Sc. gigas*, from equatorial Africa, with the forearm 3·4 inches, is by far the largest species. *Nycticejus*, with the same dental formula as *Scotophilus*, is distinguished by the first lower premolar not being crushed in between the adjoining teeth, and by the comparatively much greater size of the last upper molar. It includes only the common North American species *N. crepuscularis*, a small Bat scarcely larger than the Pipistrelle. *Atalapha*, *i* $\frac{1}{3}$, *pm* $\frac{2}{2}$ or $\frac{1}{2}$, with five species, is also limited to the New World. The Bats of this genus are generally characterized by the interfemoral membrane being more or less covered with hair (in the two commonest species, *A. noveboracensis* and *A. cinerea*, wholly thickly covered), and by the peculiar form of the tragus, which is expanded above and abruptly curved inwards. In these species, which have two upper premolars, the first is extremely small and quite internal to the tooth-row. The genus *Harpyiocephalus*, *i* $\frac{2}{3}$, *pm* $\frac{2}{2}$, includes eight very remarkable small species, distinguished at once by their prominent tube-like nostrils and hairy interfemoral membrane. *H. suillus* from Java and neighbouring islands is the best-known species, and another closely allied, *H. hilgendorfi*, has been described by Professor Peters from Japan. The remaining six species are known only from the Himalaya and Tibet. All appear to be restricted to the hill tracts of the countries in which they are found. Next to *Vesperugo*, the genus *Vespertilio*, *i* $\frac{2}{3}$, *pm* $\frac{3}{3}$, includes by far the largest number of species, amounting to forty-three; it has, however, rather a wider geographical distribution in both hemispheres, one species at least being recorded from the Navigators' Islands. The species are easily recognized by the peculiar character of the pairs of upper incisors on each side, the cusps of which diverge from each other, by the large number of premolars, of which the second upper is always very small, and by the oval elongated ear and narrow attenuated tragus. *Kerivoula*, with the same dental formula as *Vespertilio*, is easily distinguished by the parallel upper incisors, and by the comparatively large size of the second upper premolar. Ten species have been described from the Ethiopian and Oriental regions, of which *K. picta*, from India and the Indo-Malayan subregion, is the best-known, being well characterized by its brilliantly coloured orange fur and conspicuously marked membrane, which are variegated with orange and black. The genus includes the most delicately formed and most truly insectivorous, tropical, forest-haunting Bats, which appear to stand as regards the species of *Vespertilio* in a position similar to that occupied by *Chalinolobus* with respect to *Vesperugo*.

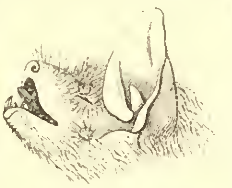

Fig. 71.—Head of *Scotophilus emarginatus*. Dobson, *Monogr. Asiat. Chiropt.*

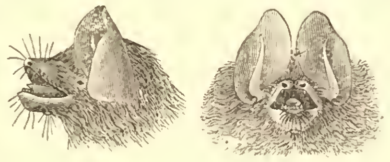

Fig. 72.—Side and Front View of the Head of *Kerivoula hardwickii*. Dobson, *Monogr. Asiat. Chiropt.*

The next group, *Miniopteri*, includes two genera, *Natalus* and *Miniopterus*, characterized by the great elevation of the crown of the head above the face-line, and by the upper incisors being separated from the canines and also in front. *Natalus*, with the same dental formula and general external form as *Kerivoula*, is distinguished by the short triangular tragus, and by the characters of the group enumerated above. It includes three species, all restricted to South and Central America and the West Indies; the head of one, *N. micropus*, lately described by the present writer, is shown in fig. 73. *Miniopterus*, *i* $\frac{2}{3}$, *pm* $\frac{2}{3}$, at once distinguished by the shortness of the first phalanx of the middle finger, and by the great length of the tail, which is wholly contained within the interfemoral membrane, includes four species, restricted to the eastern hemisphere. Of these the best-known, *M. schreibersii*, is very widely distributed, being found almost everywhere throughout the tropical and warmer temperate regions of the eastern hemisphere, specimens from Germany, Madagascar, Japan, and Australia differing in no appreciable respect.

Fig. 73.—Head of *Natalus micropus*. × 2. Dobson, *Proc. Zool. Soc.*, 1880.

The last group, *Thyropteri*, includes also two genera, distinguished not only by the presence of an additional osseous phalanx in the middle finger and an equal number of phalanges in the toes, but also by peculiar accessory clinging organs attached to the extremities. In *Thyroptera tricolor*, *i* $\frac{2}{3}$, *pm* $\frac{3}{3}$, from Brazil, these organs have the appearance of small, circular, pedunculated, hollow disks (fig. 74), resembling in miniature the sucking cups of cuttle-fishes, and attached to the inferior surfaces of the thumbs and soles of the feet, with which the animal is enabled to maintain its hold when creeping over smooth vertical surfaces (for an account of the minute anatomy of these clinging organs see the writer's paper in the *Proc. Zool. Soc.*, 1876, pp. 531–34). In *Myxopoda aurita* from Madagascar (type of the second genus), with the same dental formula, but differing much in the characters of the teeth and in the form of the ears, the whole inferior surface of the thumb supports a large sessile horse-shoe-shaped adhesive pad, with the circular margin directed forwards and notched along its edge, and a smaller pad occupies part of the sole of the foot.

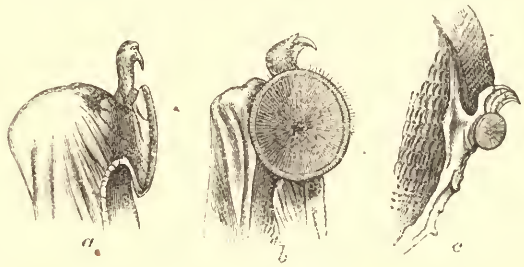

Fig. 74.—Suctorial Disks in *Thyroptera tricolor*. *a*, side, and *b*, concave surface, of thumb disk; *c*, foot with disk, and calcar with projections (all much enlarged). Dobson, *Proc. Zool. Soc.*, 1876.

Family Nycteridæ.

This small family, defined in the synopsis above, includes only two genera of Bats of very peculiar aspect, limited to the tropical and subtropical parts of the eastern hemisphere.

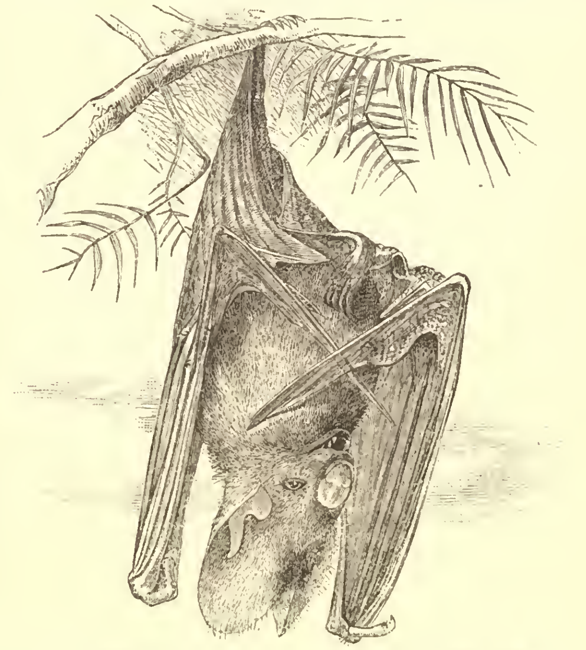

Fig. 75.—*Megaderma gigas*. × ½. Dobson, *Proc. Zool. Soc.*, 1880.

Megaderma, $i\ \frac{0}{2}$, $pm\ \frac{2}{2}$ or $\frac{1}{2}$, with five species, is distinguished by the absence of upper incisors, by the cylindrical narrow muzzle surmounted by an erect naked cutaneous process (the nose-leaf), the base of which conceals the nasal orifices, by the immense connate ears with large bifid tragi, and by the great extent of the interfemoral membrane, in the base of which the very short tail is concealed. *M. gigas*, from central Queensland (forearm 4·2 inches), is not only the largest species of the genus but also of the suborder. *M. lyra*, common in India (forearm 2·7 inches), has been caught in the act of sucking the blood, while flying, from a small species of *Vesperugo*, which it afterwards devoured (see Dobson's *Monograph of the Asiatic Chiroptera*, p 77), so that it is probable that the Bats of this genus do not confine themselves to insect prey alone, but also feed, when they can, upon the smaller species of Bats and other small mammals.

Nycteris, $i\ \frac{2}{3}$, $pm\ \frac{1}{2}$, with seven species, differs so much from *Megaderma* that it may be considered the type of a separate subfamily. As in that genus, the frontal bones are deeply hollowed out and expanded laterally, the muzzle presents a similar cylindrical form, and the lower jaw also projects, but the single elevated nose-leaf is absent, and instead of it the face is marked by a deep longitudinal sharp-edged groove extending from the nostrils (which are on the upper surface of the muzzle near its extremity) to the low band connecting the bases of the large ears; the sides of this depression are margined as far back as the eyes by small horizontal cutaneous appendages. All the species resemble one another closely, and are mainly distinguished by the form of the tragus, and the size and relative position of the second lower premolar. With the exception of *N. javanica*, all the species are limited to the Ethiopian region.

Family Rhinolophidæ.

In all the species of this family the nasal appendages are highly developed, and surround on all sides the nasal apertures, which are situated in a depression on the upper surface of the muzzle; the ears are large and generally separate, without trace of a tragus; the premaxillary bones are rudimentary, are suspended from the nasal cartilages, and support a pair of very small incisors; the molars have acute W-shaped cusps; the skull is large, and the nasal bones which support the large nasal cutaneous appendages are much expanded vertically and laterally; in females a pair of teat-like appendages are found in front of the pubis; and the tail is long and produced to the posterior margin of the interfemoral membrane. The family is found in the temperate and tropical parts of the eastern hemisphere.

From whatever point of view the *Rhinolophidæ* may be considered, they are evidently the most highly organized of insectivorous Bats. In them the osseous and cutaneous systems reach the most perfect development. Compared with theirs the bones of the extremities and the volar membranes of other Bats appear coarsely formed, and even their teeth seem less perfectly fitted to crush the hard bodies of insects. The very complicated nasal appendages, which evidently act as delicate organs of special perception (*vide supra*), here reach their highest development, and the differences in their form afford valuable characters in the discrimination of the species, which resemble one another very closely in dentition and in the colour of the fur.

Subfamily I. **Rhinolophinæ.**—First toe with two, other toes with three phalanges each; ilio-pectineal spine not connected by bone with the antero-inferior surface of the ilium.

Rhinolophus, $i\ \frac{1}{2}$, $c\ \frac{1}{1}$, $pm\ \frac{2}{3}$, $m\ \frac{3}{3}$, nose-leaf with a central process behind and between the nasal orifices, posterior extremity lanceolate, antitragus large, includes twenty-four species. *R. luctus*, forearm 3 inches, is the largest species, inhabiting elevated hill tracts in India and Malayana; *R. hipposideros* of Europe, extending into south England and Ireland, forearm 1·5 inches, is one of the smallest; and *R. ferrum-equinum*, forearm 2·3 inches, represents the average size of the species, which are mainly distinguished from one another by the form of the nose-leaf. The last-named species extends from England to Japan, and southward to the Cape of Good Hope.

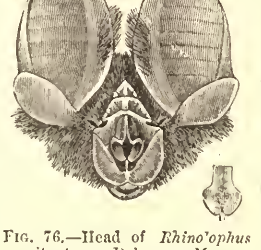

Fig. 76.—Head of *Rhinolophus mitratus*. Dobson, *Monogr. Asiat. Chiropt.*

Subfamily II. **Phyllorhininæ.**—Toes equal, of two phalanges each; ilio-pectineal spine united by a bony isthmus with a process derived from the antero-inferior surface of the ilium.

Phyllorhina, with twenty-two species, and *Rhinonycteris*, *Triænops*, and *Cœlops*, with one each, represent this subfamily. *Phyllorhina*, $i\ \frac{1}{2}$, $c\ \frac{1}{1}$, $pm\ \frac{2}{2}$ or $\frac{1}{2}$, $m\ \frac{3}{3}$, differs from *Rhinolophus* in the form of the nose-leaf, which is not lanceolate behind (see fig. 76), and is unprovided with a central process covering the nostrils; the largest species, *Ph. armigera*, appears to be the most northerly, having been taken at Amoy in China, and in the Himalaya at an elevation of 5500 feet. Many are provided with a peculiar frontal sac behind the nose-leaf, rudimentary in females (see fig. 67), which the animal can evert at pleasure; the sides of this sac secrete a waxy substance, and its extremity supports a pencil of straight hairs. *Rhinonycteris*, represented by *R. aurantia* from Australia, and *Triænops*, by *T. persicus*, from Persia and eastern Africa, are closely allied genera; the latter species is characterized by the very remarkable form of its nasal appendages and ears, and by the presence of a peculiar osseous projection from the proximal extremity of the second phalanx of the fourth finger. *Cœlops* (*C. frithii*), from the Bengal Sunderbunds, Java, and Siam (in the roof of the great pagoda at Laos), is distinguished, not only by the very peculiar form of its nose-leaf, but also by the great length of the metacarpal bone of the index finger, as well as by the shortness of the calcanea and interfemoral membrane.

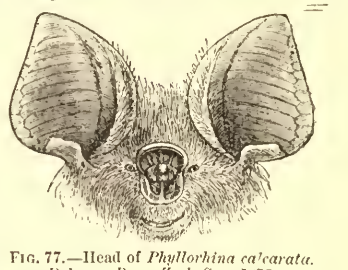

Fig. 77.—Head of *Phyllorhina calcarata*. Dobson, *Proc. Zool. Soc.*, 1877.

Fig. 78.—Head of *Triænops persicus*. × 2. Dobson, *Monogr. Asiat. Chiropt.*

II. Emballonurine Alliance.

Family Emballonuridæ.

The second group of families (as defined above) into which the *Microchiroptera* may be divided includes the *Emballonuridæ* and *Phyllostomidæ*. The former is represented by thirteen genera, including sixty-five species. The *Emballonuridæ* are generally easily distinguished by the peculiar form of the muzzle, which is obliquely truncated, the nostrils projecting more or less in front beyond the lower lip, by the first phalanx of the middle finger being folded in repose forwards on the upper surface of the metacarpal bone, by the tail, which either perforates the interfemoral membrane or is produced far beyond it, and by the upper incisors, which are generally a single pair separated from the canines and also in front. They are cosmopolitan like the *Vespertilionidæ*, but rarely extend north or south of the thirtieth parallel of latitude.

Subfamily I. **Emballonurinæ.**—Tail slender, perforating the interfemoral membrane, and appearing upon its upper surface, or terminating in it; legs long, fibulæ very slender; upper incisors weak.

Group I. *Furiæ.*—Tail terminating in the interfemoral membrane; crown of the head greatly elevated above the face-line; thumb and first phalanx of the middle finger very short; $i\ \frac{2}{3}$, $c\ \frac{1}{1}$, $pm\ \frac{2}{2}$, $m\ \frac{3}{3}$.

Two genera, *Furia* and *Amorphochilus*, each including one species of very peculiar aspect, the latter distinguished from the former by the widely separated nostrils and great extension backwards of the bony palate. Habitat South America.

Group II. *Emballonuræ.*—Part of the tail included in the basal half of the interfemoral membrane, the remaining part passing through and appearing upon its upper surface; crown of the head slightly elevated; thumb and first phalanx of the middle finger moderately long; $pm\ \frac{2}{2}$. With five genera.

Emballonura, $i\ \frac{2}{3}$, extremity of the muzzle more or less produced beyond the lower lip, forehead flat, contains five species, inhabiting islands from Madagascar through the Malay Archipelago to the Navigators' Islands. *Coleüra*, $i\ \frac{1}{3}$, extremity of the muzzle broad, forehead concave, has two species from east Africa and the Seychelles Islands. *Rhynchonycteris* is distinguished from *Coleüra* by the much produced extremity of the muzzle; the single species, *R. naso*, from Central and South America, is very common in the vicinity of streams throughout the tropical parts of these countries. It is usually found during the day resting on the vertical

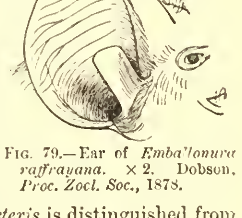

Fig. 79.—Ear of *Emballonura raffrayana*. × 2. Dobson, *Proc. Zool. Soc.*, 1878.

faces of rocks, or on the trunks of trees growing out over the water, and, owing to the peculiar greyish colour of the fur covering the body and growing in small tufts from the antebrachial membrane, counterfeiting the weathered surfaces of the rocks and the bark of the trees, easily escapes notice. As the shades of evening approach it appears early on the wing, flying close to the surface of the water, and seizing the minute insects that hover over it. *Saccopteryx*, *i* $\frac{1}{3}$, antebrachial membrane with a pouch opening on its upper surface, contains six species from Central and South America; the wing-sac varies in position in different species. It is developed only in the male; in the female it is quite rudimentary. In the adult males of the different species a valvular longitudinal opening is found on the upper surface of the membrane. This opening leads into a small pouch (in some species large enough to hold a pea), the interior of which is lined with a glandular membrane secreting an unctuous substance of a reddish colour with a strong ammoniacal odour. The presence of this sac in males only indicates that it is a secondary sexual character analogous to the shoulder pouches of *Epomophorus*, the frontal sacs of *Phyllorhina*, &c.

The next genus *Taphozous*, including ten species, inhabiting the tropical and subtropical parts of all the eastern hemisphere except Polynesia, forms the second section of this group, distinguished by its cartilaginous premaxillaries, deciduous pair of upper incisors, and by the presence of four lower incisors only. Most of the species have a peculiar glandular sac (see fig. 80) placed between the

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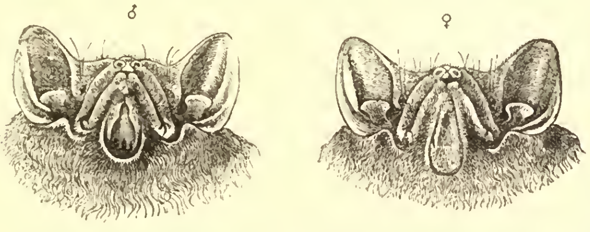

FIG. 80.—Heads of *Taphozous longimanus*, showing relative development of gular sacs in male and female. Dobson, *Proc. Zool. Soc.*, 1873.

angles of the lower jaw, a sexual character; for, while always more developed in males than in females, in some species, although distinct in the male, it is quite absent in the female. An open gular sac is wanting in both sexes in *T. melanopogon*, but about its usual position the openings of small pores may be seen, the secretion exuding from which probably causes the hairs to grow very long, forming the black beard found in many male specimens of this species.

Group III. *Dicliduri.*—This is represented by a single genus, *Diclidurus*, including two species. *D. albus*, from Central and South America, *i* $\frac{1}{3}$, *c* $\frac{1}{1}$, *pm* $\frac{2}{2}$, *m* $\frac{3}{3}$, resembles the species of *Taphozous* in the form of the head and ears, but, besides other characters, differs from all other Bats in possessing a peculiar pouch, opening on the centre of the inferior surface of the interfemoral membrane; the extremity of the tail enters this, and perforates its fundus.

Group IV. *Noctiliones.*—This also is represented by a single genus and two species, *Noctilio leporinus* and *N. dorsatus*, *i* $\frac{2}{1}$, *pm* $\frac{1}{2}$, from Central and South America. The group connects the family *Emballonuridæ* with the *Phyllostomidæ*, possessing characters common to both, but also so many remarkable special peculiarities as almost to warrant the formation of a separate family for its reception. The type, *N. leporinus* of Linnæus, is a Bat of very curious aspect, with strangely folded lips, erect cutaneous processes on the chin, and enormous feet and claws. The two middle incisors are close together, and so large as to conceal the small outer ones, while in the lower jaw there are but two small incisors. This apparent resemblance to a Rodent actually led the great naturalist to remove this species from the Bats and place it in his order *Glires* or Rodents. Similarly the next group *Rhinopomata*, represented by a single species, *R. microphyllum*, might also be elevated into the rank of a family, for it is very difficult to determine its exact affinities, a kind of cross relationship attaching it to the *Nycteridæ* on the one hand and to this family, in which it is here placed provisionally, on the other. This curious species, distinguished from all other *Microchiroptera* as well by the presence of two phalanges in the index finger as by its remarkably long and slender tail projecting far beyond the narrow interfemoral membrane, inhabits the subterranean tombs in Egypt and deserted buildings generally from north-east Africa to Burmah.

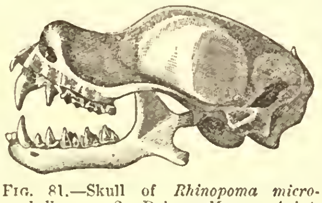

FIG. 81.—Skull of *Rhinopoma microphyllum.* × 2. Dobson, *Monogr. Asiat. Chiropt.*

Subfamily II. **Molossinæ.**—Tail thick, produced far beyond the posterior margin of the interfemoral membrane (except in *Mystacina*); legs short and strong, with well-developed fibulæ; upper incisors strong. This subfamily includes all the species of *Emballonuridæ* with short and strong legs and broad feet—whereof the first toe (and in most species the fifth also) is much thicker than the others, and furnished with long curved hairs,—with well-developed callosities at the base of the thumbs, and with a single pair of large upper incisors occupying the centre of the space between the canines. In all the species the feet are free from the wing-membrane, which folds up very perfectly under the forearm and legs; the interfemoral membrane is retractile, being movable backwards and forwards along the tail, and this power of varying its superficial extent must confer upon these Bats great dexterity in quickly changing the direction of their flight, as when obliged to double in pursuing their swiftly-flying insect prey, which their extremely expansible lips evidently enable them to secure with ease.

Group I. *Molossi.*—Tail produced beyond the posterior margin of the interfemoral membrane.

Cheiromeles, *i* $\frac{1}{1}$, *c* $\frac{1}{1}$, *pm* $\frac{1}{2}$, *m* $\frac{3}{3}$, hallux much larger than the other toes and separable from them, ears separate, is represented by a single species, *C. torquatus*, of large size (forearm 3·1 inches) and very peculiar aspect, inhabiting the Indo-Malayan subregion. This species is nearly naked, a collar only of thinly spread hairs half surrounding the neck, and is further remarkable for its enormous throat sac and curious nursing pouches. The former consists of a great semicircular fold of skin forming a deep pouch round the neck beneath, concealing the orifices of large subcutaneous pectoral glands which discharge an oily fluid of insufferably offensive smell. The nursing pouch is formed on each side by an extension of a fold of skin from the side of the body to the inferior surfaces of the humerus and femur. In the anterior part of this pouch the mamma is placed. For figures of these throat sacs and notes on the use of the nursing pouches see *Catal. Chiroptera*, p. 406, pl. xxi.

Molossus, *i* $\frac{1}{1}$ or $\frac{1}{2}$, *pm* $\frac{1}{2}$ or $\frac{2}{2}$, upper incisors close together in front, with ten species, is restricted to the tropical and subtropical regions of the New World. The woodcut of *M. glaucinus* (fig. 82) exhibits the general physiognomy of the Bats of this genus. *M. obscurus*, a small species, is very common in tropical America. It inhabits the hollow trunks of palms and other trees, and also the roofs of houses. The males and females live apart (as, indeed, appears to be the case in most if not in all species of Bats). In the hollow trunk of a palm two colonies were discovered, one consisting of from 150 to 200 individuals, exclusively males, while the other was composed of females with a male here and there among them.

FIG. 82.—Head of *Molossus glaucinus*. Dobson, *Proc. Zool. Soc.*, 1876.

Nyctinomus, *i* $\frac{1}{3}$ or $\frac{1}{2}$, *pm* $\frac{2}{2}$ or $\frac{1}{2}$, upper incisors separate in front, includes twenty-one species, inhabiting the tropical and subtropical parts of both hemispheres. The lips of the Bats of this genus are even more expansible than in *Molossus*, in many of the species (as in the woodcut of the head of *N. macrotis*, fig. 83) showing vertical wrinkles. *N. cestonii*, one of the largest species, alone extends into Europe, and has been taken as far north as Switzerland. *N. johorensis*, from the Malay Peninsula, is remarkable from the extraordinary form of its ears. *N. brasiliensis* is nearly as common as *M. obscurus* in tropical America, and extends farther north (California) and south than that species.

FIG. 83.—Head of *Nyctinomus macrotis*. Dobson, *Proc. Zool. Soc.*, 1876.

Group II. *Mystacinæ.*—Tail perforating the interfemoral membrane, and appearing upon its upper surface.

This includes a single genus and species, *Mystacina tuberculata*, a very peculiar form restricted to New Zealand, where, with *Chalinolobus tuberculatus*, it represents the whole indigenous mammalian fauna of the islands. There are three distinct phalanges in the middle finger; the greater part of the wing-membrane is exceedingly thin, but a narrow portion along the forearm, the sides of the body, and the legs is remarkably thick and leathery; beneath this thickened portion the wings are folded, and it is evidently analogous to the thickened part of the anterior wings in hemipterous insects and to the elytra of the *Coleoptera*. With the wings thus encased, this species is the most quadrupedal of Bats. Other peculiarities of structure are found in the remarkable form of the claws of the thumbs and toes, which have each a small talon projecting from its concave surface near the base, also in the sole of the foot and inferior surface of the leg, as shown in fig. 84. The plantar surface, including the toes, is covered with soft and very lax integument deeply wrinkled, and each toe is marked by a central longitudinal groove with short grooves at right angles to it,

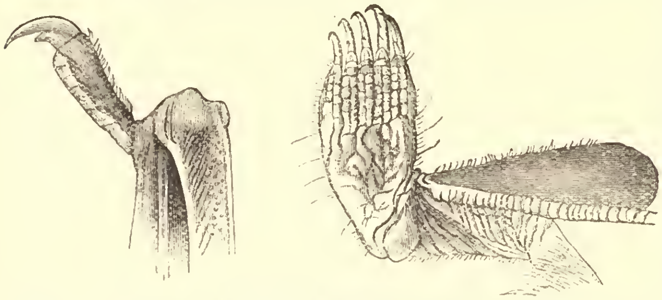

FIG. 84.—Thumb and Leg and Foot of *Mystacina tuberculata* (enlarged). Dobson, *Proc. Zool. Soc.*, 1876.

as in the genus *Hemidactylus* (*Geckotidæ*). The lax wrinkled integument is continued along the inferior flattened surface of the ankle and leg. These peculiarities appear to be related to climbing habits in the species. See the writer's remarks in *Proc. Zool. Soc.*, 1876, p. 488.

Family PHYLLOSTOMIDÆ.

The Bats included in this family are readily distinguished by the presence of a well-developed third phalanx in the middle finger, associated either with distinct cutaneous nasal appendages, or with well-developed central upper incisors, or with both. Unlike the *Rhinolophidæ*, their eyes are generally large, and the tragus well developed, maintaining almost the same form throughout the species, however much the outer parts of the body may vary. Their fur is of a dull colour, and the face and back (in the *Stenodermata* especially) are often marked with white streaks, as in the *Pteropodidæ*, of which they take the place in the western hemisphere. A few species, probably all those with the tail and interfemoral membrane well-developed, feed principally on insects, while the greater number of the species of the groups *Vampyri* and *Glossophagæ* appear to live on a mixed diet of insects and fruits, and the *Desmodontes*, of which two species only are known, are true blood-suckers, and have their teeth and intestinal tract specially modified in accordance with their habits. Limited to the tropical and sub-tropical parts of Central and South America.

Subfamily 1. **Lobostominæ.**—Nostrils opening by simple apertures at the extremity of the muzzle in front, not margined by a distinct nose-leaf; chin with expanded leaf-like appendages.

It includes two genera. In *Chilonycteris* (six species) the crown of the head is moderately elevated above the face-line, and the basi-cranial axis is almost in the same plane as the facial, while in *Mormops* the crown of the head is greatly elevated above the face-line, and the basi-cranial axis is almost at right angles to the facial; *i* $\frac{2}{2}$, *pm* $\frac{2}{3}$ in both genera. The latter genus contains two species, which, in their very peculiar physiognomy, are probably the most remarkable among the many strange forms exhibited by the different species of this order.

FIG. 85.—Head of *Mormops blainvillii*. Dobson, *Catal. Chiropt. Brit. Mus.*

Subfamily 2. **Phyllostominæ.**—Nostrils opening on the upper surface of the muzzle, the nasal apertures more or less surrounded or margined by well-developed cutaneous appendages, forming a distinct nose-leaf; chin with warts.

Group 1. *Vampyri.*—Muzzle long and narrow in front, the distance between the eyes generally less than, rarely equal to, the distance from the eye to the extremity of the muzzle; nose-leaf well-developed, horse-shoe-shaped in front, lanceolate behind; interfemoral membrane well-developed; tail generally distinct, rarely absent; inner margin of the lips not fringed; *i* $\frac{2}{2}$ or $\frac{2}{1}$, *pm* $\frac{2}{2}$ or $\frac{2}{3}$; molars with W-shaped cusps, usually well-developed.

Nearly all the species of *Vampyri* appear to be insectivorous, so that the term applied to this group cannot be considered indicative of their habits. A few, if not all, probably supplement their insect diet with fruit. *Vampyrus spectrum* (the largest Bat in the New World, forearm 4·2 inches) is said to be wholly frugivorous, and *Macrotus waterhousii* appears to prey occasionally on small species of Bats, like *Megaderma lyra* of the eastern hemisphere, which it resembles in many respects.

The species may be divided into two sections, according as the tail is produced to the hinder margin of the interfemoral membrane or perforates it and appears upon its upper surface. Those included in the first section fall into three genera, *Lonchorhina*, *Macrotus*, and *Macrophyllum*, the first-named including a very remarkable species, *L. aurita*, with an extraordinary long nose-leaf and peculiarly large ears and tragi. In the second section are included the genera *Vampyrus*, *Lophostoma*, *Schizostoma*, *Trachyops*, *Phylloderma*, *Phyllostoma*, *Tylostoma*, *Mimon*, *Carollia*, and *Rhinophylla*, all, with the exception of the last, distinguished from one another chiefly by the form of the skull and the presence or absence of the second lower premolar; *Trachyops*, *Phylloderma*, and the three last-named genera are each represented by a single species. *Phyllostoma hastatum*, forearm 3·2 inches, next in point of size to *Vampyrus spectrum*, is a well-known species in South America; *Ph. elongatum* (see fig. 86) differs in its smaller size and much larger nose-leaf. *Carollia brevicauda*, a small species, is generally found represented in collections, and externally so closely resembles *Glossophaga soricina* (of the next group) that it has often been confounded with that species. It forms a connecting link between this group and the next. *Rhinophylla pumilio*, forearm 1·25 inches, tail none, is the smallest known species of the family; it is further distinguished by the narrowness of its molars, which do not form W-shaped cusps, and by the very small size of the last upper molar, characters connecting it, and consequently the group, with the *Stenodermata*.

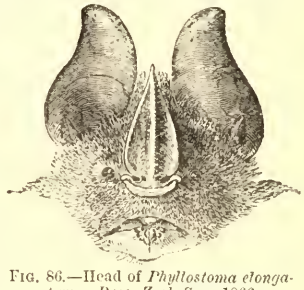

FIG. 86.—Head of *Phyllostoma elongatum*. *Proc. Zool. Soc.*, 1866.

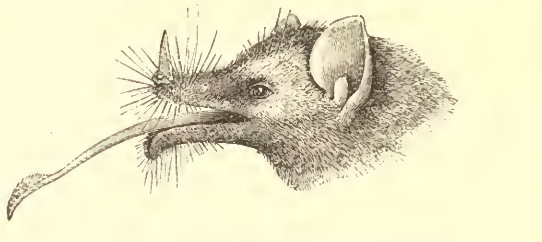

FIG. 87.—Head of *Chœronycteris mexicana*, showing fibrillated tongue. Dobson, *Cat. Chiropt. Brit. Mus.*

Group II. *Glossophagæ.*—Muzzle long and narrow; tongue remarkably long and extensible, much attenuated towards the tip, and beset with very long filiform recurved papillæ; lower lip with a wide groove above, and in front margined by small warts; nose-leaf small; tail short or none; *i* $\frac{2}{2}$, *pm* $\frac{2}{3}$ or $\frac{3}{3}$ or $\frac{2}{2}$, *m* $\frac{3}{3}$ or $\frac{2}{3}$ or $\frac{2}{2}$; teeth very narrow; molars with narrow W-shaped cusps, sometimes indistinct or absent; lower incisors very small or deciduous.

The ten species included in this group represent seven genera, which are distinguished principally by differences in the form and number of the teeth, and by the presence or absence of the zygomatic arches. The form and position of the upper incisors are extremely variable. In *Glossophaga* and *Phyllonycteris* the upper incisors form, as in the *Vampyri*, a continuous row between the canines; in *Monophylla* and *Ischnoglossa* they are separated into pairs by a narrow interval in front; while in *Lonchoglossa*, *Glossonycteris*, and *Chœronycteris* they are widely separated and placed in pairs near the canines; in the first four genera the lower incisors are present (at least up to a certain age), in the last three they are deciduous even in youth. The zygomatic arch is wanting in *Phyllonycteris*, *Glossonycteris*, and *Chœronycteris*.

The typical species is *Glossophaga soricina*, which so closely resembles *Carollia brevicauda*, both in external form and dentition, that it has frequently been confounded with it. Its long fibrillated tongue (which it possesses in common with other species of the group) led Spix to describe it as a very cruel blood-sucker (*sanguisuga crudelissima*), believing that it was used to increase the flow of blood. This view is, however, altogether without foundation, and from the observations of Osburn and others it is evident that the peculiarly shaped tongue is used by the animal, as in the case of the *Macroglossi* among the frugivorous *Pteropodidæ*, to lick out the pulpy contents of fruits having hard rinds. The food of the species of this group appears to consist of both fruit and insects, and the long tongue may also be used for extracting the latter from the deep corollæ of certain flowers.

Group III. *Stenodermata.*—Muzzle very short and generally broad in front, the distance between the eyes nearly always exceeding (rarely equal to) the distance from the eye to the extremity of the muzzle; nose-leaf short, horse-shoe-shaped in front, lanceolate behind (except in *Brachyphylla* and *Centurio*); interfemoral membrane always concave behind; tail none; inner margin of the lips fringed with conical papillæ; *i* $\frac{2}{2}$ or $\frac{2}{1}$, *pm* $\frac{2}{2}$, *m* $\frac{3}{3}$ or $\frac{2}{3}$ or $\frac{2}{2}$; premolars and molars very broad (except in *Sturnira*), the latter with concave or flat crowns margined externally by raised cutting edges.

Although the *Stenodermata* are generally easily distinguished from the *Vampyri* by the peculiar shortness and breadth of the muzzle, and by the form of the molar teeth, certain species of the latter group closely resemble those of the former in external appearance, agreeing almost absolutely in the form of the nose-leaf, of the ears and tragus, and of the warts on the chin. These resemblances show that, while the form of the teeth and jaws has become modified to suit the food of the animals, the external characters, being but slightly affected by this cause, have remained much the same, and now indicate their common origin. The food of these Bats appears to be wholly or in great part tree fruit. The twenty species have been divided into nine genera, distinguished by the form of the skull and teeth. *Artibeus*, with five, includes among them the well-known frugivorous Bat, *A. perspicillatus* of Linnæus, so common in collections. *Stenoderma achradophilum*, found in Jamaica and Cuba, associated with the above, and scarcely distinguishable externally except by its very much smaller size, differs altogether in the absence of the horizontal plate of the palate bones. *Sturnira lilium*, while agreeing with the above in the form of the nose-leaf and ears, differs from all the species of the family in its longitudinally-grooved molars, which resemble those of the frugivorous *Pteropodidæ* more closely than those of any other Bats; and the presence of tufts of long differently-coloured hairs over glands in the sides of the neck shows yet another character in common still more remarkable, which can scarcely be considered, like the teeth, the result of adaptive change. *Centurio senex* is the type of a genus distinguished from *Stenoderma* and other genera of this group by the absence of a distinct nose-leaf. This most remarkable form stands alone among the species of *Chiroptera*, and, indeed, in its peculiar and grotesque physiognomy is unrivalled among known mammals.

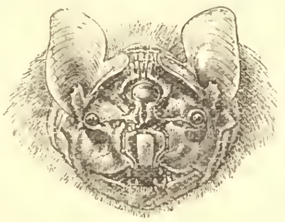

FIG. 88.—Head of *Centurio senex*. Dobson, *Cat. Chiropt. Brit. Mus.*

Group IV. *Desmodontes.*—Muzzle short and conical; nose-leaf distinct; interfemoral membrane very short; tail none; *i* $\frac{1}{2}$, *pm* $\frac{2}{3}$, *m* $\frac{1}{1}$ or $\frac{0}{0}$; upper incisors very large, trenchant, occupying the whole space between the canines; premolars very narrow, with sharp-edged longitudinal crowns; molars rudimentary or none; stomach greatly elongated, intestiniform.

There are two genera, *Desmodus*, without calcaneum or true molars, and *Diphylla*, with a short calcaneum and with a single rudimentary molar on each side,—restricted to Central and South America. *Desmodus rufus*, the commoner species, is a little larger than the Noctule Bat of Europe, and abundant in certain parts of South America, where it is very troublesome owing to its attacks upon domestic animals, sucking their blood and often leaving them much weakened from repeated bleedings. See VAMPIRE.

FOSSIL CHIROPTERA.

Fossil remains of *Chiroptera* extend as far back as the Upper Eocene of Europe and America, if, indeed, the beds in which they have been found are rightly considered as belonging to that age. Of these *Vesperugo* (*Nyctitherium*) *parisiensis*, described by Cuvier from the gypsum of Montmartre, is very like a small specimen of the widely distributed *V. serotinus*; *V. velox* and *priscus* of the same subsection, and *Nyctilestes serotinus*, have been characterized by Marsh from the Eocene of the United States, and *Vespertilio morloti*, Pictet, from that of Switzerland. From the Quercy lacustrine deposits comes *Rhinolophus antiquus*, Filhol, but these are very doubtfully of Eocene age. *Palæonycteris* (allied to *Rhinolophus*), with *P. robustus*, *Vesperugo*, with *V. noctuloides* and *murinoides*, and *Vespertilio*, with *V. aquensis*, *præcox*, and *insignis*, have been found in Miocene beds of France and Germany. Pliocene bone caves have also yielded remains, in all cases closely allied to species now inhabiting the same countries. All these forms, however, exhibit as much specialization in their general structure as any existing species of the same families, indicating (if the age assigned to the deposits can be trusted) that the first appearance of *Chiroptera* must be referred to a very remote period.

Bibliography of Chiroptera.—G. E. Dobson. *Catalogue of the Chiroptera in the Collection of the British Museum*, 1878, including descriptions of all the species of Bats then known; subsequent papers by the same author in *Rep. Brit. Assoc. Adv. Science, Proc. Zool. Soc.*, *Ann. Mag. Nat. Hist.*, and *Bullet. Soc. Zool. de France*, by Peters in *Monatsb. Akad. Wissensch. Berlin*, and by Oldfield Thomas and J. Scully in *Ann. Mag. Nat. Hist.*; H. A. Robin, *Recherches Anatomiques sur les Mammifères de l'Ordre des Chiroptères*, Paris, 1881.

ORDER RODENTIA.

Terrestrial, rarely arboreal or natatorial, diphyodont placental mammals of small size; with plantigrade or semiplantigrade, generally pentadactyle, unguiculate, rarely subungulate, feet; with clavicles (sometimes imperfect or rudimentary); with never more than two incisors in the mandible, and without canines.

The upper incisors resemble the lower in growing uninterruptedly from persistent pulps, and (except in *Lagomorpha*) agree with them in number; the premolars and molars are rooted or rootless, with tuberculated or laminated crowns, and arranged in an unbroken series; the orbits are not circumscribed by bone; the mandibular condyle is antero-posteriorly elongated; the intestine (except in *Myoxidæ*) has a large cæcum; the testes are inguinal or abdominal; the uterus is two-horned, the cornua opening separately into the vagina or uniting to form a corpus uteri; the placenta is discoidal and deciduate; and the smooth cerebral hemispheres do not extend backwards so as to cover any part of the cerebellum.

The Rodents form a very compact order, readily distinguished by their large chisel-shaped incisors, and by the absence of canines. They include by far the greatest number of species (over 900), and have the widest distribution, of any of the orders of terrestrial mammals, being in fact cosmopolitan, although more abundant in some parts, as in South America, which may be considered their headquarters, than in others, as in Australasia and Madagascar, where representatives of a few genera of one family (*Muridæ*) only are found, thus contrasting remarkably with the *Insectivora*, which constitute at least half the mammalian fauna of Madagascar, but are without living representatives in South America.

If, as we have seen, the term entomophagous is applicable to most *Insectivora*, much more so, on the other hand, may the species of this great order be defined as phytophagous, and this uniformity in their food and in the mode of obtaining it, namely, by gnawing, has evidently led to such corresponding general uniformity in structure, which is observable throughout the species, that with difficulty we obtain characters sufficiently salient for dividing them into genera and families. Although, like the *Insectivora*, they present much diversity of habit,—some being arboreal, as the Squirrels, many species of which are provided with cutaneous parachutes on which they glide from tree to tree; some cursorial, as the Hares; some agile jumpers, as the Jerboas; some fossorial, as the great Mole-Rats; and some natatorial, as the Beavers and Water-Rats,—yet we do not find corresponding structural modifications comparable with those noticed in that order.

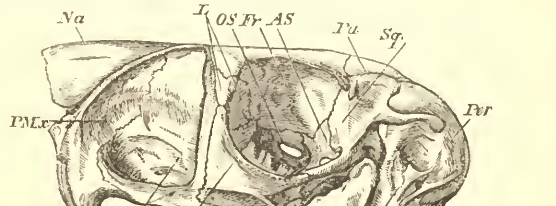

FIG. 89.—Side View of Skull of Cape Jumping Hare (*Pedetes caffer*). $\times \frac{2}{3}$. *PMx*, premaxilla; *Mx*, maxilla; *Ma*, malar; *Fr*, frontal; *L*, lachrymal; *Pa*, parietal; *Na*, nasal; *Sq*, squamosal; *Ty*, tympanic; *ExO*, exoccipital; *AS*, alisphenoid; *OS*, orbito-sphenoid; *Per*, mastoid bulla. Flower, *Osteol. Mammal.*

The Rodent skull is characterized by the great size of the premaxillary bones, which completely separate the nasals from the maxillaries, by the invariable presence of zygomatic arches, and by the wide unoccupied space existing between the alveoli of the incisors and the molar teeth, and (except in *Lagomorpha*) by the antero-posteriorly elongated glenoid cavity. Post-orbital processes of the frontals exist only in the Squirrels, Marmots, and Hares; in all other genera they are rudimentary or altogether absent; the zygoma never sends upwards a corresponding process, and the orbit in all is freely continuous with the temporal fossa; the lachrymal foramen is always within the orbital margin; in many species the infra-orbital foramen is very large (in some as large as the orbit), and

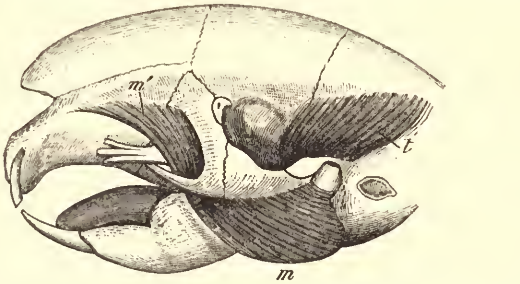

FIG. 90.—Skull of *Hystrix cristata* (juv.). *t*, temp ral muscle; *m*, masseter, *m′*, portion of masseter transmitted through the infra-orbital foramen, the superior maxillary nerve passing outwards between it and the maxillary bone.

transmits part of the masseter muscle; the zygomatic arch is variously developed, and the position of the malar in it is used as a distinguishing character for grouping the families; the nasals are, with few exceptions, large, and extend far forwards; the parietals are moderate, and there is generally a distinct interparietal; the palate is narrow from before backwards,—this is especially pronounced in the Hares, where it is reduced to a mere bridge between the premolars,—in others, as in the great Rodent Moles (*Bathyerginæ*), it is extremely narrow transversely, its width being less than that of one of the molar teeth; tympanic bullæ osseæ are always present and generally large; in some genera, as in the Gerbilles (*Gerbillinæ*) and Jerboas (*Dipodinæ*), there are supplemental mastoid bullæ which form great hemispherical bony swellings at the back of the skull (see fig. 89, *Per*); in these genera, and in the true Hares, the meatus auditorius is tubular and directed upwards and backwards. The mandible is characterized by its abruptly narrowed and rounded symphysial part supporting the pair of large incisors, as well as by the small size of the coronoid process and great development of the angular portion.

The dental formula varies from $i\,\frac{2}{1}$, $c\,\frac{0}{0}$, $pm\,\frac{3}{2}$, $m\,\frac{3}{3}$ (total 28) in the Hares and Rabbits to $i\,\frac{1}{1}$, $c\,\frac{0}{0}$, $pm\,\frac{0}{0}$, $m\,\frac{2}{2}$ (total 12) in the Australian Water-Rats; but in the vast majority of the species it presents striking uniformity, and may be set down typically as $i\,\frac{1}{1}$, $c\,\frac{0}{0}$, $pm\,\frac{1}{1}$ or $\frac{0}{0}$, $m\,\frac{3}{3}$. In *Lagomorpha* only are there more than a single pair of incisors, and in them the additional pair are small and placed quite behind the middle pair,[1] and in this group alone does the enamel extend even partially to the back of the tooth; in all others it is restricted to its front surface, and so, by the faster wearing away of the softer structures behind, a chisel-shaped edge is always maintained. Both the upper and lower incisors are regularly curved, the upper slightly more so than the lower, and, their growth being continuous, should anything prevent the normal attrition by which their length is regulated, as by the loss of one of them, or by displacement owing to a broken jaw or other cause, the unopposed unused incisor may gradually curve upon itself until a complete circle or more has been formed, the tooth, perhaps, passing during its growth through some part of the animal's head. The molar teeth may be rooted or

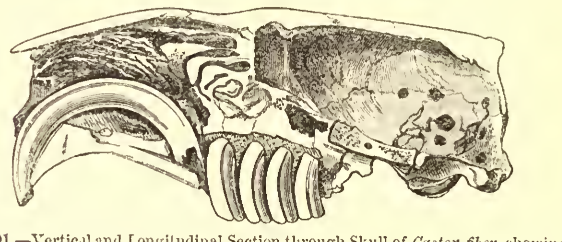

FIG. 91.—Vertical and Longitudinal Section through Skull of *Castor fiber*, showing the cerebral cavity, the greatly-developed turbinal lamellæ, the mode of implantation of the large ever-growing chisel-edged incisor, and the curved rootless molars.

rootless, tuberculated or laminated; and this diversity of structure may be noticed even in the same family. When there are more than three back teeth those which precede the last three have succeeded milk teeth, and must therefore be considered premolars. In some species, as in the Agoutis (*Dasyproctidæ*), the milk teeth are long retained, while in the allied Cavies (*Caviidæ*) they are shed before birth.

There are generally nineteen dorso-lumbar vertebræ (13 thoracic and 6 lumbar), and their forms vary in the different genera; in the cursorial and leaping species the lumbar transverse processes are generally very long, and in the Hares there are large compressed hypapophyses. The caudal vertebræ exhibit as much variety as in *Insectivora*, from their rudimentary condition in the Guinea-Pig to their great size in the Jumping Hares and prehensile-tailed Porcupines. The scapula is usually narrow, with a long acromion; the clavicles may be altogether absent or imperfect, as in the Porcupines, Cavies, and Hares, but in most species they are well developed; the humerus has no supra-condylar foramen, and the forearm bones are distinct; in most species the manus has five digits with phalanges normally developed, the pollex rarely rudimentary or absent. In contrast to the normal condition of the pelvis in *Insectivora*, we find here largely developed ischiatic and pubic bones, with a long usually osseous symphysis; the femur varies considerably in form, and there is generally a well-defined third trochanter; in the Sciurine and Hystricine Rodents the tibia and fibula are distinct, but in the Rats and other Murines, and in the Hares, these bones are united, often high up; the pes is much more variable than the manus, the digits varying in number from five, as in the Squirrels and Rats, to four, as in the Hares, or even three, as in the Capybara, Viscacha, and Agouti; in the *Dipodidæ* the metatarsals are greatly elongated, and in some of the species, as in the Jerboas, they are ankylosed together.

The mouth is divided into two cavities communicating by a constricted orifice, an anterior containing the large incisors and a posterior in which the molars are placed, the hairy integument of the face being continued inwards behind the incisors. This evidently prevents substances not intended for food getting into the mouth, as when the animal is engaged in gnawing through an obstacle. In the Hares and Pacas the inside of the cheeks is hairy, and in some species, as in the Pouched Rats and Hamsters, there are large internal cheek pouches lined with the hairy integument, which open near the angles of the mouth and extend backwards behind the ears; in the New-World Pouched Rats (*Geomyidæ*) the pouches open externally on the cheeks.

[1] Professor Huxley remarks (*Proc. Zool. Soc.*, 1880, p. 655):—"The deciduous molars and the posterior deciduous upper incisors of the Rabbit have long been known. But I have recently found that unborn Rabbits possess, in addition, two anterior upper and two lower deciduous incisors. Both are simple conical teeth, the sacs of which are merely embedded in the gum. The upper is not more than one-hundredth of an inch long, the lower rather larger."

The tongue presents little of that variability in length observable in the preceding orders; it is characteristically short and compressed, with an obtuse apex never protruded beyond the incisors; in most species there are, as in *Insectivora*, three papillæ circumvallatæ at the base; and the apical portion is generally covered with small filiform papillæ, some of which in the Porcupines (*Hystrix*) become greatly enlarged, forming toothed spines. The stomach varies in form from the simple oval sac of the Squirrel to the complex ruminant-like organ of the Lemming. In the Water-Vole (*Arvicola amphibius*) and in the Agouti (*Dasyprocta agouti*) it is strongly constricted between the œsophagus and pylorus; in the common Dormouse the œsophagus immediately before entering the stomach is much dilated, forming a large egg-shaped sac with thickened glandular walls, and in some other species, as in *Lophiomys imhausi* and in the Beaver, glandular masses are attached to and open into the cardiac or pyloric pouches. All Rodents, with the exception only of the species of Dormice (*Myoxidæ*), have a cæcum, often of great length and sacculated, as in the Hares, Water-Voles, and Porcupines, and the long colon is in some, as in the Hamster and Water-Vole, spirally twisted upon itself near its commencement. The liver is typically divided in all, but the lobes are variously subdivided in the different species (in *Capromys* they are divided into minute lobules); and the gall-bladder, though present in most, is absent in a few. In most species, as in many *Insectivora*, the penis (which is generally provided with a bone) may be more or less completely retracted within the fold of integument surrounding the anus, and lie curved backwards upon itself under cover of the integument, or it may be carried forward some distance in front of the anal orifice, from which in the breeding season, as in the Voles and Marmots, the prominent testicular mass separates it. The testes in the rut form projections in the groins, but (except in *Lagomorpha*) do not completely leave the cavity of the abdomen. Prostatic glands and, except in *Lagomorpha*, vesiculæ seminales are present in all. The uterus may be double, each division opening by a separate os uteri into a common vagina, as in *Leporidæ*, *Sciuridæ*, and *Hydrochœrus*, or two-horned, as in most species. The mammary teats vary in number from the single abdominal pair of the Guinea-Pig to the six thoracico-abdominal pairs in the Rats. In the *Octodontidæ* the teats are placed high up on the sides of the body.

The peculiar odour evolved by many Rodents is due, as in the *Insectivora*, to the secretions of special glands, which may open into the prepuce, as in *Mus*, *Arvicola*, *Cricetus*, &c., or into the rectum, as in *Arctomys* and *Aulacodus*, or into the passage common to both, as in the Beaver, or into pouches opening near the anus, as in the Hare, Agouti, and Jerboa.

The integument is generally thin, and the panniculus carnosus rarely much developed. The fur varies exceedingly in character,—in some very fine and soft, as in the Chinchillas and Hares, in others more or less replaced by spines on the upper surface, as in the Spiny Rats and Porcupines; in several genera, as in *Xerus*, *Acomys*, *Platacanthomys*, *Echiothrix*, *Loncheres*, and *Echinomys*, the spines are flattened. In the muscular structures the chief peculiarities are noticeable in the comparatively small size of the temporal muscles, generally so largely developed in *Insectivora*, and in the great double masseters, which are the principal agents in gnawing; the digastrics also are remarkable for their well-defined central tendon, and in many species their anterior bellies are united between the mandibular rami; the cleidomastoid generally arises from the basi-occipital, and the pectoralis major is connected with the latissimus dorsi; in the Porcupines and Hares the tendons of the flexor digitorum longus and flexor hallucis longus are connected in the foot, while in the Rats and Squirrels they are separate, and the flexor digitorum longus is generally inserted into the halluceal metatarsal. (See Dobson, *Journ. Anat. Phys.*, vol. xvii.)

Suborder I. *RODENTIA SIMPLICIDENTATA.*

Rodents with two incisors only in the upper jaw, having their enamel confined to their front surfaces. The incisive foramina are moderate and distinct; the fibula does not articulate with the os calcis; and the testes are abdominal, and descend periodically only into the inguinal canal.

Section I. Sciuromorpha.

Zygomatic arch slender, chiefly formed by the malar, which is not supported by a long maxillary process extending backwards beneath it; post-orbital processes present or absent; infra-orbital

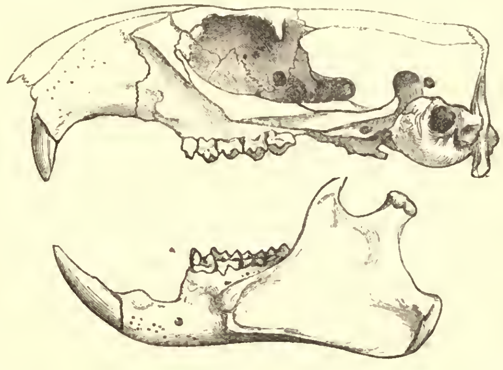

Fig. 92.—Skull of *Arctomys monax*.

opening small (except in *Anomalurus*); mandible with the angular part arising from the inferior surface of the bony socket of the lower incisor; clavicles well-developed; fibula distinct.

Family 1. Anomaluridæ.

Arboreal Rodents, having their limbs connected by a cutaneous expansion supported by a cartilaginous process arising from the olecranon; with a long hairy tail having large scales on its inferior surface near its root; with sixteen pairs of ribs, and without post-orbital processes of the frontals; *pm* $\frac{1}{1}$; molars not tuberculate, with transverse enamel folds. Ethiopian.

Fig. 93.—*Anomalurus fulgens* (reduced). Alston, *Proc. Zool. Soc.*, 1875.

Anomalurus, with (?) five species from West Africa, alone represents the family. The peculiar caudal scales, which evidently assist the animal in climbing, and the position of the cartilaginous support of the parachute, are well shown in the above woodcut (fig. 93).

Family 2. SCIURIDÆ.

Arboreal or terrestrial Rodents, with cylindrical hairy tails, without scales, and with twelve or thirteen pairs of ribs. Skull with distinct post-orbital processes; infra-orbital opening small; palate broad; $pm\ \frac{2}{1}$; first upper premolar very small or deciduous; molars rooted, tubercular.

Subfamily 1. **Sciurinæ.**—Incisors compressed, form slender, tail long and hairy (True Squirrels). Cosmopolitan (excluding Australian region).

There are four genera. *Pteromys*,—limbs united by a cutaneous expansion forming a parachute, the supporting cartilage of which springs from the carpus,—includes the Flying Squirrels of both hemispheres. *Sciurus*, with more than eighty species, comprises the true Tree Squirrels. To this group also belong the Short-eared Squirrels of the genera *Xerus* and *Tamias*; the first-named, distinguished from *Sciurus* by possessing only two pairs of mammary teats, by the comparatively short tail, and by the fur being mixed with flattened spines, includes a few African species which live in burrows; *Tamias*, separated by the presence of large internal cheek-pouches, includes the well-known Ground Squirrels of North America, of which one species (*T. asiaticus*) extends into North Europe and Asia. See SQUIRREL.

Subfamily 2. **Arctomyinæ.**—Incisors not compressed; form stout; tail short (Marmots). Palæarctic and Nearctic.

Spermophilus, distinguished by its large cheek-pouches and by the absence or rudimentary condition of the pollex claw, resembles *Tamias* in the slender form of the body, and connects the Marmots with the true Squirrels. The distribution and habits of the species are similar to those of *Tamias*. *Cynomys*, with shallow cheek-pouches, long pollex claw and stout form, includes the well-known Prairie Dogs peculiar to North America, which live together in large communities, inhabiting burrows which they excavate at short distances apart; they feed on the buffalo-grass which covers the plains. The small burrowing owl (*Athene cunicularia*) and the rattlesnake are often found inhabiting their burrows, the former probably availing itself of the convenience of a ready-made habitation, the latter coming there to feed on the young Marmots. *Arctomys*, distinguished by its rudimentary pollex, includes the true Marmots. See MARMOT.

Family 3. HAPLODONTIDÆ.

Terrestrial Rodents, distinguished from *Sciuridæ* by the absence of post-orbital processes, the depressed form of the skull, and the rootless molars. Premolars $\frac{2}{1}$, the first upper one small.

Haplodon, with *H. rufus*, from North America west of the Rocky Mountains, alone represents the family. The habits of the single species are similar to those of the Prairie Dog.

Family 4. CASTORIDÆ.

Natatorial Rodents, with massive skulls, without post-orbital processes, with mandibular angle rounded, and with semi-rooted or rootless molars with re-entering enamel folds; $pm\ \frac{1}{1}$.

Castor, with one species only, *C. fiber*, the Beaver of the northern parts of Asia, Europe, and America. The upper molars are subequal, each with one internal and two external enamel folds; the stomach has a large glandular mass situated to the right of the œsophageal orifice; the anal and urethro-genital orifices open within a common cloaca; the tail is broad, horizontally flattened, and naked; and the hind feet are webbed. See BEAVER.

Section II. MYOMORPHA.

Zygomatic arch slender, the malar rarely extending far forwards, and usually supported below by the long zygomatic process of the

FIG. 94.—Skull of *Fiber zibethicus*. Natural size.

maxillary; no post-orbital processes; infra-orbital opening variable; mandible with the angular part arising from the inferior surface of the bony socket of the lower incisor (except in *Bathyerginæ*); clavicles well-developed (except in *Lophiomys*); tibia and fibula united.

Family 1. MYOXIDÆ.

Arboreal Rodents, with long hairy tails, large eyes and ears, and short fore limbs. The intestine is without a cæcum; the skull has contracted frontals; the infra-orbital foramen is moderate, high, and narrow; and the mandible has a long and slender coronoid process. $Pm\ \frac{1}{1}$; molars rooted, with transverse enamel plates. Palæarctic and Ethiopian.

There are four genera:—*Myoxus*, with *M. glis* of Europe, with bushy, distichous tail, simple stomach, and large molars with well-marked enamel folds; *Muscardinus*, with *M. avellanarius*, the common Dormouse, distinguished by the cylindrical bushy tail and thickened glandular walls of the cardiac extremity of the œsophagus; *Eliomys*, with about six species, with tufted and distichous tail, simple stomach and smaller molar teeth with concave crowns and faintly marked enamel folds; and *Graphiurus*, with two species, with short cylindrical tail ending in a pencil of hairs, and very small molars almost without trace of enamel folds. The Dormice form a very natural family, distinguished from all other Rodents by the absence of a cæcum. In their habits and form they evidently closely approach the Squirrels.

Family 2. LOPHIOMYIDÆ.

Arboreal Rodents, with rudimentary clavicles and rooted tuberculate molars. Premolars none. Skull murine in form, but the temporal fossæ are completely arched over by thin plates arising from the temporal ridge and malar bone. Intestine with a small cæcum.

FIG. 95.—*Lophiomys imhausi* (reduced). A. Milne-Edwards.

Lophiomys, with *L. imhausi* (fig. 95), alone represents the family. This very extraordinary species from north-east Africa differs from all other Rodents in the peculiar granulated plates which cover the temporal fossæ, and from all the species of the section in the rudimentary condition of the clavicles as well as in the possession of an opposable hallux. The hair is very peculiar in structure, and forms a crest along the back and tail. For full description see A. Milne-Edwards, *L'Institut*, xxxv. p. 46.

Family 3. MURIDÆ.

Rodents of various habit, but generally terrestrial; with contracted frontals, with the lower root of the maxillary zygomatic process more or less flattened into a perpendicular plate; with a short and slender malar, generally reduced to a splint between the maxillary and squamosal processes; with (in typical forms) a high, perpendicular infra-orbital foramen, wide above and narrow below; with compressed lower incisors and rooted or rootless molars, tuberculate or with angular enamel folds. Premolars none (except in *Sminthinæ*); pollex rudimentary; tail generally sub-naked and scaly.

This large family includes more than one-third of all the species of Rodents, and is represented by thirty-five genera of cosmopolitan distribution. These fall into two sections corresponding to the rooted or rootless condition of the molars.

I. *Molars rooted.*

Subfamily 1. **Sminthinæ.**—$Pm\ \frac{1}{0}$, $m\ \frac{3}{3}$; infra-orbital opening subtriangular, widest below; incisive foramina long.

Sminthus, with one species, *S. vagus*, a Rat-like Rodent inhabiting northern Asia and Europe.

Subfamily 2. **Hydromyinæ.** $M\ \frac{2}{2}$, divided into transverse lobes; infra-orbital opening crescentic, scarcely narrowed above; incisive foramina very small.

Hydromys, with two species from Australia, Tasmania, and New Guinea, includes the Water-Rats of the Australian region, with partially webbed toes. They are distinguished from all other Rodents by the small number of their molars.

Subfamily 3. **Platacanthomyinæ.**—*M* $\frac{3}{3}$, with transverse laminæ; fur mixed with flattened spines; tail densely hairy.

Platacanthomys, with *P. lasiurus*, a small Dormouse-like species from western India, inhabiting the rocky mountains of Travancore.

Subfamily 4. **Gerbillinæ.**—Incisors narrow, molars with transverse laminæ; auditory bullæ osseæ usually large; hind limbs elongated; tail generally long and hairy. Palæarctic, Indian, and Ethiopian.

Gerbillus, with nearly fifty species, has a range coextensive with that of the subfamily. *Pachyuromys* is distinguished by the enormous size of the auditory bullæ, as well as by the short fleshy club-shaped tail. *Mystromys*, *Otomys*, and *Dasymys* differ in the form of the molars, and are represented by a few species, all from South Africa.

Subfamily 5. **Phlæomyinæ.**—Incisors broad, molars with transverse laminæ; claws large. Indian.

Phlæomys, with *P. cumingii* from the Philippines, and *Nesokia*, with eight species widely distributed throughout the Indian Region. The latter (distinguished from the former genus by the short, subnaked, scaly tail) includes the Great Bandicoot Rat of India (*N. bandicota*).

Subfamily 6. **Dendromyinæ.**—Incisors convex in front, molars tuberculate; ears hairy; claws long. Ethiopian.

Three genera, *Dendromys*, *Steatomys*, and *Lophuromys*, include several species of small Mouse-like Rodents with the habits of Dormice generally, though some burrow in corn-fields.

Subfamily 7. **Cricetinæ.**—Molars tuberculate. Large internal cheek-pouches. Palæarctic and Ethiopian.

Of the three genera, *Cricetus*, *Saccostomus*, and *Cricetomys*, the last is distinguished from the others by the grooved upper incisors, while *Saccostomus* is separated from *Cricetus* by the tubercles of the molar teeth being arranged in threes. The cheek pouches in *Cricetus* are very large, and their walls are connected with muscles arising from the lumbar vertebræ. The best-known species is *C. frumentarius*. See HAMSTER.

Subfamily 8. **Murinæ.**—Molars tuberculate, at least in youth. Cheek-pouches absent. Tail scaly, more or less naked. Cosmopolitan.

This includes the typical murine forms, divided into fifteen genera with over three hundred species, of which nearly half, however, are contained in the genus *Mus*. *M. decumanus*, the common Grey Rat, and *M. musculus* (see MOUSE) are familiar examples which have been introduced in ships into almost every part of the habitable world. In *Acomys* the skull and teeth are as in *Mus*, but the fur is mixed with sharp flattened spines. *A. dimidiatus* presents the appearance of a little Hedgehog when its spines are erected; it inhabits the stony deserts of Arabia Petræa and Palestine, and feeds on bulbs. *Echiothrix*, *Uromys*, and *Hapalotis*, the latter with about a dozen species, are limited to the Australian region. *Brachytarsomys*, *Nesomys*, *Hallomys*, and *Hypogeomys*, each with one or two species, are peculiar to Madagascar, where they alone represent the order. *Drymomys*, *Holochcilus*, *Ochetodon*, and *Hesperomys* are New-World genera, the last-named including many species representing the Old-World Mice, but distinguished by the indenting enamel folds of the molars. Of the remaining genera, *Reithrodon*, with grooved incisors, includes two very remarkable Rabbit-like species, one inhabiting Patagonia, the other Tierra del Fuego.

II. *Molars Semi-Rooted or Rootless.*

Subfamily 9. **Arvicolinæ.**—Molars composed of triangular prisms placed alternately; limbs moderate; tail moderate or short, hairy. Palæarctic and Nearctic.

Arvicola, with over thirty species, includes the Voles, of which the Field-Vole (*A. agrestis*) and the Water-Vole (*A. amphibius*) are well-known examples (see VOLE). *Myodes*, distinguished by the hairy foot-sole, includes two species, of which *M. lemmus*, of the Scandinavian Peninsula, is remarkable for its extraordinary migrations (see LEMMING). *Fiber* is represented by a single large species, *F. zibethicus* (see fig. 94), the Musk-Rat, or Musquash, a Beaver-like Water-Rat with webbed toes, but a laterally flattened tail, inhabiting the banks of rivers and lakes in North America, and constructing dome-roofed dwellings like those of the Beaver; it is much hunted for its fur.

Subfamily 10. **Siphneinæ.**—Molars as in *Arvicolinæ*; form cylindrical; ear-conch rudimentary; limbs and tail very short. Palæarctic.

Ellobius, with short claws, connects the species of this subfamily of fossorial Mole-like Rodents with the *Arvicolinæ*. *Siphneus*, on the other hand, leads to the next family, which includes the true Mole-Rats; the species, which chiefly inhabit northern Asia, closely resemble the Golden Moles (*Chrysochloris*) in general form and in the great development of the claws of the fore feet (compare fig. 96 with fig. 64, p. 405).

Family 4. SPALACIDÆ.

Rodent Moles, with very small or rudimentary eyes and ear-conchs, large claws, and short or rudimentary tail. Form cylindrical. Incisors large; molars rooted, with re-entering enamel folds; palate narrow.

Subfamily 1. **Spalacinæ.**—Angular part of the mandible arising from the lower edge of the socket of the lower incisor. Palæarctic, Indian, and Ethiopian.

Spalax, with *S. typhlus* of south-east Europe, agrees with the insectivorous Golden Moles in the complete external absence of the eye, which is covered by the hairy skin, showing similar adaptive modification in widely removed species. In *Rhizomys*, including several species from China, Tibet, Malay Peninsula, and eastern Africa, the eye is very small.

FIG. 96.—*Siphneus armandii* (reduced). A. Milne-Edwards, *Mammif. Tibet.*

Subfamily 2. **Bathyerginæ.**—Angular part of the mandible arising from the side of the socket of the lower incisor. Ethiopian.

Bathyergus, with *B. maritimus*, the Great Rodent-Mole, inhabiting the sand-dunes along the coast in the vicinity of the Cape of Good Hope, is distinguished chiefly by its grooved incisors from the other species included in the genera *Georychus* and *Heliophobius*, the former with several, the latter with one species, and differing from both in the presence of two or three premolars.

Family 5. GEOMYIDÆ.

Terrestrial or fossorial Rodents, with large cheek-pouches opening on the cheeks outside the mouth. The squamosal bones are much expanded, and the malars extend forwards to the lachrymals. *Pm* $\frac{1}{1}$; molars rooted or rootless. Nearctic and Neotropical.

Subfamily 1. **Geomyinæ.**—Incisors broad; mastoid not appearing on the top of the skull; eyes small; ear-conch rudimentary; limbs short, subequal. Fossorial.

Geomys bursarius, the common Pouched Rat of North America, with deeply-grooved incisors, inhabits the plains of the Mississippi, living in burrows like the Mole. Four other species from the Southern States, Mexico, and Central America are recognized. *Thomomys talpoides*, with plain incisors, extends all over Canada and North America west of the Rocky Mountains.

Subfamily 2. **Heteromyinæ.**—Incisors narrow; mastoid appearing largely on the top of the skull; eyes and ears moderate or large; hind limbs and tail elongated. Terrestrial.

Dipodomys has the molars rootless; *D. phillipsi* is the Kangaroo-Rat of the desert regions east of the Rocky Mountains. *Perognathus* and *Heteromys* have rooted molars; the latter genus is distinguished by the presence of flattened spines among the fur, with species extending into South America.

Family 6. DIPODIDÆ.

Terrestrial leaping Rodents, of slender form, with elongated hind limbs. The incisors are compressed, the molars have transverse enamel folds, the infra-orbital opening is rounded and very large, the malar ascends in front to the lachrymal in a flattened perpendicular plate (see fig. 89, p. 415), and the mastoid part of the auditory bulla is usually greatly developed.

Subfamily 1. **Zapodinæ.**—Molars rooted; cervical vertebræ free; metatarsals separate; hind feet with five digits. Nearctic.

Zapus hudsonius, the American Jumping-Mouse, extends over almost the whole North-American continent from Labrador to Mexico.

Subfamily 2. **Dipodinæ.**—Molars rooted; cervical vertebræ more or less ankylosed; metatarsals united; hind feet with three functional digits only. Palæarctic and Ethiopian.

This includes the true Jerboas. It contains three genera: *Dipus* with three toes, and *Alactaga* and *Platycercomys* with five, the last-named distinguished by the total absence of premolars, comprising many species extending from Siberia to Nubia.

Subfamily 3. **Pedetinæ.**—Molars rootless; cervical vertebræ free; metatarsals separate; hind feet with four digits. Ethiopian.

Pedetes caffer, the Cape Jumping Hare, by far the largest species of the family, extends from Mozambique and Angola to the Cape of Good Hope. See JERBOA.

Section III. HYSTRICOMORPHA.

Zygomatic arch stout; malar not supported below by a continuation of the maxillary zygomatic process; infra-orbital opening large;

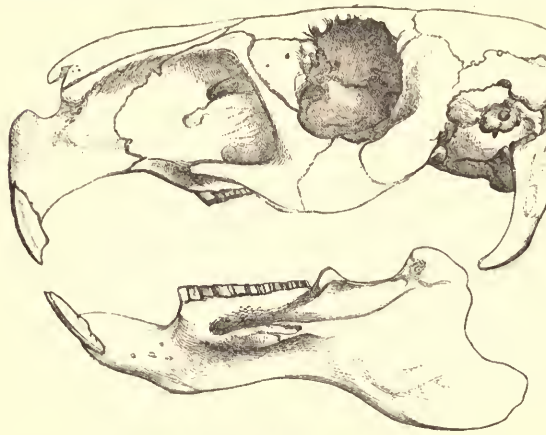

FIG. 97.—Skull of *Hydrochœrus capybara* (reduced).

mandible with the angular part arising from the outer side of the bony socket of the lower incisor; clavicles perfect or imperfect; fibula distinct.

Family 1. OCTODONTIDÆ.

Terrestrial, rarely fossorial or natatorial Rodents, with perfect clavicles and long incisive foramina extending into the maxillaries. Malar with an inferior angle; molars with external and internal enamel folds; mammary teats placed high on the sides of the body.

Subfamily 1. **Ctenodactylinæ.**—Molars semi-rooted; malar as in *Dipodidæ*; the two inner toes of the hind feet with a horny comb and rigid bristles. Ethiopian.

Ctenodactylus gundi and *Pectinator spekei*, both from North Africa, alone represent the subfamily; the peculiar comb-like inner toes are used in dressing the soft fur.

Subfamily 2. **Octodontinæ.**—Molars semi-rooted or rootless, with simple enamel folds; fur soft. Ethiopian and Neotropical.

There are six genera, including several species of Rat-like Rodents. *Octodon cumingii*, common in Chili and Peru, about the size of a Rat, lives like Rabbits in large communities. *Petromys typicus* is the only African representative.

Subfamily 3. **Echiomyinæ.** Molars semi-rooted or rooted, with deep, curved enamel folds; fur more or less harsh, often mixed with spines. Neotropical and Ethiopian.

Aulacodus, with *A. swinderianus*, the Ground-Rat of western Africa; the remaining nine genera are all Neotropical. Of these *Myopotamus* includes *M. coypu*, about 2 feet in length, the largest species of the family, common in South America, living in burrows near water, and feeding on aquatic plants. *Capromys pilorides*, nearly as large, is arboreal in habits, and inhabits Cuba and Hayti, where it is the largest indigenous mammal; the species of this genus are remarkable for the manner in which the liver is divided into minute lobules. *Plagiodontia ædium* is peculiar to Hayti and Jamaica, and in the latter island (besides Bats and Mice, the latter probably introduced) appears to be the only indigenous mammal. In *Loncheres* and *Echinomys* most of the species have the fur mixed with flattened lanceolate spines.

Family 2. HYSTRICIDÆ.

Terrestrial or arboreal Rodents, of stout form, with subequal limbs and more or less spiny integument. Malar without an inferior angle; the facial part of the skull short and broad; molars with external and internal enamel folds.

Subfamily 1. **Spingurinæ.**—Molars rooted; clavicles perfect; soles of feet tuberculated; teats four; tail generally prehensile. Arboreal. Nearctic and Neotropical.

There are three genera, including several species. Of these *Erethizon dorsatus*, the Urson, is distributed all over the forest regions of North America; *Synetheres* (=*Cercolabes*) *prehensilis*, the well-known prehensile-tailed Porcupine of South America (fig. 98), has the whole upper surface of the body protected by long white-tipped spines; *Chætomys subspinosus* is clothed with strong wavy bristles; in the last two genera the feet have four digits only.

Subfamily 2. **Hystricinæ.**—Molars semi-rooted; clavicles imperfect; soles of feet smooth; teats six; tail not prehensile. Terrestrial. Palæarctic, Indian, and Ethiopian.

Hystrix cristata, the Common Porcupine of southern Europe and northern Africa, is typical of this genus, which includes several other

FIG. 98.—*Synetheres prehensilis.*

species from the Indian region. The spines are cylindrical, the tail short and covered with spines and slender stalked open quills. In *Atherura fasciculata* of the Malay Peninsula the spines are flattened, and the tail is long and scaly, with a tuft of compressed bristles. A closely allied species, *A. africana*, inhabits western Africa. See PORCUPINE.

Family 3. CHINCHILLIDÆ.

Terrestrial Rodents, with elongated hind limbs, bushy tails, very soft fur, and perfect clavicles. The malar is without an inferior angle, and extends forwards to the lacrymal; the palate is contracted in front and deeply emarginate behind; the incisors are short, and the molars divided by continuous folds into transverse laminæ. Neotropical.

This small family includes only three species, divided into as many genera. *Chinchilla lanigera* and *Lagidium peruanum* are restricted to the alpine zones of the Andes from the northern boundary of Peru to the southern parts of Chili, and *Lagostomus trichodactylus*, the Viscacha, to the pampas from the Uruguay river to the Rio Negro. In *Chinchilla* the fore feet have five and the hind four digits, the tail is long and bushy, and the auditory bullæ are enormous, appearing on the top of the skull; *Lagidium* has four digits in both fore and hind feet, and *Lagostomus* three only in the hind feet, while the auditory bullæ are much smaller. See CHINCHILLA.

Family 4. DASYPROCTIDÆ.

Terrestrial Rodents, with subequal limbs, hoof-like claws, short or obsolete tail, and rudimentary clavicles. Mandibular masseteric ridge obsolete; palate broad; incisors long; molars semi-rooted, with external and internal enamel folds. Neotropical.

With two genera:—*Dasyprocta*, including several species of slender-limbed, subungulate Rodents with three hind toes, inhabiting Central and South America, one (*D. cristata*) extending into the West-Indian Islands; and *Cœlogenys*, with five hind toes, remarkable for the extraordinary development of its zygomatic arches, which are enormously expanded vertically, forming great convex bony capsules on the sides of the face, enclosing on each side a large cavity lined with mucous membrane internally, and communicating by a small opening with the mouth; *C. paca* is about 2 feet long, and, like the species of *Dasyprocta*, lives generally in the forests or along the banks of rivers.

Family 5. DINOMYIDÆ.

Terrestrial Rodents, distinguished from *Dasyproctidæ* by the cleft upper lip and rather long and bushy tail, and by the presence of four digits in the fore and hind feet. The manubrium is broad; the optic foramina are confluent, the incisors broad and the molars rootless, with folds dividing them into transverse lobes.

This family includes but a single species, *Dinomys branickii*, known only from a single specimen obtained in Peru, which resembles *Cœlogenys paca* in the general form of its body and in size. It is regarded by its describer, Professor Peters, as a connecting link between the families *Octodontidæ*, *Chinchillidæ*, *Dasyproctidæ*, and *Caviidæ*.

Family 6. CAVIIDÆ.

Terrestrial or natatorial Rodents, with short incisors, strong mandibular masseteric ridges, long and curved paroccipitals, and palate contracted in front. Fore feet with four digits, hind feet with three; clavicles imperfect; molars divided by enamel folds into transverse lobes; milk teeth shed before birth. Other characters as in *Dasyproctidæ*. Neotropical.

Cavia, limbs and ears short, subequal, tail none, includes several species widely distributed throughout South America, extending even to the Straits of Magellan, from one of which (*C. aperea*, probably) the common Guinea-Pig is derived. *Dolichotis* has the limbs and ears long, tail very short, with *D. patagonica*, a large species, nearly 3 feet long, inhabiting the gravelly plains of Patagonia. The palate is so much contracted in front that the premolars of opposite sides touch by their antero-internal edges. *Hydrochœrus*, with all the feet fully webbed, also includes a single species, which is the largest of living Rodents. The skull (fig. 97) is distinguished, not only by its great size, but also by the enormous development of the paroccipital processes. See CAVY and CAPYBARA.

SUBORDER II. *RODENTIA DUPLICIDENTATA.*

Rodents with four incisors in the upper jaw (two of them very small, and placed directly behind the large middle pair), the enamel of which extends round to their posterior surfaces. At birth there are six of these incisors, but the outer one on each side is soon lost. The incisive foramina are large and usually confluent; the bony palate is very narrow from before backwards; there is no true alisphenoid canal; the fibula is ankylosed to the tibia, and articulates with the os calcis; and the testes are permanently external.

Section IV. LAGOMORPHA.

Characters those of the suborder.

Family 1. LAGOMYIDÆ.

Terrestrial Rodents, with complete clavicles, subequal limbs, no external tail, and short ears. Skull depressed, frontals contracted and without post-orbital processes; *pm* $\frac{1}{1}$ or $\frac{2}{2}$; molars rootless, with transverse enamel folds. Palæarctic and Nearctic.

Lagomys, with about a dozen species of small Guinea-Pig-like animals, inhabiting chiefly the mountainous parts of northern Asia (from 11,000 to 14,000 feet), one species only being known from south-east Europe and one from the Rocky Mountains.

Family 2. LEPORIDÆ.

Terrestrial Rodents, with imperfect clavicles, elongated hind limbs, short recurved tail, and long ears. Skull compressed,

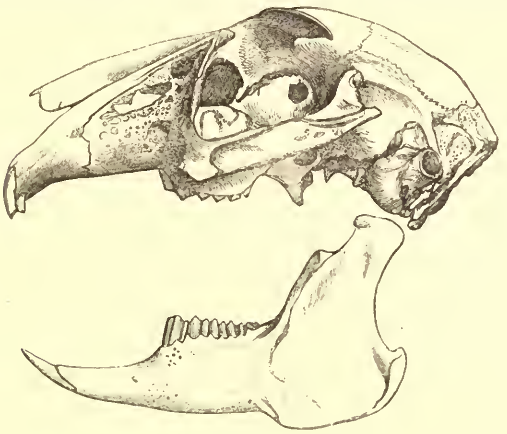

FIG. 99.—Skull of *Lepus timidus*.

frontals with large wing-shaped post-orbital processes (fig. 99); *pm* $\frac{3}{2}$; molars as in *Lagomyidæ*. Cosmopolitan (except Australasia).

Lepus includes about twenty species, which all resemble one another in general external characters. In all the fore limbs have five and the hind only four digits, and the soles of the feet are densely clothed with hairs similar to those covering the legs; the inner surface of the cheeks also is hairy. Although the family has such a wide distribution, the greater number of the species are restricted to the Palæarctic and Nearctic regions, and a single species only (*L. brasiliensis*) extends into South America. See HARE and RABBIT.

FOSSIL RODENTIA.

Fossil representatives of all the above-defined families, with the exception only of the small groups included under *Anomaluridæ*, *Haplodontidæ*, *Lophiomyidæ*, *Spalacidæ*, and *Dinomyidæ*, have been described from various deposits. Of these the earliest have been found in the Upper Eocene of Europe and America, and belong to the family *Sciuridæ*, of which the genera *Colonomys*, *Taxymys*, *Tillomys*, *Paramys*, *Heliscomys*, and *Mysyops* have been characterized from the Eocene of North America, and *Plesiarctomys* from that of both America and France, while examples of even the recent genus *Sciurus* have been found in beds of the same age in the latter country. Other recent families have representatives in later deposits, as *Castoridæ* with *Steneofiber* and *Palæomys* from the Miocene of Europe and North America, *Trogonotherium* from that of India, *Chalicomys* from that of Germany, and *Eucastor* from North America, *Myoxidæ* with *Myoxus* and *Muridæ* with *Elomys*, *Decticus*, *Oreomys*, and *Cricetodon* from the European Miocene, *Hystricidæ* with *Erethizon* extending back to the Miocene of India, *Geomyidæ* with *Entoptychus* and *Pleurolicus* and *Dasyproctidæ* with *Paciculus* from the Miocene of North America, *Lagomyidæ* with *Titanomys* and *Myolagus* from the European Miocene, and *Leporidæ* with *Palæolagus* from corresponding North American beds. Later Tertiary strata have yielded Rodent remains more abundantly; many of them referable to recent genera, or even closely allied to or undistinguishable from existing species, have been described from Brazilian bone-caves.

Besides those referable to existing families, several fossil remains have been discovered which cannot be so classed. These have been included in three families:—*Ischromyidæ* with *Pseudotomus* from the Eocene, and *Ischromys* and *Gymnoptychus* from the Miocene of North America; *Theridomyidæ* with *Theridomys* extending from the Eocene to the Pliocene of France, and *Archæomys*, *Issidioromys*, and *Dipoides* from the Miocene; and *Castoroididæ* with *Castoroides* from post-Pliocene deposits of North America, and *Amblyrhiza* and *Loxomylus* from the bone-breccias of the island of Anguilla. The first-named family appears to be intermediate between the *Sciuridæ* and *Castoridæ*; the second is allied to *Geomyidæ* and *Dipodidæ*; and the last, connected with *Chinchillidæ*, includes *Castoroides ohioensis*, a species vastly exceeding in size the largest of existing Rodents. A fourth family, *Mesotheriidæ*, including a single fossil form, *Mesotherium cristatum*, also of large size, from the Pliocene of South America, has been referred to this order, but it is evident that an animal which, besides presenting many other structural differences, possesses four lower incisors completely surrounded by enamel, and in which the mandibular condyle is transversely extended and the maxillaries articulate freely with the nasals, cannot be considered as coming under the definition of a Rodent.

Thus, like the *Insectivora* and *Chiroptera*, fossil remains of *Rodentia* are found as far back as the Eocene period, and of these some are even referable to one or more recent genera, and differ but slightly from existing species, while all others are either capable of being classed in recent families or are more or less closely related to them. It follows therefore (if the age of the beds in which these remains were found has been correctly determined) that, as in the case of these orders also, the first appearance of true Rodents must be sought for much farther back in time, and the question of their descent must be deferred till the discovery of sufficient material admits of reliable generalizations.

Bibliography of Rodentia.—G. R. Waterhouse, "Observations on the Rodentia," *Mag. Nat. Hist.*, iii. (1839); Id., *Ann. Nat. Hist.*, viii. and x. (1839-42); Id., "On the Geographical Distribution of the Rodentia," *Proc. Zool. Soc.*, 1839, pp. 162-174; Id., *Natural History of the Mammalia*, vol. ii., "Rodentia," (1848); Gervais, *Dict. Univ. d'Hist. Nat.*, xi., p. 202 (1848); Brandt, "Untersuchungen über die craniologischen Entwickelungsstufen und Classification der Nager der Jetzwelt," *Mém. de l'Acad. Imper. de St Pétersbourg* (1855); Lilljeborg, *Systematisk Œfversight af de Gnagande Däggdjuren*, Upsala, 1866; Alston, "On the Classification of the Order *Glires*," *Proc. Zool. Soc.*, 1876, pp. 61-98; Trouessart, "Catal. de Rongeurs, Vivants et Fossiles," *Bullet. Soc. d'Études Scient. d'Angers*, 1880-1; various papers by Peters in *Monatsb. Akad. Wissensch. Berlin*, and by Alston, Anderson, Blandford, A. Milne-Edwards, Thomas, and others, in *Proc. Zool. Soc.*, *Jour. Asiat. Soc. Beng.*, *Ann. Mag. Nat. Hist.*, &c.

[For the above sections on the *Insectivora*, *Chiroptera*, and *Rodentia* we are indebted to Dr G. E. Dobson.]

ORDER UNGULATA.

Under this term may be included provisionally a large and rather heterogeneous group of mammals, the existing members of which form the *Pecora* and *Belluæ* of Linnæus, the *Ruminantia* and *Pachydermata* of Cuvier. A few years ago it was found convenient to restrict the order to a well-marked and distinctly circumscribed group, comprising the two sections known as *Perissodactyla* and *Artiodactyla*, and to leave out such isolated forms as the Elephant and Hyrax; but the discovery of a vast number of extinct species, which could not be brought under the definition of either Perissodactyle or Artiodactyle Ungulates, and yet are evidently allied to both, and which to a certain extent bridge over the interval between these and the isolated groups just mentioned, makes it necessary either to introduce a number of new and ill-defined ordinal divisions, or to widen the scope of the original order so as to embrace them all.

They are all animals eminently adapted for a terrestrial life, and in the main for a vegetable diet. Though a few are more or less omnivorous, and may under some circumstances kill living creatures smaller and weaker than themselves for food, none are distinctly and habitually predaceous. Their teeth are markedly heterodont and diphyodont,—the milk set being well developed and not completely changed until the animal attains its full stature. The molars have broad crowns with tuberculated or ridged surfaces. They have no clavicles. Their toes are provided with blunt, broad nails, or in the majority of cases with hoofs, more or less enclosing the ungual phalanges. The scaphoid and lunar bones of the carpus are always distinct.

The whole group may be divided into the *Ungulata Vera*, containing the suborders *Perissodactyla* and *Artiodactyla*, and a less well-known assemblage of animals which may be called *Subungulata* or *Ungulata Polydactyla*. Cope has pointed out a character in the structure of the carpus by which the latter are differentiated from the former. In all the *Subungulata* the bones of the proximal and distal row retain the primitive or more typical relation to each other (see fig. 100). The os magnum of the second row articulates mainly with the lunar of the first, or with the cuneiform, but not with the scaphoid, while in the group to which the vast majority of modern Ungulates belong the second or distal row has been shifted altogether towards the inner side of the limb (see figs. 107 and 109), so that the magnum is brought considerably in relation with the scaphoid, and is entirely removed from the cuneiform, as in the great majority of existing mammals.

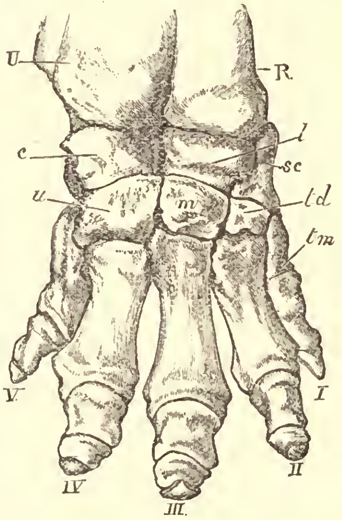

Fig. 100.—Right Fore Foot of Indian Elephant. × ⅙. U, ulna; R, radius; c, cuneiform; l, lunar; sc, scaphoid; u, unciform; m, magnum; td, trapezoid; tm, trapezium; I to V, first to fifth digit.

SUBUNGULATA.

By far the greater number of the *Subungulata* are extinct, and of many of those whose former existence has been revealed, chiefly by the labours of the American palæontologists, our knowledge is at present necessarily imperfect, though daily extending. It will only be possible here to give any details of some of the more interesting or best-known forms.

Suborder *HYRACOIDEA*.

This division is constituted to receive a single family of mammals, the affinities of which have long constituted a puzzle to zoologists. They were first placed among the Rodents, to which animals their small size and general appearance and habits give them much superficial resemblance. Cuvier's investigations into their anatomical structure, and especially their dental characters, led him to place them among the Ungulates, near the genus *Rhinoceros*, a position still accepted by many zoologists. Further knowledge of their organization and mode of development has caused Milne-Edwards, Huxley, and others to disassociate them from this connexion, and, failing to find any agreement with any other known forms, to place them in a group entirely apart. Palæontology has thrown no light upon the affinities of this anomalous and isolated group, as no extinct animals possessing their distinctive characters have as yet been discovered.

The dentition consists only of incisors and molars, the formula in all known species being $i\ \frac{1}{2}$, $c\ \frac{0}{0}$, $p\ \frac{4}{4}$, $m\ \frac{3}{3}$. The upper incisors have persistent pulps, and are curved longitudinally, forming a semicircle as in Rodents. They are, however, not flattened from before backwards as in that order, but prismatic, with an antero-external, an antero-internal, and a posterior surface, the first two only being covered with enamel; their apices are consequently not chisel-shaped, but sharp pointed. They are preceded by functional, rooted milk teeth. The lower incisors have

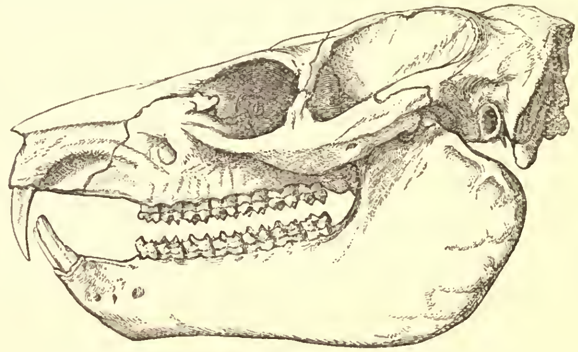
Fig. 101.—Skull and Dentition of *Dendrohyrax dorsalis*. × ⅔.

long tapering roots, but not of persistent growth. They are straight, procumbent, with awl-shaped, trilobed crowns. Behind the incisors is a considerable diastema or interval. The molars and premolars are all contiguous, and formed almost exactly on the pattern of some of the Perissodactyle Ungulates. The hyoid arch is unlike that of any known mammal. The dorsal and lumbar vertebræ are very numerous, 28 to 30, of which 21 or 22 bear ribs. The tail is extremely short. There are no clavicles. In the fore foot, the three middle toes are subequally developed, the fifth is present, but smaller, and the hallux is rudimentary, although, in one species at least, all its normal bones are present. The ungual phalanges of the four outer digits are small, somewhat conical, and flattened in form. The carpus has a distinct os centrale. There is a slight ridge on the femur in the place of a third trochanter. The fibula is complete, thickest at its upper end, where it generally ankyloses with the tibia. The articulation between the tibia and astragalus is more complex than in other mammals, the end of the malleolus entering into it. The hind foot is very like that of Rhinoceros, having three well-developed toes. There is no trace of a hallux, and the fifth metatarsal is represented by a small nodule only. The ungual phalanx of the inner (or second) digit is deeply cleft, and has a peculiar long curved claw, the others having short broad nails. The stomach is formed upon much the same principle as that of the Horse or Rhinoceros, but is more elongated transversely and divided by a constriction into two cavities—a large left *cul de sac*, lined by a very dense white epithelium, and a right pyloric cavity, with a very thick, soft, vascular lining. The intestinal canal is long, and has an arrangement perfectly unique among mammals, indeed among vertebrated animals, for, in addition to the ordinary short, but capacious and sacculated cæcum at the commencement of the colon, there is, lower down, an additional pair of large, conical, pointed cæca. The liver is much subdivided, and there is no gall-bladder. The brain resembles that of the typical Ungulates far more than the Rodents. The testes are permanently abdominal. The ureters open into the fundus of the bladder as in some Rodents. The female has six teats, of which four are inguinal and two axillary, and the placenta is zonary, as in the Elephant and *Carnivora*.

There are two distinct forms of Hyrax, differing both in structure and habits, and which may well be accorded generic rank.

1. *Hyrax*.—Molar teeth having the same pattern as those of *Rhinoceros*. Interval between upper incisors less than the width of the teeth. Lower incisors slightly notched at the cutting edge. Vertebræ: C 7, D 22, L 8, S 6, C 6. Of this form the earliest known species, *H. capensis*, is the type. There are several other species, as *H. syriacus* and *habessinicus*, from eastern Africa and Syria. They inhabit mountainous and rocky regions, and live on the ground.

2. *Dendrohyrax*.—Molar teeth having the same pattern as *Palæotherium* (except that the third lower molar has but two lobes). Interval between upper incisors exceeding the width of the teeth. Lower incisors with very distinctly trilobed crowns. Vertebræ: C 7, D 21, L 7, S 5, C 10. The members of this section frequent the trunks and large branches of trees, sleeping in holes. There are several species, not distinctly defined, from western and south Africa, as *D. arboreus* and *D. dorsalis*. The members of both groups appear to have a power like that possessed by the Lizards called Geckos of clinging to vertical surfaces of rocks and trees by the soles of their feet. See HYRAX.

The anatomy of Hyrax was first described by Pallas (*Spicilegia Zoologica*). Besides minor memoirs, two very detailed accounts of its structure have recently appeared—one by Brandt, in *Mém. Acad. Nat. Scien. St Pétersbourg*, series vii. vol. xiv., No. 2, 1869; and another by George, in *Annales des Sciences Naturelles*, series vi. tom. i., 1874, in which references to all the previous literature will be found. The mechanism by which the sole of the foot is enabled to adhere to smooth surfaces is fully described by G. E. Dobson, *Proc. Zool. Soc.*, 1876, p. 526.

SUBORDER *PROBOSCIDEA*.

This name has been appropriated to a well-marked group of animals, presenting some very anomalous characters, allied in many respects to the *Ungulata*, but belonging neither to the Artiodactyle nor Perissodactyle type of that order. It has been thought that they possess some, though certainly not very close, affinities with the *Rodentia*, and also with the *Sirenia*. It is certain, however, that the two species of Elephant which are the sole living representatives of the group, stand quite alone among existing mammals, differing widely from all others in many points of their structure. In some respects, as the skull, proboscis, and dentition, they are highly specialized, but in others, as in the presence of two anterior venæ cavæ, and in the structure of the limbs, they retain a low or generalized condition. A considerable series of extinct forms, extending back through the Pliocene and Miocene epochs, show the same type under different modifications, and in still more generalized outlines; and certain recently discovered forms from the Eocene of North America, if their affinities are rightly interpreted, appear to link the true *Proboscidea* to some unknown primitive type of Perissodactyle *Ungulata*.

The following are the principal characters common to existing, and, by inference, to the extinct, *Proboscidea*. The nose extended into a long, muscular, very flexible and prehensile proboscis, at the end of which the nostrils are situated, and from which the name given to the group is derived. The teeth consisting of ever-growing incisors of very great size, but never exceeding one pair in each jaw, and often present in one jaw only; no canines; large and transversely ridged molars. No clavicles. Limbs strong, the upper segment, especially in the hind limb, the longest. Radius and ulna distinct, the latter articulating extensively with the carpus. Fibula and tibia distinct. Astragalus very flat on both surfaces. Manus and pes short, broad, and massive, each with five toes, though the outer pair may be more or less rudimentary, all encased in a common integument, though with distinct, broad, short, hoofs. Third digit the largest. Two anterior venæ cavæ entering the right auricle. Stomach simple. A capacious cæcum. Testes permanently abdominal. Uterus bicornuate. Placenta non-deciduate and zonary. Mammæ two pectoral.

With regard to the teeth, the incisors,[1] which project largely out of the mouth, and are commonly called "tusks," are of an elongated conical form, and generally curved. They are composed mainly of solid dentine, the fine elastic quality and large mass of which renders it invaluable as "ivory" for commerce and the arts. A peculiarity of the dentine of the *Proboscidea* is that it shows, in transverse fractures or sections, striæ proceeding in the arc of a circle from the centre to the circumference in opposite directions, and forming by their decussations curvilinear lozenges, as in the "engine-turning" of the case of a watch. The enamel covering in existing species is confined to the extreme apex, and very soon wears off, but in some extinct species it forms persistent longitudinal bands of limited breadth. The tusks have small milk predecessors, shed at an early age.

The molar teeth present a remarkable series of modifications from the comparatively simple form in *Dinotherium*, with two or three strongly pronounced transverse ridges and a normal mode of succession, to the extremely complex structure and anomalous mode of replacement found in the true Elephants. The intermediate conditions occur in the various species of *Mastodon*. In this genus the enamel-covered transverse ridges of each tooth are generally more numerous than in *Dinotherium*, and often complicated by notches dividing their edge or by accessory columns attached

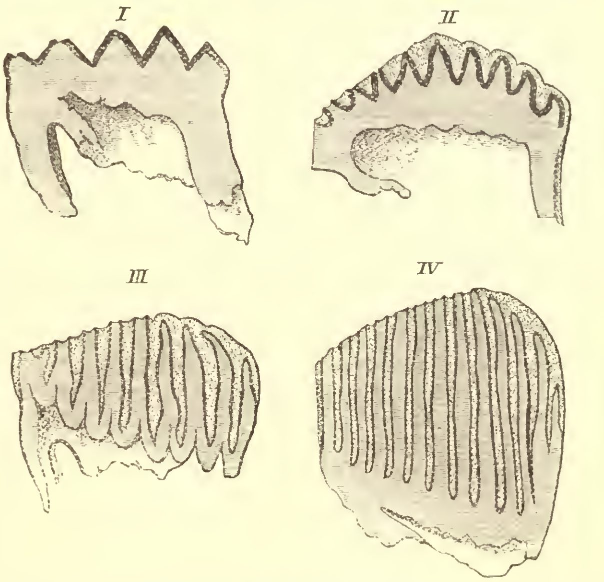

FIG. 102.—Longitudinal Sections of the Crown of a Molar Tooth of various Proboscideans, showing stages in the gradual modification from the simple to the complex form. I, *Mastodon ohioticus*; II, *Stegodon insignis*; III, *Loxodon africanus*; IV, *Elephas primigenius*. The dentine is indicated by transverse lines, the cementum by a dotted surface, and the enamel is black.

to them, but in the unworn tooth they stand out freely on the surface of the crown, with deep valleys between (fig. 102, I). In the Elephants the ridges are still further increased in number, and consequently narrower from before backwards, and are greatly extended in vertical height, so that, in order to give solidity to what would otherwise be a laminated or pectinated tooth, it becomes necessary to envelop and unite the whole in a large mass of cementum,

[1] These teeth are by some writers classed as canines, as their roots are implanted in the maxillæ; but, as in Rodents, they are originally developed in the gum covering the premaxillæ, in which bones their primitive alveoli are sunk. As growth proceeds, however, firm support for such massive and weighty bodies can only be obtained by their roots gradually sinking through the premaxillæ into the great and specially modified alveolar processes of the maxillæ, but this does not vitiate their homology with the incisors of other mammals.

which completely fills up the valleys, and gives a general smooth appearance to the organ when unworn; but as the wear consequent upon the masticating process proceeds, the alternate layers of tissue of different hardness—cementum, dentine, and enamel—which are disclosed upon the surface form a fine and very efficient triturating instrument. The modification of the tooth of a Mastodon into that of an Elephant is therefore precisely the same in principle as that of the molar of a Palæotherium into that of a Horse (see vol. xiii. p. 174), or of the corresponding tooth of one of the primitive Artiodactyles into that of an Ox. The intermediate stages, moreover, even in the present state of our knowledge, are so numerous that it is not possible to draw a definite line between the two types of tooth structure (see fig. 102, II, III, IV).

As regards the mode of succession, that of modern Elephants is, as before mentioned, very peculiar. During the complete lifetime of the animal there are but six molar teeth on each side of each jaw, with occasionally a rudimentary one in front, completing the typical number of seven. The last three represent the true molars of ordinary mammals; those in front appear to be milk molars, which are never replaced by permanent successors, but the whole series gradually moves forwards in the jaw, and the teeth become worn away and their remnants cast out in front, while development of others proceeds behind. The individual teeth are so large, and the processes of growth and destruction by wear take place so slowly, that not more than one, or portions of two, teeth are ever in place and in use on each side of each jaw at one time, and the whole series of changes coincides with the usual duration of the animal's life. On the other hand, the Dinotherium, the opposite extreme of the Proboscidean series, has the whole of the molar teeth in place and use at one time, and the milk molars are vertically displaced by premolars in the ordinary fashion. Among Mastodons transitional forms occur in the mode of succession as well as in structure, many species showing a vertical displacement of one or more of the milk molars, and the same has been observed in one extinct species of Elephant (*E. planifrons*) as regards the posterior of these teeth.

All known Proboscideans are animals of large dimensions, and some are the most colossal of land mammals. The head is of great proportionate size; and, as the brain case increases but little in bulk during growth, while the

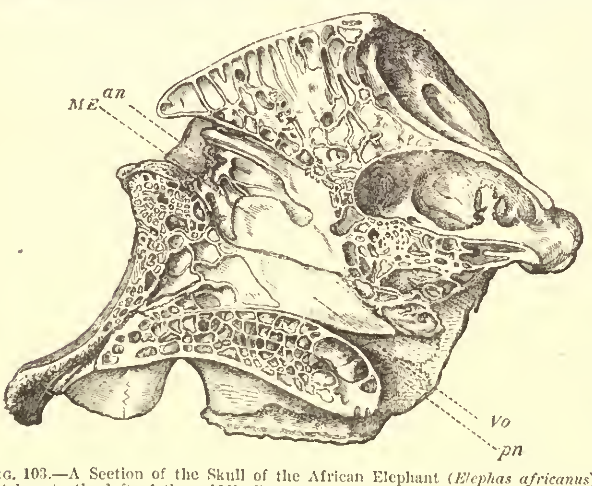

Fig. 103.—A Section of the Skull of the African Elephant (*Elephas africanus*) taken to the left of the middle line, and including the vomer (*Vo*) and the mesethmoid (*ME*). *an*, anterior, and *pn*, posterior narial aperture. 1/12 nat. size. Flower's *Osteology of Mammalia*.

exterior wall of the skull is required to be of great superficial extent to support the trunk and the huge and ponderous tusks, and to afford space for the attachment of muscles of sufficient size and strength to wield the skull thus heavily weighted, an extraordinary development of air-cells takes place in the cancellous tissue of nearly all the bones of the cranium. These cells are not only formed in the walls of the cranium proper, but are also largely developed in the nasal bones and upper part of the premaxillæ and maxillæ, the bones forming the palate and the basi-cranial axis, and even extend into the interior of the ossified mesethmoid and vomer. Where two originally distinct bones come into contact, the cells pass freely from one to the other, and almost all the sutures become obliterated in old animals. The intercellular lamellæ in the great mass which surrounds the brain cavity superiorly and laterally mostly radiate from the inner to the outer table, but in the other bones their direction is more irregular. Like the similar but less developed air-cells in the skulls of many other mammals, they all communicate with the nasal passages, and they are entirely secondary to the original growth of the bones, their development having scarcely commenced in the new-born animal, and they gradually enlarge as the growth of the creature proceeds towards maturity. The nasal bones are very short, and the anterior narial aperture situated high in the face. The zygomatic arch is slender and straight, the malar bones being small, and forming only the middle part of the arch, the anterior part of which (unlike that of all true Ungulates) is formed only by the maxilla. The maxillo-turbinals are but rudimentary, the elongated proboscis supplying their place functionally in warming and clearing from dust the inspired air.

The neck is very short. The limbs are long and stout, and remarkable for the great length of the upper segment (especially the femur) as compared with the distal segment, the manus and pes. It is owing to this and the vertical position of the femur that the knee-joint in the hind leg is placed much lower, and is more conspicuous externally than in most quadrupedal mammals, and, this having been erroneously compared with the hock-joint or ankle of Ungulates, the popular fallacy that the joints of the Elephant's leg bend in a contrary direction to that of other mammals has arisen. There is no round ligament in the hip-joint, or third trochanter to the femur. The radius and ulna are distinct, though fixed in a crossed or prone position. The fibula also is quite distinct from the tibia. The feet are short and broad, the carpal and tarsal bones being very square, with flattened surfaces for articulation; the astragalus especially differs from that of true Ungulates in its flatness, in the absence of a distinct pulley-like articular surface at either extremity, and in having no articular facet for the cuboid. The fibula articulates with the calcaneum, as in Artiodactyles. Of the five toes present on each extremity (see fig. 100), the middle one is somewhat the largest, and the lateral ones smallest, and generally wanting (especially in the hind foot) the complete number of phalanges. The ungual phalanges are all small, irregular in form, and late in ossification. The whole are encased in a common integument, with a flat, subcircular, truncated sole, the only external indication of the toes being the broad oval nails or hoofs arranged in a semicircle around the front edge of the sole. The hind foot is smaller and narrower than the front. The liver is small and simple, and there is no gall-bladder. In form the brain resembles that of the Rodents and other lower orders of mammals, the cerebellum being entirely behind and uncovered by the cerebrum, but the hemispheres of the latter are richly convoluted.

The *Proboscidea* are exclusively vegetable feeders, living chiefly on leaves and young branches of forest trees and various kinds of herbage, which they gather and convey to their mouth by the very mobile proboscis, an organ which combines in a marvellous manner strength with dexterity of application, and is a necessary compensation for the shortness and inflexibility of the neck, as by it many of the functions of the lips of other animals are performed. By its means the Elephant is enabled to drink without bending the head or limbs; the end of the trunk being dipped into the stream or pool, a forcible inspiration fills the two capacious air-passages in its interior with water, which, on the tip of the trunk being turned upwards and inserted into the mouth, is ejected by a blowing action, and swallowed; or if the animal wishes to refresh and cool its skin, it can throw the water in a copious stream over any part of its surface. Elephants can also throw dust and sand over their bodies by the same means and for the same purpose, and wild animals have been frequently observed fanning themselves with leafy boughs held in the trunk. The species are at present limited in their geographical distribution to the Ethiopian and Oriental regions, but they formerly had a far more extensive range.

Elephas.—Dentition: $i\,\frac{1}{0}$, $c\,\frac{0}{0}$, $m\,\frac{6}{6}=26$. The incisors variable, but usually of very large size, especially in the male sex, directed somewhat outwards, and curved upwards, without enamel except on the apex before it is worn; preceded by small milk incisors. The molars succeed each other by horizontal replacement from before backwards, never more than one or part of two being in use on each side of each jaw at the same time; each composed of numerous flattened enamel-covered plates or ridges of dentine, projecting from a common many-rooted base, surrounded and united together by cementum. The number of plates increases from the anterior to the posterior molar in regular succession, varying in the different species, but the third and fourth (or the last milk molar and the first true molar), and these only, have the same number of ridges, which always exceeds five. Skull of adult very high and globular. Mandible ending in front in a prolonged deflected and spout-like symphysis. Vertebræ: C 7, D 19–21, L 3–4, S 4, C 26–33.

The existing species of the genus differ so much that they must be placed in two distinct sections, considered by some zoologists as distinct genera.

1. *Elephas* proper. *Elasmodon*, F. Cuv.; *Euelephas*, Falc.—Average number of plates of the six successive molar teeth expressed by the "ridge formula" 4, 8, 12, 12, 16, 24. The plates compressed from before backwards, the anterior and posterior surfaces (as seen in the worn grinding face of the tooth) being nearly parallel. Ears of moderate size. Upper margin of the end of the proboscis developed into a distinct finger-like process, much longer than the lower margin. Five nails on the fore feet, and four (occasionally five) on the hind feet.

The well-known Asiatic Elephant, *E. indicus*, inhabits in a wild state the forest lands of India, Burmah, the Malay Peninsula, Cochin China, Ceylon, and Sumatra. Those from the last-named islands, presenting some variations from those of the mainland, have been separated under the name of *E. sumatranus*, but the distinction has not been satisfactorily established. The appearance of the Asiatic Elephant is familiar to all. Though rarely breeding in captivity, it has been domesticated from the most remote antiquity, and is still extensively used in the East as a beast of burden. In the wild state it is gregarious, associating in herds of ten, twenty, or more individuals, and, though it may under certain circumstances become dangerous, it is generally inoffensive and even timid, fond of shade and solitude and the neighbourhood of water. The height of the male at the shoulder when full grown is usually from 8 to 10 feet, occasionally as much as 11. The female is somewhat smaller. See ELEPHANT.

2. *Loxodon.*—Molar teeth of coarse construction, with fewer and larger plates and thicker enamel. Ridge formula: 3, 6, 7, 7, 8, 10. The plates not flattened, but thicker in the middle than at the edges, so that their worn grinding surfaces are lozenge-shaped. Ears very large. The upper and lower margins of the end of the trunk forming two nearly equal prehensile lips. But three hoofs on the hind foot. The one species, *E. africanus*, now inhabits the wooded districts of the whole of Africa south of the Sahara, except where it has been driven away by human settlements. Fossil remains of Pleistocene age, undistinguishable specifically, have been found in Algeria, Spain, and Sicily. It was trained for war and show by the ancient Carthaginians and Romans, and recent experience of the species in captivity in England shows that it is as intelligent as its Asiatic relative, if not more so, while surpassing it in courage, activity, and obstinacy. Nevertheless, in modern times, no people in Africa have been sufficiently civilized or enterprising to care to train it for domestic purposes. It is hunted chiefly for the sake of the ivory of its immense tusks, of which it yields the principal source of supply to the European market, and the desire to obtain which is rapidly leading to the extermination of the species. In size the male African elephant often surpasses that of Asia, but the female is usually smaller. The circumference of the forefoot is half the height at the shoulder, a circumstance which enables the hunters to judge from the footprints the exact size of the animals of which they are in pursuit.

Extinct Species of Elephant.—Abundant remains of Elephants are found embedded in alluvial gravels, or secreted in the recesses of caves, into which they have been washed by streams and floods, or dragged as food by Hyænas and other carnivorous inhabitants of these subterranean dens. Such remains belonging to the Pleistocene and Pliocene periods have been found in many parts of Europe, including the British Isles, in North Africa, throughout the North American continent from Alaska to Mexico, and extensively distributed in Asia, where the deposits of the sub-Himalayan or Sivalik hills, belonging to the earliest Pliocene, are rich in the remains of Elephants of varied form. These species are chiefly known and characterized at present by the teeth, some of which resemble the existing Indian and some the African type, but the majority are between the two, and make the distinction between *Elephas* and *Loxodon* as different genera quite impracticable. Others again approach so closely in the breadth and coarseness of the ridges and paucity of cementum to *Mastodon* as to have been placed by some zoologists in that genus. These form the group or subgenus called *Stegodon* by Falconer.

Among the best known extinct Elephants are *E. primigenius*, the Mammoth, very closely resembling the existing Indian species, and one of the most recently extinct and extensively distributed (see MAMMOTH); *E. antiquus* and *E. meridionalis*, also found in Britain, as well as in Europe generally, of rather earlier date, and inclining more to the *Loxodon* type, as also do two species found in the island of Malta, *E. mnaidiensis* and *E. melitensis*, the latter the smallest known species of the suborder, sometimes not exceeding 3 feet in height when adult. The *Stegodon* forms, *E. clifti*, *bombifrons*, *insignis*, and *ganesa*, are all from India, which locality would appear, from the abundance of remains and variety of forms, as well as the generalized character of some and the geological horizon (Plio-Miocene) in which the remains are found, to be the earliest habitation of the true Elephants yet discovered. Remains of Elephants of the last-named group have also lately been found in China and Japan. A tusk the dentine of which presents the characters hitherto considered peculiar to the *Proboscidea*, from Australia, has been lately described by Professor Owen under the name of *Notelephas*.

Mastodon.—Dentition: $i\,\frac{1}{1\text{ or }0}$, $c\,\frac{0}{0}$, p and $m\,\frac{6}{6}$. Upper incisors very large, as in *Elephas*; sometimes with longitudinal bands of enamel, more or less spirally disposed. Lower incisors variable: when present comparatively small and straight, sometimes persistent, sometimes early deciduous, and in some species never present. Grinding surface of molars with transverse ridges, the summits of which are divided more or less into conical or mammillary cusps, and often with secondary or additional cusps between and clustering against the principal ridges; enamel thick; cementum very scanty, never filling up the interspaces between the ridges. The third, fourth, and fifth molars having the same number of ridges,[1] which never exceeds five. In some species (*M. ohioticus*) no vertical succession has been observed, but in others, as *M. angustidens*, the two posterior premolars, and in the American *M. productus* apparently all three, are preceded by milk molars. There is also a horizontal succession as in Elephants, the anterior teeth being lost before the posterior ones are fully developed, but not so complete as in the former genus, for as many as three teeth may be in place in one jaw at one time. The skull generally is less elevated and less cellular than in *Elephas*; otherwise the remainder of the skeleton is similar.

All known Mastodons are gigantic animals, equalling or exceeding the recent Elephants in size. Their remains have been found in Europe and southern Asia and America, from the Miocene to the Pleistocene epochs.

Dinotherium.—Dentition of adult: $i\,\frac{0?}{1}$, $c\,\frac{0}{0}$, $p\,\frac{2}{2}$, $m\,\frac{3}{3}=22$; all present at the same time, there being no horizontal succession, but the premolars replace milk teeth in the ordinary manner. The presence or absence of upper incisors has not yet been clearly ascertained. Lower incisors, large, conical, descending and slightly curved backwards, implanted in a greatly thickened and deflected beak or prolongation of the symphysis. In section they do not show the decussating striæ characteristic of Mastodons and Elephants. Crowns of molars with strong, transverse, crenulated ridges, with deep valleys between, much resembling those of the Tapirs. Ridge formula of the permanent molar series: 2, 2, 3, 2, 2. The three ridges of the first true molar appear to be constant in both upper and lower jaws, although it is quite an anomalous character among

[1] This, and the larger number of ridges in the latter, are the only absolute distinctions which Falconer could find between *Mastodon* and *Elephas* (*Palæont. Memoirs*, ii. p. 9), and it is clear that they are somewhat arbitrary. The line between the two genera is drawn at this point more as a matter of convenience for descriptive purposes than as indicating any great natural break in the sequence of modifications of the same type.

Proboscideans for this molar to have more ridges than those which come behind it. The last milk molar has also three ridges, the penultimate but two. The cranium is much depressed, with compara-

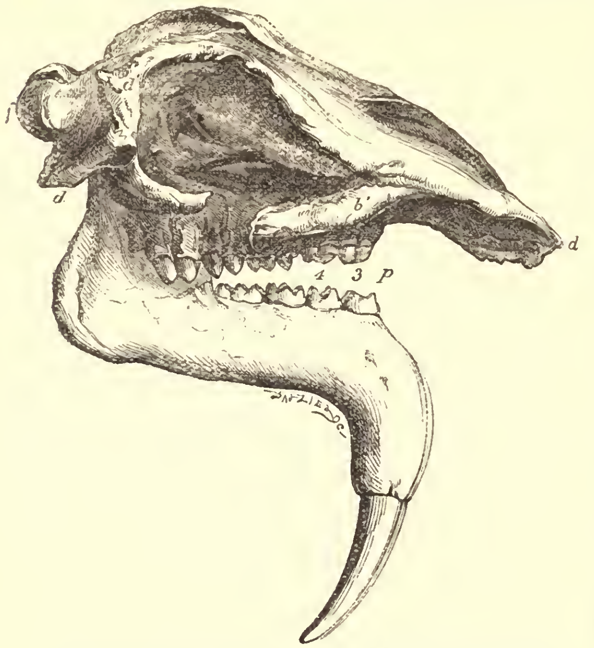

FIG. 104.—Skull of *Dinotherium giganteum* (Miocene, Eppelsheim).

tively little development of air-cells. The remainder of the skeleton is imperfectly known, but apparently agrees in its general characters with that of the other Proboscideans.

Remains of *Dinotherium giganteum*, an animal of elephantine proportions, strikingly characterized by the pair of huge tusks descending nearly vertically from the front of the lower jaw, were first discovered at Eppelsheim, near Darmstadt, and described by Kaup. They have since been met with in various Middle and Upper Miocene formations in the south of Germany, France, Greece, and Asia Minor. Three species, *D. pentapotamiæ*, *D. indicum*, and *D. sindiense*, have been described by Falconer and Lydekker from north-western India. The genus has hitherto not been found in England or in America.

The genus *Phenocodus*, from the Lower Eocene of Wyoming, lately described by Cope (*Am. Naturalist*, December 1881 and June 1882), is placed by that zoologist in a special group called *Condylarthra*, allied to the *Proboscidea*, but distinguished by "a post-glenoid process, and a third trochanter of the femur, and no calcaneal facet for the fibula." This and the *Proboscidea* are united by Cope to form the order *Taxeopoda*, one of his primary divisions of the *Ungulata*.

In all the preceding forms the astragalus articulates only with the navicular bone, in those that follow with both navicular and cuboid.

SUBORDER *AMBLYPODA.*

Among the most remarkable of the recent discoveries in the Eocene formations of the western States of North America has been that of a group of animals of huge size, approaching if not equalling that of the largest existing Elephants, presenting a combination of characters quite unlike those known among either recent or extinct creatures, and of which there were evidently many species living contemporaneously, but all of which became extinct before the close of the Eocene period. To form some idea of their appearance, we must imagine animals very elephantine in general proportions and in the structure of their limbs. The fore foot had five, and the hind foot four toes. The tail, as in the Elephants, was long and slender, but the neck, though still short, was not so much abbreviated as in modern Proboscideans, and there is no evidence that they possessed a trunk. The head differed greatly from that of the Elephants, being long and narrow, more like that of a Rhinoceros, and, as in that animal, was elevated behind into a great occipital crest, and it had developed upon its upper surface three pairs of conspicuous, laterally diverging protuberances, one pair in the parietal region, one on the maxillaries in front of the orbits, and one (much smaller) near the fore part of the elongated nasal bones. Whether these were merely covered by bosses of callous skin, as the rounded form and ruggedness of their extremities would indicate, or whether they formed the bases of attachment for horns of still greater extent, like those of the Rhinoceros or of the Cavicorn Ruminants, can only be a matter of conjecture. There were no upper incisors, but three on each side below, of comparatively small size, as was also the lower canine. A huge, compressed, curved, sharp-pointed canine tusk, very similar in form and position to that of the Musk-Deer, descended from each side of the upper jaw. These were present in both sexes, but very much smaller in the female, as was also the flange-like process of the lower jaw by which they were guarded. Behind these, and at some distance from them, were on each side above and below six molar teeth, of comparatively small size, placed in continuous series, each with a pair of oblique ridges conjoined internally and diverging externally in a V-like manner, and provided with a stout basal cingulum. The dental formula was therefore $i\,\frac{0}{3}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{3}{3} = 34$; and the dentition had thus already attained a remarkable degree of specialization, although the brain was smaller and more rudimentary in characters than in almost any other known mammal.

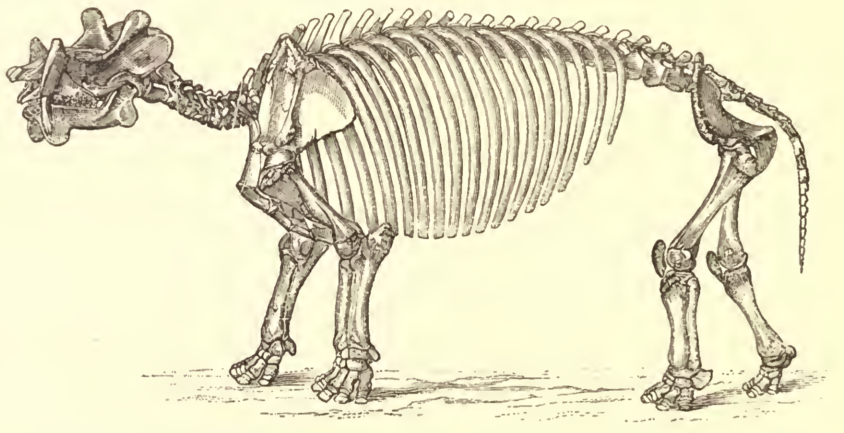

FIG. 105.—Restoration of *Dinoceras mirabile.* $\frac{1}{30}$ nat. size. From Marsh (*Am. Jour. Sci.*, vol. xii. pl. 2).

The first-discovered evidences of the existence of animals of this group were described by Leidy in 1872, under the name of *Uintatherium* (from the Uintah mountains, near which they were found). Other nearly allied forms have been named *Dinoceras* (restoration of which is shown in fig. 105), *Tinoceras*, and *Loxolophodon.* They constitute the order *Dinocerata* of Marsh, but are included by Cope in the *Amblypoda.*

Another interesting form referred to this suborder is *Coryphodon*, which appears to connect the *Proboscidea* with the most primitive *Perissodactyla*, especially *Lophiodon.* It was first described by Owen in 1846 from a fragment of a jaw from the London Clay. More perfect remains were afterwards discovered in France, and lately in great abundance, indicating many species from the size of a Tapir to that of a Rhinoceros, in the lowest Eocenes of New Mexico and Wyoming, in the United States. It had forty-four teeth; the canines of both jaws were large and sharp-pointed, and the molars had strongly pronounced oblique ridges. The general proportions were those of a Bear, but the tail was of moderate length, and the feet short and wide, with five toes on each.

The Tertiaries of South America have yielded some very remarkable forms of mammalian life, the nature and affinities of which have greatly puzzled all zoologists who have attempted to unravel them. *Macrauchenia*, an animal with a Camel-like neck, is now known to be a Perissodactyle, though in some characters somewhat aberrant. The articulation of the fibula with the calcaneum is an Artiodactyle or perhaps generalized character. The teeth ally it to *Palæotherium* and *Rhinoceros*. *Homalodontotherium*, from the banks of the river Gallegos, south-east Patagonia, is known by the teeth alone, which, though very generalized, are on the whole rhinocerotic. *Nesodon*, from the same locality, also only known by the dentition and some parts of the skull, connects the last and *Macrauchenia* with *Toxodon*. These three genera have the typical dental formula of $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $p\,\frac{4}{4}$, $m\,\frac{3}{3} = 44$. *Toxodon* is an animal about the size of a Hippopotamus; it was first discovered by Darwin, and many specimens have since been found in Pleistocene deposits near Buenos Ayres, and described by Owen, Gervais, and Burmeister. The teeth consist of large incisors, very small lower canines, and strongly curved molars, all with persistent roots, the formula being apparently $i\,\frac{2}{3}$, $c\,\frac{0}{1}$, $p\,\frac{4}{3}$, $m\,\frac{3}{3} = 38$. The cranial characters exhibit a combination of those found in both Perissodactyles and Artiodactyles, but the form of the hinder part of the palate and the absence of an alisphenoid canal belong to the latter; and the tympanic, firmly fixed in between the squamosal and the exoccipital, ankylosed to both, and forming the floor of a long upward-directed meatus auditorius, is so exactly like that of the *Suina* that it is difficult to believe it does not indicate some real affinity to that group. These characters seem to outweigh in importance those by which some zoologists have linked *Toxodon* to the *Perissodactyla*, and the absence of the third trochanter and the articulation of the fibula with the calcaneum tell in the same direction. The structure of the feet is not completely known, but Cope has shown that the tarsal bones differ altogether from those of either Artiodactyles or Perissodactyles, and more nearly resemble those of the *Proboscidea* than any other known Ungulates.

Mesotherium, also called *Typotherium*, from the same locality, was an animal rather larger than a Capybara, and of much the same general appearance. Its skeleton is completely known, and shows a singular combination of characters, resembling *Toxodon* or a

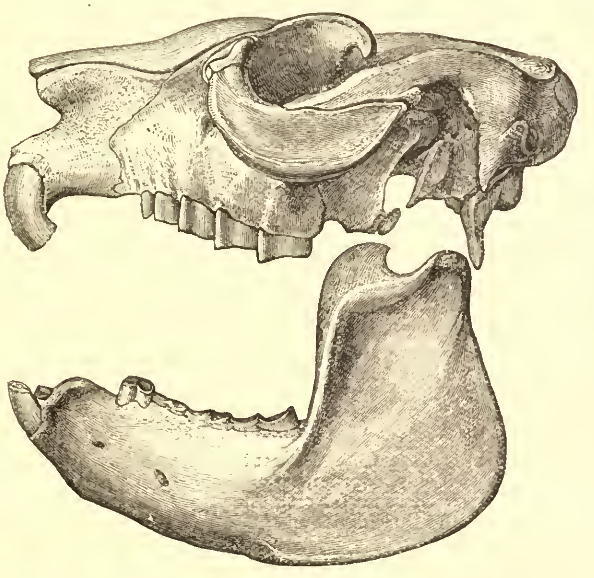

Fig. 106.—Cranium and Lower Jaw of *Mesotherium cristatum*. ½ nat. size. From Gervais.

generalized Ungulate on the one hand, and the Rodents, especially the *Leporidæ*, on the other. In the presence of clavicles it differs from all known Ungulates, and in having four lower incisors from all Rodents. The teeth are $i\,\frac{1}{2}$, $c\,\frac{0}{0}$, $p\,\frac{2}{1}$, $m\,\frac{3}{3} = 24$.

It will thus be seen that, although our knowledge of many of these forms is still very limited, we may trace among them a curious chain of affinities, which would seem to unite the Ungulates on the one hand with the Rodents on the other; but further materials are required before we can establish with certainty so important a relationship, one which, if true, would alter materially some of the prevailing views upon the classification of mammals.

UNGULATA VERA.

In the typical *Ungulata* the feet are never plantigrade, and the functional toes do not exceed four,—the inner digit being suppressed, at all events in all forms which have existed since the Early Eocene period. The os magnum of the carpus articulates freely with the scaphoid. The allantois is largely developed, and the placenta, so far as is known, is non-deciduate, the chorionic villi being either evenly diffused or collected in groups or cotyledons (in *Pecora*). The testes descend into a scrotum. There is never an os penis. The uterus is bicornuate. The mammæ are usually few and inguinal, or may be numerous and abdominal (as in *Suina*), but are never solely pectoral. The cerebral hemispheres in existing Ungulates are well convoluted.

The group is now, and has been throughout the whole of the Tertiary period, composed of two perfectly distinct sections, differing from each other, not only in the obvious characters of the structure of the limbs, but in so many other parts of their organization that they must be considered as of the rank at least of suborders. The characters of these divisions, first indicated by Cuvier, were thoroughly established by Owen, by whom the names whereby they are now generally known were proposed.

Suborder *PERISSODACTYLA*.

This is a perfectly well-defined group of Ungulate mammals, represented in the actual fauna of the world by only three distinct types or families—the Tapirs, the Rhinoceroses, and the Horses—poor in genera and species, and (except in the case of the two domesticated species of *Equus*, which have been largely multiplied and diffused by man's agency) not generally numerous in individuals, though widely scattered over the earth's surface. Palæontological records show very clearly that these are but the surviving fragments of a very extensive and much varied assemblage of animals which flourished upon the earth throughout the whole of the Tertiary geological period, and which, if it could be reconstructed in its entirety, would not only show members filling up structurally the intervals between the existing apparently isolated forms, but would show several marked lines of specialization which have become extinct without leaving any direct successors.

The following are the principal characters distinguishing them from the *Artiodactyla*. Premolar and molar teeth in

A B C

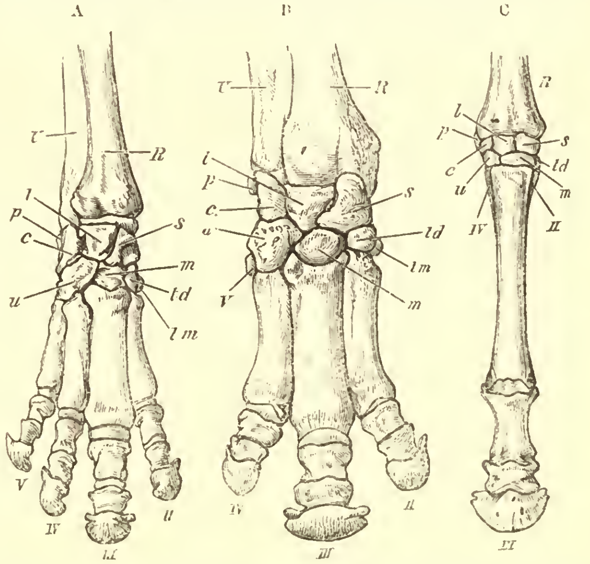

Fig. 107.—Bones of Fore Foot of existing Perissodactyles. A, Tapir (*Tapirus indicus*), × ⅕; B, Rhinoceros (*Rhinoceros sumatrensis*), × ⅕; C, Horse (*Equus caballus*), × ⅙. U, ulna; *R*, radius; *c*, cuneiform; *l*, lunar; *s*, scaphoid; *u*, unciform; *m*, magnum; *td*, trapezoid; *tm*, trapezium. *Osteology of Mammalia.*

continuous series, with massive, quadrate, transversely ridged or complex crowns,—the posterior premolars resembling the true molars in size and structure. Crown of the last lower molar commonly bilobed.[1] Dorso-lumbar vertebræ never fewer than twenty-two, usually twenty-three in the existing species. Nasal bones expanded posteriorly. An alisphenoid canal. Femur with a third trochanter. The middle or third digit on both fore and hind feet larger than any of the others, and symmetrical in itself, the free border of the ungual phalanx being evenly rounded (see fig. 107). This may be the only functional toe, or the second and fourth may be subequally developed on each side of it. In the Tapirs and many extinct forms, the fifth toe also remains on the fore limb, but its presence does not interfere with the symmetrical arrangement of the remainder of the foot around the median line of the third or middle digit. Traces of a hallux have only been found in some extremely ancient and primitive forms. The astragalus has a pulley-like surface above for articulation into the tibia, but its distal surface is flattened and unites to a much greater extent with the navicular than with the cuboid, which bone is of comparatively less importance than in the Artiodactyles. The calcaneum does not articulate with the lower end of the fibula. The stomach is simple, the cæcum large and capacious, the placenta diffused, and the mammæ inguinal.

The very distinct minor groups into which the Perissodactyles are divided in the later periods of the earth's history are, even by the knowledge already gained of the ancient members of the sub-order, so closely united by connected forms that it is difficult to make any satisfactory classification of the whole. This is of course what might be expected, and would probably be the case with all other groups if we knew as much of their past history as we do of that of the Perissodactyles. It is necessary, however, for descriptive purposes to have some arrangement; and perhaps, if not the most natural, the most convenient division (especially as it is chiefly or only by these organs that many are known) is one founded upon the structure of the lower molar teeth. By this character we may make three primary divisions, each of which has a representative at the present time:—(*A*) those in which the crowns of the lower molars are disposed in transverse ridges, as in the Tapirs; (*B*) those in which the crowns of the lower molars are formed by a pair of crescents, as in Rhinoceros; (*C*) those in which the crowns of the lower molars are formed of a pair of crescents, with the addition of inner lobes or columns, as in the Horses. As these forms are all modifications of the same essential pattern, transitions in certain or all of the teeth must be expected in many cases, and, as before implied, the grouping of the Perissodactyles into Tapiroid, Rhinocerotic, and Equine sections according to the pattern of their molar teeth may not be a true exposition of the real affinities of the genera, but must be looked upon rather as a convenient provisional arrangement.

A. Tapiroid Section.

Lower molars bilophodont.

Family Lophiodontidæ.

Both upper and lower true molars bilophodont. Premolars smaller and simpler than the true molars. Four toes on the anterior and three on the posterior feet. This family includes a large number of more or less imperfectly known forms, all extinct, ranging from the size of a Rabbit to that of an Ox. They are the earliest in time and most generalized in structure of the known Perissodactyles. It is possible that from some either of the known or the still undiscovered members of this group most of the other types of the order have been derived. Their remains have been found in Europe only in the Lower and Middle Eocene, though in North America they appear to have lingered to a somewhat later date. The genus *Hyracotherium* was established in 1839 by Owen for a small animal, no larger than a Hare, the skull of which was found in the London Clay at Herne Bay. A more perfect specimen apparently of the same species was afterwards (in 1857) described under the name of *Philophus vulpiceps.* Closely allied forms from the European continent have been named *Pachynolophus* and *Lophiotherium.* These have all the complete dentition, viz., $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $p\,\frac{4}{4}$, $m\,\frac{3}{3} = 44$. The posterior lower molar has three lobes. The genus *Lophiodon* (Cuvier, 1822) contains animals of much larger size and later geological period (Middle or Upper Eocene), in which the dentition was so far specialized as to have lost the anterior premolar of both jaws, the formula being $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{3}{3} = 40$. The transverse ridges of the upper molars are placed obliquely, the posterior is smaller than the anterior, and they are united by their external borders; those of the mandible are distinct and only connected by a feeble diagonal crest, the last bearing a talon or rudiment of a third lobe. On the premolars the anterior ridge only is developed. Nearly allied was the American genus *Hyrachyus*, the structure of which is now very completely known from well-preserved remains. The skeleton closely resembles that of the Tapir, though the dentition is more like that of *Lophiodon*, except that the last lower molar has but two lobes. As many as nine species have been already described, all from the Upper Eocene. Another form from the same deposits, *Colonoceras* of Marsh, is said to have had an attachment for a dermal horn on each nasal bone. *Triplopus*, otherwise closely similar to *Hyrachyus*, wants the fifth digit of the manus, and hence is placed by Cope in a distinct family, *Triplopidæ.*

Family Tapiridæ.

Both upper and lower true molars bilophodont. Posterior premolars above and below resembling the true molars. This family is connected with the last by the Middle Miocene genus *Listriodon.* The genus *Tapirus*, in which as many as three premolars resemble the true molars, and in which the last lower molar has no talon, appears first in the Upper Miocene of Europe, and has continued with scarcely any appreciable change until the present time, being represented by several species in Central and South America, and one in the Malay Peninsula and adjacent islands. It is therefore probably the oldest existing genus of mammals. One of the American species differs from all the others in the great anterior prolongation of the ossification of the mesethmoid cartilage, and has been separated generically by Gill under the name of *Elasmognathus.* See Tapir.

B. Rhinocerotic Section.

Lower molar teeth with the ridges, instead of being transverse, curved in a crescentic manner. The outer extremity of each ridge is curved forwards so that the hinder ridge abuts against the external surface of the ridge in front of it. An unworn lower molar of a Rhinoceros has thus externally two convex areas separated by a vertical groove, and internally two principal sinuses, corresponding to the projections externally. The entrances to these sinuses are bordered by three conical pillars—the first of comparatively little importance, representing the anterior talon of the Tapir's tooth, the second, the largest, representing the antero-internal principal cusp, and the third the postero-internal principal cusp. The upper molars of all the animals of this section resemble those of *Lophiodon* in principle, the transverse ridges being joined by an outer wall and placed obliquely, their inner ends inclining backwards and their posterior surfaces being more or less concave. There are two further chief modifications of this type:—(1) that in which the free edge of the outer wall acquires a strongly zigzag or bicrescentic character, being deviated inwards opposite each of the principal outer cusps, and outwards at the anterior and posterior angles of the tooth and in the middle between the cusps, as in *Palæotherium*; and (2) that in which the outer wall is greatly developed, and in the main flat or smoothly convex, though with slight elevations and depressions corresponding with those so regular and well-marked in the last section; this is the character of the teeth of Rhinoceros and its allies.

Family Hyracodontidæ.

Separated by Cope from the next, and containing the genus *Hyracodon* of Leidy, a primitive or simple Rhinoceros-like type, from the Lower Miocene of North America, with the full number of teeth, but only three digits on each foot.

Family Rhinocerontidæ.

A very extensive group, of which many modifications, forming a gradual series, showing increasing specialization from primitive *Lophiodon*-like animals, have been discovered both in North America and in the Old World. One of the most remarkable of these specializations has been the development of dermal horns over the nasal bones, either in laterally placed pairs as in some of the early forms, or in the median line, either single or double. In America they all became extinct before the close of the Pliocene period; but in the Old World, although their geographical distribution has become greatly restricted, at least five well-marked species survive. See Rhinoceros.

Family Macraucheniidæ.

This contains one extinct genus, *Macrauchenia*, with two species *M. patachonica* and *M. boliviensis*, both from South America, and apparently from Pliocene formations. They are very singular and specialized forms, quite out of the line of descent of any of the existing Perissodactyles, and the steps by which they are connected with the rest of the group have not yet been discovered. Of the larger species, *M patachonica*, the skeleton is completely known. It had the full number of forty-four

[1] These dental characters are not strictly applicable to the most ancient forms.

teeth, forming an uninterrupted series. The cervical vertebræ resemble those of the Camels in the position of the vertebrarterial canal, but the ends of the centra are flat, and not opisthocœlous as in the allied forms. In some of the limb characters it resembles

but others have been gradually becoming more specialized and more perfected in structure, and its latest modification, the Cavicorn Ruminants or *Bovidæ* (Antelopes, Sheep, and Oxen), are now the dominating members of the great Ungulate order, widespread in geographical range, rich in generic and specific variation, and numerous in individuals, —forming in all these respects a great contrast to such

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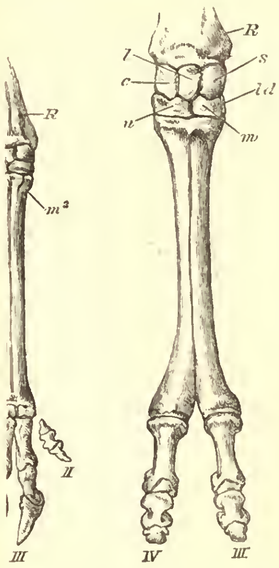

ng Artiodactyles. A, Pig (*Sus scrofa*).
¼; C, Camel (*Camelus bactrianus*), ×⅛.
ınar; *s*, scaphoid; *u*, unciform; *m*, mag-
from *Osteology of Mammalia*.

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been the following:—

1. As regards the teeth. Assumption of the grinding surfaces of the molar teeth either of a distinctly tubercular (*bunodont*) or of a crescentic ridged (*selenodont*) form. Modification of the latter from

last lower molar commonly bilobed.[1] Dorso-lumbar vertebræ never fewer than twenty-two, usually twenty-three in the existing species. Nasal bones expanded posteriorly. An
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A. TAPIRO

Lower molars bilophodont.

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molar of both jaws, the formula being $i\frac{3}{3}$, $c\frac{1}{1}$, $p\frac{3}{3}$, $m\frac{3}{3}=40$. The transverse ridges of the upper molars are placed obliquely, the

posterior is smaller than the anterior, and they are united by their external borders; those of the mandible are distinct and only connected by a feeble diagonal crest, the last bearing a talon or rudiment

are very singular and specialized forms, quite out of the line of descent of any of the existing Perissodactyles, and the steps by which they are connected with the rest of the group have not yet been discovered. Of the larger species, *M patachonica*, the skeleton is completely known. It had the full number of forty-four

[1] These dental characters are not strictly applicable to the most ancient forms.

teeth, forming an uninterrupted series. The cervical vertebræ resemble those of the Camels in the position of the vertebrarterial canal, but the ends of the centra are flat, and not opisthocœlous as in the allied forms. In some of the limb characters it resembles the *Equidæ*, but in the articulation of the fibula with the calcaneum it agrees with the Artiodactyles. The structure of the feet is, however, distinctly Perissodactyle, there being three toes on each.

Families CHALICOTHERIIDÆ *and* MENODONTIDÆ.

These families, with not very distinctly defined boundaries, contain a large number of extinct forms from Eocene and Miocene formations of both the Old and the New World. Among the latter the most remarkable is a group of animals of gigantic size, to the first-known fragment of which the name of *Menodus* was given in 1849 by Pomel, but of which more perfect remains have since been described by Leidy as *Titanotherium* and *Megacerops*, by Marsh as *Brontotherium*, and by Cope as *Symborodon*, some of which appear to represent distinct generic modifications, but the synonymy of the group is at present much confused. The head was large and much elongated, as in the Rhinoceros; but they had a pair of stout diverging osseous protuberances like horn-cores on the maxillaries in front of the orbits. Their molar teeth were of a simple palæotheroid type, and the incisors and canines were very much reduced. Their fore feet had four and their hind feet three short, stout toes. Their remains abound in the Lower Miocene strata of North America.

Family PALÆOTHERIIDÆ.

The structure of the type of this family, *Palæotherium*, was made known by Cuvier, from specimens found in the Paris gypsum beds (Upper Eocene). Fig. 108 gives an idea of its general appearance, not unlike that of a Tapir, which also it resembled in size. It had, however, but three toes on the fore feet. The dentition was $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{3}{3} = 44$. Many species and allied genera (as

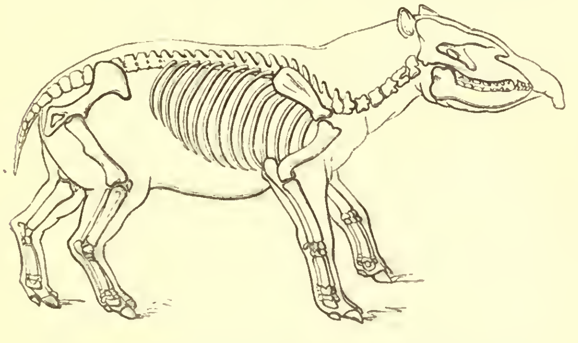


FIG. 108.—Restoration of *Palæotherium* (Upper Eocene). Cuvier.

Palaplotherium, an earlier form from the Middle Eocene, and *Anchitherium*, a later one from the Miocene) have been discovered both in Europe and North America. To some of these the ancestral form of the modern Horses may be traced, the transition from this to the next family being formed by almost imperceptible gradations.

C. EQUINE SECTION.

Lower molars formed of a pair of crescents complicated by the addition of columns or lobes at the inner extremities. Upper molars a modification of the palæotheroid type, but gradually passing as time advanced from the brachyodont to the hypsodont form. Outer digits becoming gradually reduced, until, as in the modern Horses, there is but one (the third) functional digit on each foot. To these alone the family *Equidæ* is restricted by some authors, but in few groups is the artificial nature of the boundaries placed between such divisions so apparent as in the Perissodactyles, for the simple reason that their palæontological history is better known than that of most others, and so many of the intermediate forms have been preserved. For the history, characters, and present distribution of the *Equidæ*, see the article HORSE, vol. xii. p. 172 *sq.*

SUBORDER *ARTIODACTYLA*.

This is an equally well-defined group, traceable from the Early Eocene period, though then apparently by no means so numerous as the Perissodactyles. Some of its types, as that represented in the existing Swine, have retained to the present time much of the primitive character of the group; but others have been gradually becoming more specialized and more perfected in structure, and its latest modification, the Cavicorn Ruminants or *Bovidæ* (Antelopes, Sheep, and Oxen), are now the dominating members of the great Ungulate order, widespread in geographical range, rich in generic and specific variation, and numerous in individuals,—forming in all these respects a great contrast to such decadent types as those represented by the Tapirs and Rhinoceroses.

The principal anatomical characters by which they are distinguished from the Perissodactyles are as follows. The premolar and molar teeth not alike, the former being single and the latter two-lobed. The last lower molar of both first and second dentition almost invariably three-lobed. Nasal bones not expanded posteriorly. No alisphenoid canal. Dorsal and lumbar vertebræ together always nineteen, though the former may vary from twelve to fifteen. Femur without third trochanter. Third and fourth digits of both feet almost equally developed, and their ungual phalanges flattened on their inner or contiguous surfaces, so that each is not symmetrical in itself,

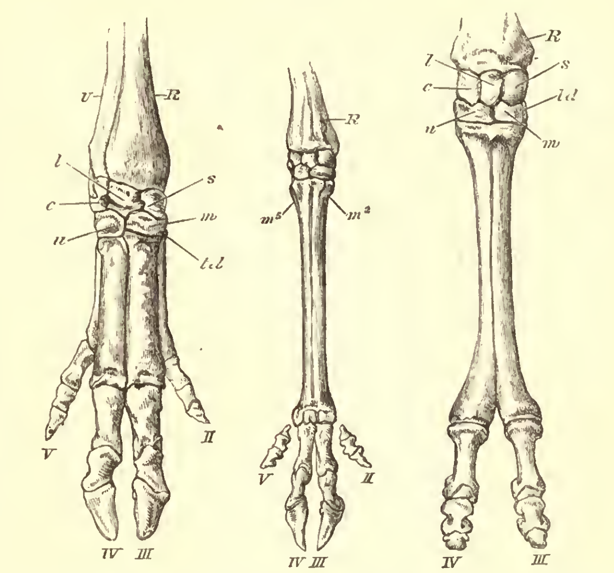


FIG. 109.—Bones of Fore Foot of existing Artiodactyles. A, Pig (*Sus scrofa*). ×⅓; B, Red Deer (*Cervus elaphus*), ×⅓; C, Camel (*Camelus bactrianus*), ×⅕. U, ulna; *R*, radius; *c*, cuneiform; *l*, lunar; *s*, scaphoid; *u*, unciform; *m*, magnum; *td*, trapezoid; *tm*, trapezium. From *Osteology of Mammalia.*

but when the two are placed together they form a figure symmetrically disposed to a line drawn between them. Or, in other words, the axis or median line of the whole foot is a line drawn between the third and fourth digits, while in the Perissodactyles it is a line drawn down the centre of the third digit. Distal articular surface of the astragalus divided into two nearly equal facets, one for the navicular and one for the cuboid bone. The calcaneum with an articular facet for the lower end of the fibula. Stomach almost always more or less complex. Colon convoluted. Cæcum small. Placenta diffused or cotyledonary. Mammæ few and inguinal, or numerous and abdominal.

In treating of many sections of mammals, it is only from the existing species that our characters and classification can be derived, and to these chiefly our observations upon the group must be directed, the extinct forms being so little known that they can only be referred to incidentally. With the *Ungulata*, however, it is quite otherwise. As with the last section, the history of the *Artiodactyla* throughout the Tertiary period is now well known, and throws great light upon the position and relations of the existing groups.

The principal modifications which have taken place in the type from its earliest known and most generalized manifestation have been the following:—

1. As regards the teeth. Assumption of the grinding surfaces of the molar teeth either of a distinctly tubercular (*bunodont*) or of a crescentic ridged (*selenodont*) form. Modification of the latter from

a brachyodont to a hypsodont type. Loss of upper incisors. Development of canines into projecting tusks. Loss of anterior premolars.

2. As regards the limbs. Reduction of the ulna from a complete and distinct bone to a comparatively rudimentary state in which it coalesces more or less firmly with the radius. Reduction of the fibula till nothing but its lower extremity remains. Reduction and final loss of outer pair of digits (second and fifth), with coalescence of the metapodial bones of the two middle digits. Union of the navicular and cuboid, and sometimes the ectocuneiform bone, of the tarsus.

3. Change of form of the odontoid process of the axis from a cone to a hollow half-cylinder.

4. Development of horns or antlers on the frontal bones, and gradual complication of form of antlers.

5. By inference only, increasing complication of stomach with ruminating function superadded. Modification of placenta from simple diffused to cotyledonary form.

The primitive Artiodactyles, with the typical number (44) of incisor, canine, and molar teeth, brachyodont molars, conical odontoid process, four distinct toes on each foot, with metapodium and all carpal bones discrete, no frontal appendages, and (in all probability) simple stomach and diffused placenta, were separated even in the earliest known forms into *Bunodonta* and *Selenodonta.*

A. Bunodonta.

This, the most primitive group, with various offsets which became partially specialized and then extinct, unable apparently to adapt themselves to new conditions, has been continued to the present day with comparatively little change in the section of the suborder called *Suina,* containing the families *Hippopotamidæ* and *Suidæ.* See HIPPOPOTAMUS, PECCARY, and SWINE.

B. Selenodonta.

Members of this group having the complete typical dentition as regards number, but with various modifications in the details of the form of the teeth, and also in the structure of the feet, abounded in the Middle and Upper Eocene and Lower Miocene of Europe and America. One of the earliest known, *Anoplotherium,* was fully described by Cuvier from remains found in the Paris gypsum beds (Upper Eocene). Its teeth formed a series unbroken by a gap or diastema, and were of uniform height (as in Man alone of existing mammals). Its tail was long, with large chevron bones

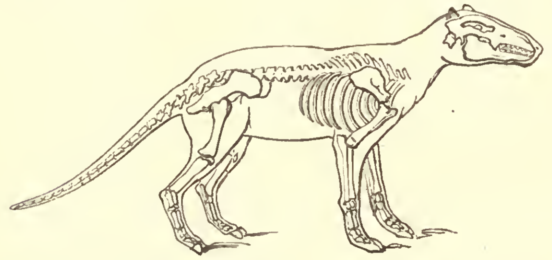


FIG. 110.—Restoration of *Anoplotherium commune* (Upper Eocene). Cuvier.

underneath, not usually found in Ungulates, and there were but two toes on each foot. It was in many respects a much specialized form, apparently not on the line of descent of any of the existing groups. *Chœropotamus, Anthracotherium, Hyopotamus, Xiphodon, Dichodon, Dichobune, Cainotherium,* the American *Oreodon,* and numerous others were forms more or less intermediate in character between the three distinct sections into which, by their extinction, the Selenodont Artiodactyles can now be divided,—the *Tylopoda,* also called *Phalangigrada,* the *Tragulina,* and the *Pecora* or *Cotylophora.*

I. TYLOPODA.

Represented at the present time by the two species of Camels of the Old World and the Llamas of America. For their special distinguishing characters see articles LLAMA and CAMEL.

II. TRAGULINA.

No teeth in premaxillæ. Upper canines well-developed, especially in the males; narrow and pointed. Lower canines incisiform. No caniniform premolars in either jaw. Molariform teeth in a continuous series consisting of $p\ \frac{3}{3}$, $m\ \frac{3}{3}$. Odontoid process of axis conical. Fibula complete. Four complete toes on each foot. The middle metapodials generally confluent, the outer ones (second and fifth) very slender but complete, *i.e.*, extending from the carpus or tarsus to the digits. Navicular, cuboid, and ectocuneiform bones of tarsus united. Tympanic bullæ of skull filled with cancellar tissue. No frontal appendages. Ruminating, but the stomach with only three distinct compartments, the maniplies or third cavity of the stomach of the *Pecora* being rudimentary. Placenta diffused.

This section contains the single family *Tragulidæ,* containing a few animals of small size, commonly known as Chevrotains, intermediate in their structure between the Deer and the Pigs. The large size of the canines of the male and the absence of horns caused them to be associated formerly with *Moschus,* one of the true Deer; hence they are often spoken of as "Pigmy Musk-Deer," although they have no musk-secreting gland, or, except in the above-named trivial external characters, no special affinities with the true Musk. There has scarcely been a more troublesome and obdurate error in zoology than in this association of animals so really distinct. It has been troublesome, not only as preventing a just conception of the relations of existing Artiodactyles, but also in causing great confusion and hindrance in palæontological researches among allied forms; and most obdurate, inasmuch as all that has been recently done in advancing our knowledge of both groups has not succeeded in eradicating it, not only from nearly every one of our zoological text-books, whether British or Continental, but even from works of the highest scientific pretensions.

The family is now generally divided into two genera.

Tragulus, containing the smallest of the existing Ungulates, animals having more of the general aspects and habits of some Rodents, as the Agoutis, than of the rest of their own order. The best-known species are *T. javanicus, T. napu, T. kanchil, T. stanleyanus,* and *T. memmina.* The first four are from the Malay Peninsula, or the islands of the Indo-Malayan Archipelago, the last from Ceylon and Hindustan.

Hyomoschus is distinguished chiefly by the feet being stouter and shorter, the outer toes better developed, and the two middle metacarpals not ankylosed together. Its dental formula (as that of *Tragulus*) is $i\ \frac{0}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{3}{3} = 34$. Vertebræ: C 7, D 13, L 6, S 5, C 12–13. The only existing species, *H. aquaticus* (fig. 111), from the west coast of Africa, is rather larger than any of the

FIG. 111.—African Water Chevrotain (*Hyomoschus aquaticus*).

Asiatic Chevrotains, which it otherwise much resembles, but it is said to frequent the banks of streams, and have much the habits of Pigs. It is of a rich brown colour, with back and sides spotted and striped with white. It is evidently the survivor of a very ancient form, as remains of a species only differing in size (*H. crassus*) have been found in Miocene deposits at Sansan, department of Gers, France.

III. PECORA or COTYLOPHORA.

No premaxillary teeth or caniniform premolars. Upper canines generally absent, though sometimes largely developed. Inferior incisors, three on each side with an incisiform canine in contact with them. Molariform teeth consisting of $p\ \frac{3}{3}$, $m\ \frac{3}{3}$, in continuous series. Auditory bullæ simple and hollow within. Odontoid process in the form of a crescent, hollow above. Distal extremity of the fibula represented by a distinct malleolar bone of peculiar shape, articulating with the outer surface of the lower end of the tibia. Third and fourth metacarpals and metatarsals confluent. Outer toes small and rudimentary, or in some cases entirely suppressed; their metapodial bones never complete. Navicular and cuboid bones of tarsus united. Horns or antlers usually present, at least in the male sex. Left brachial artery arising from a common innominate trunk, instead of coming off separately from the aortic arch as in the preceding sections. Stomach with four complete cavities. Placenta cotyledonous.

The Pecora or true Ruminants form at the present time an extremely homogeneous group, one of the best-defined and most closely united of any of the *Mammalia*. But, though the original or common type has never been departed from in essentials, variation has been very active among them within certain limits; and the great difficulty which all zoologists have felt in subdividing them into natural minor groups arises from the fact that the changes in different organs (feet, skull, frontal appendages, teeth, cutaneous glands, &c.) have proceeded with such apparent irregularity and absence of correlation that the different modifications of these parts are most variously combined in different members of the group. It appears, however, extremely probable that they soon branched into two main types, represented in the present day by the *Cervidæ* and the *Bovidæ*,—otherwise the Antlered and Horned Ruminants. Intermediate smaller branches produced the existing Musk-Deer and Giraffe, as well as the extinct *Helladotherium* inclining to the first-named group and the extinct *Sivatherium*, *Brahmatherium*, *Hydaspitherium* and others more allied to the latter, although upon the true relationship of these forms there is a difference of opinion between the two palæontologists who have paid most attention to the group, Rütimeyer and Lydekker, but the materials forthcoming at present are scarcely sufficient for forming a decided opinion.

The earliest forms of true *Pecora*, as *Gelocus* and *Dremotherium* (Miocene), had no frontal appendages, and some few forms (*Moschus* and *Hydropotes*) continue to the present day in a similar case. In the very large majority, however, either in both sexes or in the male only, a pair or occasionally two pairs (*Tetraceros* and the extinct *Sivatherium*) of processes are developed as weapons of offence and defence from the frontal bones, these being almost always formed on one or other of two types.

1. "Antlers" are an outgrowth of true bone, covered during their growth with vascular, sensitive integument coated with short hair. In this state they remain permanently in the Giraffe, but in the true *Cervidæ*, when the growth of the antler is complete, the supply of blood to it ceases, the skin dies and peels off, leaving the bone bare and insensible, and after a time, by a process of absorption near the base it becomes detached from the skull and is "shed." A more or less elongated portion or "pedicle" always remains on the skull, from the summit of which

FIG. 112.—Head of Deer (*Cervus schomburgkii*), showing Antlers. From Sclater, *Proc. Zool. Soc.*, 1877, p. 682.

a new antler is developed. In the greater number of existing species of Deer this process is repeated with great regularity at the same period of each year. The antler may be simple, straight, subcylindrical, tapering and pointed, but more often it sends off one or more branches called "tynes" or "snags." In this case the main stem is termed the "beam." Commonly all the branches of the antler are cylindrical and gradually tapering. Sometimes they are more or less expanded and flattened, the antler being then said to be "palmated." In young animals the antlers are always small and simple, and in those species in which they are variously branched or palmated, this condition is only gradually acquired in several successive annual growths. An interesting parallel has been observed here, as in so many other cases, between the development of the race and that of the individual. The earliest known forms of Deer, those of the Lower Miocene, have no antlers, as in the young of the existing species. The Deer of the Middle Miocene have simple antlers, with not more than two branches, as in existing Deer of the second year. Species occur in the Upper Miocene with three branches to the antlers, but it is not until the Upper Pliocene and Pleistocene times that Deer occur with antlers developed with that luxuriance of growth and beauty of form characteristic of some of the existing species in a perfectly adult state. Among recent *Cervidæ*, antlers are wanting in the genera *Moschus* and *Hydropotes*; they are present in both sexes in *Tarandus* (the Reindeer), and in the male sex only in all others.

2. The "horns" of the *Bovidæ* consist of permanent, conical, usually curved, bony processes, into which air-cells continued from the frontal sinuses often extend, called "horn-cores," ensheathed in a case of true horn, an epidermic development of fibrous structure, which grows continuously, though slowly, from the base, and wears away at the apex, but is very rarely shed entire. The only existing species in which such a process occurs regularly and periodically is

FIG. 113.—Head of Antelope (*Gazella granti*), showing Horns. From Sir V. Brooke, *Proc. Zool. Soc.*, 1878, p. 724.

the American Prong-Buck (*Antilocapra*), in which the horns also differ from those of all others in being bifurcated. Horns are not present at birth, but begin to grow very soon afterwards. The males of all existing *Bovidæ* possess them, and they are also present (though usually not so fully developed) in the females of all except the genera *Portax*, *Tragelaphus*, *Procapra*, *Antilope*, *Æpyceros*, *Saigo*, *Kobus*, *Cervicapra*, *Pelea*, *Nanotragus*, *Neotragus*, and *Tetraceros*.[1]

Another character by which the different members of the *Pecora* can be distinguished is derived from the characters of the molar teeth. Although there is nothing in the general mode and arrangement of the enamel folds, or in the accessory columns, absolutely distinctive between the two principal families, existing species may generally be distinguished inasmuch as the true molars of the *Cervidæ* are "brachyodont," and those of the *Bovidæ* "hypsodont," *i.e.*, the teeth of the former have comparatively short crowns, which, as in most mammals, take their place at once with the neck (or point where the crown and root join) on a level with or a little above the alveolar border, and remain in this

[1] Sir Victor Brooke, *Proc. Zool. Soc.*, 1878, p. 884.

position throughout the animal's life; whereas in the other forms, the crown being lengthened and the root small, the neck does not come up to the alveolar level until a considerable part of the surface has worn away, and the crown of the tooth thus appears for the greater part of the animal's life partially buried in the socket. In this form of tooth (which is almost always most developed in the posterior molars of the permanent series), the constituent columns of the crown are necessarily nearly parallel, whereas in the first-described they diverge from the neck towards the free or grinding surface of the tooth. In the more complete hypsodont form the interstices of the lengthened columnar folds of enamel and dentine are filled up with cementum, which gives stability to the whole organ, and which is entirely or nearly wanting in the short-crowned teeth. The same modification from low to high crowns without essential alteration of pattern is seen in an even still more marked manner in some of the Perissodactyle Ungulates, the tooth of the Horse bearing to that of *Anchitherium* (see HORSE, vol. xii. p. 174) the same relation as that of an Ox does to the early Selenodont Artiodactyles. A parallel modification has been also shown to have taken place in the molar teeth of the *Proboscidea* (see p. 423).

As the hypsodont tooth is essentially a modification of and, as it were, an improvement upon the brachyodont, it is but natural to expect that all intermediate forms may be met with. Even among the Deer themselves, as pointed out by Lartet, the most ancient have very short molars, and the depressions on the grinding surface are so shallow that the bottom is always visible, while in the *Cervidæ* of the more recent Tertiary periods, and especially the Pleistocene and living species, these same cavities are so deep that whatever be the state of the dentition the bottom cannot be seen. Some existing Deer, as the *Axis*, are far more hypsodont than the majority of the family; and, on the other hand, many of the Antelopes (as *Tragelaphus*) retain much of the brachyodont character, which is, however, completely lost in the more modern and highly specialized Sheep and Oxen.

Family CERVIDÆ.

Frontal appendages, when present, in the form of antlers. First molar at least in both jaws brachyodont. Two orifices to the lacrymal duct, situated on or inside the rim of the orbit. An antorbital vacuity of such dimensions as to exclude the lacrymal bone from articulation with the nasal. Upper canines usually present in both sexes, and sometimes attaining a very great size in the male (see fig. 114). Lateral digits of both fore and hind feet almost

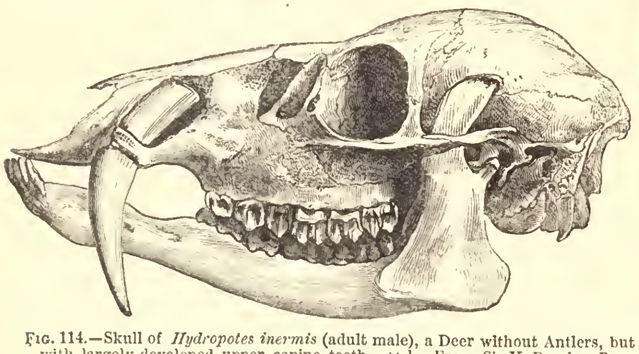


FIG. 114.—Skull of *Hydropotes inermis* (adult male), a Deer without Antlers, but with largely-developed upper canine teeth. × ½. From Sir V. Brooke, *Proc. Zool. Soc.*, 1872, p. 524.

always present, and frequently the distal ends of the metapodals. Placenta with few cotyledons. Gall-bladder absent (except in *Moschus*). This family contains numerous species, having a wide geographical distribution, ranging in the New World from the Arctic Circle as far south as Chili, and in the Old World throughout the whole of Europe and Asia, but absent in the Ethiopian and Australian regions. For the characters of the generic subdivisions and their distribution, see STAG, also DEER, MUNTJAC, and MUSK-DEER.

Family CAMELOPARDALIDÆ.

Frontal appendages consisting of a pair of short, erect, permanent bony processes, ossified from distinct centres, and for a time suturally connected with the frontals, though afterwards ankylosed to them, covered externally with a hairy skin, present in both sexes, and even in the new-born animal. Anterior to these is a median protuberance on the frontal and contiguous parts of the nasal bones, which increases with age, and is sometimes spoken of as a third horn. No upper canines. Molars brachyodont. Lateral digits entirely absent on both fore and hind feet, even the hoofs not developed.

This family contains but a single species, the well-known and very remarkable animal the Giraffe, or Camelopard (*Camelopardalis giraffa*). See GIRAFFE.

Family BOVIDÆ.

Frontal appendages when present in the form of horns. Molars usually hypsodont. Usually only one orifice to the lacrymal canal, situated inside the rim of the orbit. Lacrymal bone almost always articulating with the nasal. Canines absent in both sexes. The lateral toes may be completely absent, but more often they are represented by the hoofs alone, supported sometimes by a very rudimentary skeleton, consisting of mere irregular nodules of bone. Distal ends of the lateral metapodals never present. Gall-bladder almost always present. Placenta with many cotyledons.

The *Bovidæ*, or hollow-horned Ruminants (*Cavicornia*), form a most extensive family, with members widely distributed throughout the Old World, with the exception of the Australian region; but in America they are less numerous, and confined to the Arctic and northern temperate regions, no species being indigenous either to South or Central America. There is scarcely any natural and well-defined group in the whole class which presents greater difficulties of subdivision than this; consequently zoologists are as yet very little agreed as to the extent and boundaries of the genera into which it should be divided. The principal species will be found more particularly described under the headings ANTELOPE, BISON, BUFFALO, CATTLE, CHAMOIS, ELAND, GNU, GOAT, HARTEBEEST, IBEX, MUSK-OX, NYLGHAU, OX, SAIGA, and SHEEP.

GROUP TILLODONTIA.

Here may be noticed a remarkable group of animals, called by Marsh *Tillodontia*, the remains of which are found abundantly in the Lower and Middle Eocene beds of North America. They seem to combine the characters of the *Ungulata*, *Rodentia*, and *Carnivora*. In the genus *Tillotherium* of Marsh (probably identical with the previously described *Anchippodus* of Leidy) the skull resembled

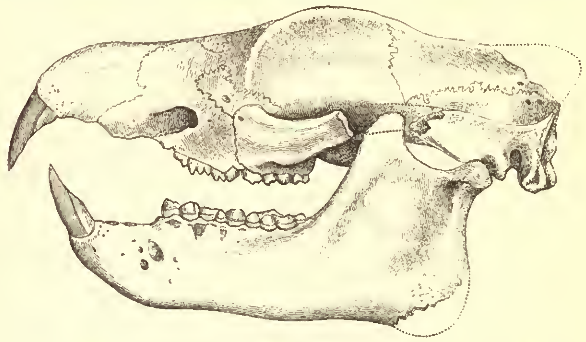


FIG. 115.—Skull of *Tillotherium fodiens*. ¼ nat. size. From Marsh.

that of the Bears, but the molar teeth were of the Ungulate type, while the large incisors were very similar to those of the Rodents. The skeleton resembled that of the Carnivores, but the scaphoid and lunar bones were distinct, and there was a third trochanter on the femur. The feet were plantigrade, and each had five digits, all with long pointed claws. In the allied genus *Stylinodon* all the teeth were rootless. Some were as large as a Tapir.

These, with other similar animals, constituting a group called *Tæniodonta*, are included by Cope in his large order *Bunotheria*, to which also the existing *Insectivora* are referred. The constantly increasing knowledge of these annectant forms adds to the difficulty so often referred to in this article of establishing anything like a definite classification of the heterodont mammals.

ORDER CARNIVORA.

Though the *Carnivora* as at present restricted[1] form a very natural and well-defined order among the *Mammalia*, it is difficult to find any important common diagnostic characters by which they can be absolutely separated; but, as in the case of so many other natural groups, it is by the possession of a combination of various characters that

[1] The *Feræ* of Linnæus included all the then known species of the modern orders *Carnivora*, *Insectivora*, and *Marsupialia*.

they must be distinguished. They are unguiculate, and have never less than four well-developed toes on each foot, with nails more or less pointed, rarely rudimentary or absent. The pollex and hallux are never opposable to the other digits. They are regularly diphyodont and heterodont, and their teeth are always rooted.[1] Their dentition consists of small pointed incisors, usually three in number, on each side of each jaw, of which the first is always the smallest and the third the largest, the difference being most marked in the upper jaw; strong conical, pointed, recurved canines; molars variable, but generally, especially in the anterior part of the series, more or less compressed, pointed, and trenchant; if the crowns are flat and tuberculated they are never complex or divided into lobes by deep inflexions of enamel. The condyle of the lower jaw is a transversely placed half-cylinder working in a deep glenoid fossa of corresponding form. The brain varies much in relative size and form, but the hemispheres are never destitute of well-marked convolutions. The stomach is always simple and pyriform. The cæcum is either absent or short and simple, and the colon is not sacculated or greatly wider than the small intestine. Vesiculæ seminales are never present. Cowper's glands are present in some, absent in other groups. The uterus is bicornuate. The mammæ are abdominal, and very variable in number. The placenta is deciduate, and almost always zonary. The clavicle is often entirely absent, and when present is never complete. The radius and ulna are distinct. The scaphoid and lunar bones are always united into one, and there is never a distinct os centrale in the adult. The fibula is always a distinct slender bone.

The large majority of the species composing this order subsist chiefly upon some variety of animal food, though many are omnivorous, and some few chiefly, though not entirely, vegetable eaters. The more typical forms live altogether on recently-killed warm-blooded animals, and their whole organization is thoroughly adapted to a predaceous mode of life. In conformity with this manner of obtaining their subsistence they are generally bold and savage in disposition, though some species are capable of being domesticated, and when placed under favourable circumstances for the development of such qualities exhibit a very high degree of intelligence and fidelity. The order is naturally divided into two suborders, the members of one being the more typical, and mainly terrestrial in their mode of life, while those of the other are aberrant, having the whole of their organization specially modified for living habitually in water. These are called respectively the True or Fissiped and the Pinniped *Carnivora*.

SUBORDER *CARNIVORA VERA* OR *FISSIPEDIA*.

Generally adapted for terrestrial progression and mode of life, though some may be partially aquatic in their habits. The fore limbs never have the first digit, or the hind limbs the first and fifth digits, longer than the others. Incisors $\frac{3}{3}$ on each side, with very rare exceptions. Cerebral hemispheres more or less elongated; always with three or four gyri on the outer surface forming arches above each other, the lowest surrounding the Sylvian fissure. The molar series of teeth have not the uniform characters of those of the *Pinnipedia*. There is always one tooth in each jaw which is specially modified, and to which the name of "sectorial" or "carnassial" tooth has been applied. The teeth in front of this are more or less sharp-pointed and compressed; the teeth behind it are broad and tuberculated. The characters of the sectorial teeth deserve special attention, as, though fundamentally the same throughout the suborder, they are greatly modified in different genera. The upper sectorial is the most posterior of the teeth which have predecessors, and is therefore reckoned as the last premolar ($\overline{p\ 4}$ of the typical dentition). It consists essentially of a more or less compressed

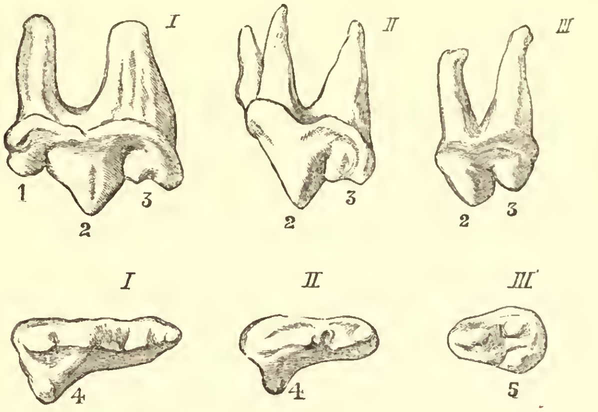


FIG. 116.—Upper Sectorial Teeth of *Carnivora*. I, *Felis*; II, *Canis*; III, *Ursus*. 1, anterior, 2, middle, and 3, posterior cusp of blade; 4, inner lobe supported on distinct root; 5, inner lobe, posterior in position, and without distinct root, characteristic of the *Ursidæ*.

blade supported on two roots and an inner lobe supported by a distinct root (see fig. 116). The blade when fully developed has three cusps (1, 2, and 3), but the anterior is always small, and often absent. The middle lobe is conical, high, and pointed; the posterior lobe has a compressed straight knife-like edge. The inner lobe (4) varies very much in extent, but it is generally placed near the anterior end of the blade, though sometimes it is median in position.

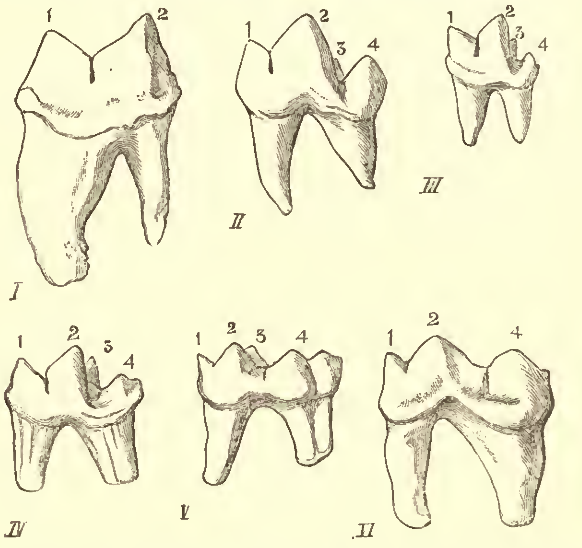


FIG. 117.—Modifications of the Lower Sectorial Tooth in *Carnivora*. I, *Felis*; II, *Canis*; III, *Herpestes*; IV, *Lutra*; V, *Meles*; VI, *Ursus*. 1, anterior lobe of blade; 2, posterior lobe of blade; 3, inner tubercle; 4, heel. It will be seen that the relative size of the two roots varies according to the development of the portion of the crown they have respectively to support.

In the *Ursidæ* alone both inner lobe and root are wanting, and there is often a small internal and posterior cusp (5) without root. In this aberrant family also the sectorial is relatively to the other teeth much smaller than in the rest of the *Carnivora*. The lower sectorial (see fig. 117) is the most anterior of the teeth without predecessors in the milk series; it is therefore reckoned the first true molar ($\underline{m\ 1}$). It has two roots supporting a crown, consisting when fully developed of a compressed bilobed blade (1 and 2), a heel (4), and an inner tubercle (3). The lobes of the blade, of which the hinder (2) is the larger, are separated by a notch,

[1] The tusks of the Walrus, altogether so aberrant in its dentition, are partial exceptions to this statement, but in old individuals the pulp cavity fills up, and they cease to grow.

generally prolonged into a linear fissure. In the most specialized *Carnivora*, as the *Felidæ* (I.), the blade alone is developed, both heel and inner tubercle being absent or rudimentary. In others, as *Meles* (V.) and *Ursus* (VI.), the heel is greatly developed, broad, and tuberculated. The blade in these cases is generally placed obliquely, its flat or convex (outer) side looking forwards, so that the two lobes are almost side by side, instead of anterior and posterior. The inner tubercle (3) is generally a conical pointed cusp, placed to the inner side of the hinder lobe of the blade. The special characters of these teeth are more disguised in the Sea Otter (*Enhydra*) than in any other form, but even in it they can be traced.

The toes are nearly always armed with large, strong, curved, and tolerably sharp claws, ensheathing the ungual phalanges, and held more firmly in their places by broad laminæ of bone reflected over their attached ends from the bases of the phalanges. In some forms, most notably the *Felidæ*, these claws are "retractile." The ungual phalanx, with the claw attached, folds back in the fore foot into a sheath by the outer or ulnar side of the middle phalanx of the digit, being retained in this position when the animal is at rest by a strong elastic ligament. In the hind foot the ungual phalanx is retracted on to the top, and not the side of the middle phalanx. By the action of the deep flexor muscles, the ungual phalanges are straightened out, the claws protruded from their sheath, and the soft "velvety" paw becomes suddenly converted into a most formidable weapon of offence. The habitual retraction of the claws preserves their points from wear in ordinary progression.

The Fissipedal *Carnivora* were divided by Cuvier into two groups, according to the position of the feet in walking,—the *Plantigrada*, or those that place the whole of the soles to the ground, and the *Digitigrada*, or those that walk only on the toes; and the difference between these groups was considered of equal importance to that which separated from them both the *Pinnigrada* or Seals. The distinction is, however, quite an artificial one, and every intermediate condition exists between the extreme typical plantigrade gait of the Bears and the truly digitigrade walk of the Cats and Dogs; in fact, the greater number of the *Carnivora* belong to neither one form nor the other, but may be called "subplantigrade," often when at rest applying the whole of the sole to the ground, but keeping the heel raised to a greater or less extent when walking.

A more natural classification is into three distinct sections, of which the Cats, the Dogs, and the Bears may be respectively taken as representatives, and which are hence called *Æluroidea*, *Cynoidea*, and *Arctoidea*. This division is founded mainly on characters exhibited by the base of the skull, but is corroborated by the structure of other parts.[1] The presence or absence of a bridge of bone, covering the external carotid artery in a part of its course by the side of the alisphenoid bone, and enclosing the "alisphenoid canal," a character to which the late Mr H. N. Turner first drew attention, might seem unimportant at first sight, but it is curiously constant in certain groups, which we have other reasons, derived often from a combination of less easily definable characters, to regard as natural. It is therefore generally mentioned in the following family definitions.

Section ÆLUROIDEA.

The *Æluroidea* or Cat-like forms include the *Felidæ*, *Viverridæ*, *Protelidæ*, and *Hyænidæ*.

[1] See W. H. Flower, "On the Value of the Characters of the Base of the Cranium in the Classification of the order *Carnivora*," *Proc. Zool. Soc.*, 1869, p. 4; St George Mivart, "On the Classification and Distribution of the *Æluroidea*," *ibid.*, 1882, p. 135; and Id., *The Cat, an Introduction to the Study of Backboned Animals, especially Mammals*, 1881.

Family FELIDÆ.

True molars reduced to one above and below, that of the upper jaw very small and transversely extended. Only two inferior premolars. Auditory bulla not externally constricted, but internally divided by a septum. No alisphenoid canal. Carotid canal very minute. Digits 5–4. Dorsal vertebræ 13.

Felis.—The whole structure of the animals of this genus exhibits the carnivorous type in its fullest perfection. Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{2}$, $m\ \frac{1}{1} = \frac{8}{7}$; total 30. The upper anterior premolar, always small, may sometimes be absent without any other modification in the dental or other structures. Such a variation should not therefore be considered as of generic importance. Incisors very small. Canines large, strong, slightly recurved, with trenchant edges and sharp points, and placed wide apart. Premolars compressed and sharp-pointed. The most posterior in the upper jaw (the sectorial) a very large tooth, consisting of a subcompressed blade, divided into three unequal cusps supported by two roots, with a very small inner lobe placed near the front end of the tooth and supported by a distinct root. The upper true molar a very small tubercular tooth placed more or less transversely at the inner side of the hinder end of the last. In the lower jaw the true molar (sectorial) reduced to the blade alone, which is very large, trenchant, and much compressed, divided into two subequal lobes. Occasionally it has a rudimentary heel, but never an inner tubercle. The skull generally is short and rounded, though proportionally more elongated in the larger forms. The facial portion is especially short and broad, and the zygomatic arches very wide and strong. The auditory bullæ are large, rounded, and smooth. Vertebræ: C 7, D 13, L 7, S 3, C 13–29. Clavicles better developed than in other *Carnivora*, but not articulating with either the shoulder bones or sternum. Limbs digitigrade. Anterior feet with five toes, the third and fourth nearly equal and longest, the second slightly and the fifth considerably shorter; the pollex still shorter, not reaching as far as the metacarpo-phalangeal articulation of the second. Hind feet with only four toes. The third and fourth the longest, the second and fifth somewhat shorter and nearly equal; the hallux represented only by the rudimentary metatarsal bone. The claws all very large, strongly curved, compressed, very sharp, and exhibiting the retractile condition in the highest degree. The tail varies greatly in length, being in some a mere stump, in others nearly as long as the body. Ears of moderate size, more or less triangular and pointed. Eyes rather large. Iris very mobile, and with a pupillary aperture which contracts under the influence of light in some species to a narrow vertical slit, in others to an oval, and in some to a circular aperture. Tongue thickly covered with sharp-pointed, recurved horny papillæ. Cæcum small and simple.

As in structure so in habits, the Cats may be considered the most specialized of all the *Carnivora*. All the known members of the genus feed, in the natural state, almost exclusively on warm-blooded animals which they have themselves killed. One Indian species (*F. viverrina*) is said to prey on fish and even freshwater molluscs. Unlike the Dogs, they never associate in packs, and rarely hunt their prey in open ground, but from some place of concealment wait until the unsuspecting victim comes within reach, or with noiseless and stealthy tread, crouching close to the ground for concealment, approach near enough to make the fatal spring. In this manner they frequently attack and kill animals considerably exceeding their own size. They are mostly nocturnal, and the greater number, especially the smaller species, more or less arboreal. None are aquatic, and all take to the water with reluctance, though some may habitually haunt the banks of rivers or pools, because they more easily obtain their prey in such situations. The numerous species of the genus are very widely diffused over the greater part of the habitable world, though most abundant in the warm latitudes of both hemispheres. No species are, however, found in the Australian region, or in Madagascar. Although the Old-World and New-World Cats (except perhaps the Northern Lynx) are all specifically distinct, no common structural character has been pointed out by which the former can be separated from the latter. On the contrary, most of the minor groups into which the genus has been divided have representatives in both hemispheres.

Notwithstanding the considerable diversity in external appearance and size between different members of this extensive genus, the structural differences are but slight, and so variously combined in different species that the numerous attempts hitherto made to subdivide it are all unsatisfactory and artificial. The principal differences are to be found in the form of the cranium, especially of the nasal and adjoining bones, the completeness of the bony orbit posteriorly, the development of the first upper premolar and of the inner lobe of the upper sectorial, the length of the tail, the form of the pupil, and the condition and coloration of the fur, especially the presence or absence of tufts or pencils of hair on the external ears. There is one decidedly aberrant form, which enables us to divide the genus into two sections, to which the rank of genera is sometimes accorded.

1. *Felis* proper.—A distinctly cusped inner lobe to the upper sectorial tooth. Claws completely retractile. There are about

fifty species, of which the following are the most important and best known.

A. *Old-World Species.*

For *F. leo*, see LION; and for *F. tigris*, see TIGER. With regard to *F. pardus*, the Leopard or Panther, it is still a matter of uncertainty whether the large spotted Cats to which these names are given, found chiefly in wooded districts through nearly the whole of Africa and the warmer parts of Asia as far as Japan, belong to one or several species. See LEOPARD. *F. uncia*, the Ounce, inhabits the highlands of Central Asia, from the snowy mountains of Tibet to the southern parts of Siberia, at altitudes of from 9000 to 18,000 feet above the sea. It is about the size of the common Leopard, but lighter in colour, with longer fur and less distinct spots. Its skull differs in shape from that of all the other *Felidæ*, the facial portion being very broad, the nasal bones especially being wide and depressed, and the zygomatic arches very strong and deep. *F. macroclis*, the Clouded Tiger, is a beautifully marked species, with elongated head and body, long tail, and rather short limbs. The canine teeth are proportionally longer than in any existing member of the genus. It is thoroughly arboreal, and is found in the forests of south-east Asia and the islands of Sumatra, Java, Borneo, and Formosa. *F. serval*, the Serval, from South Africa, is yellow with black spots, and has a short tail and large ears. Numerous smaller species called Tiger Cats and Wild Cats, many of them by no means clearly defined zoologically, are found throughout the warmer parts of Asia and Africa. The Wild Cat of Europe, *F. catus*, still inhabits the mountainous and wooded parts of Great Britain. The Domestic Cat is an introduced species, and generally supposed to be derived from *F. maniculata* of Egypt and Syria. Moderate-sized Cats, with short tails, rather long limbs, especially the hinder ones, and tufts or pencils of hair on their ears, are called Lynxes. See LYNX.

B. *New-World Species.*

F. concolor, the Puma or Couguar, commonly called "Panther" in the United States, is about the size of a Leopard, but of an uniform brown colour, spotted only when young, and is extensively distributed in both North and South America, ranging between the parallels of 60° N. and 50° S. *F. onca*, the Jaguar, is a larger and more powerful animal than the last, and more resembles the Leopard in its colours. It also is found in both North and South America, but with less extensive range, reaching northwards only as far as Texas, and southwards nearly to Patagonia. See JAGUAR. *F. pardalis*, and several allied smaller elegantly-spotted species inhabiting the intratropical regions of America, are commonly confounded under the name of Ocelot or Tiger Cat. *F. yaguarundi*, rather larger than the Domestic Cat, with an elongated head and body, and of a uniform brownish-grey colour, ranges from Matamoras to Paraguay. *F. eyra* is a small Cat, very Musteline in form, having an elongated head, body, and tail, and short limbs, and is also of a uniform light reddish-brown colour. It is a native of South America and Mexico. *F. pajeros* is the Pampas Cat. Four species of Lynx are described from North America, but it is doubtful whether these are specifically distinct from each other and from the Lynx of northern Europe.

2. *Cynælurus.*—Sometimes considered as a distinct genus. The Cheetah or Hunting Leopard, *F. jubata*, is distinguished from the other *Felidæ* by the inner lobe of the upper sectorial, though supported by a distinct root, having no salient cusp upon it, by the tubercular molar being more in a line with the other teeth, and by the claws being smaller, less curved, and less completely retractile, owing to the feebler development of the elastic ligaments. The skull is short and high, with the frontal region broad and elevated in consequence of the large development of the frontal air-sinuses. The head is small and round, the body light, the limbs and tail long. Its colour is pale yellowish-brown with small black spots. The Cheetah is less savage and more easily tamed than most of the Cats. In Asia it has been trained for the chase of the Antelope. It has rather an extensive geographical range from the Cape of Good Hope, throughout Africa and the south-western parts of Asia, as far as southern India.

Fossil Felidæ.—Numerous extinct species of the genus are found in Pleistocene, Pliocene, and even later Miocene deposits in Europe, Asia, and America. Among them is the Cave Lion, *F. spelæa*, which can scarcely be separated specifically from *F. leo*, and of which abundant remains are found in caves in England and other parts of Europe. *F. cristata*, from the Siwalik Hills, intermediate in size between a Tiger and Jaguar, is distinguished from the other *Felidæ* by the shortness of the face as compared with the cranial part of the skull. These and many others, mostly of smaller size, present no greater modifications of form than the various existing members of the genus *Felis*, and can therefore be properly included within its limits; but numerous other forms are gradually becoming known, especially through the researches of American palæontologists, which, though evidently animals of the same general type and therefore to be included in the family *Felidæ*, depart so much in various details of structure that they must be placed in different genera. As one of the points in which *Felis* manifests its specialization is the reduction of the number of the molar series of teeth, with concomitant shortening of the jaws, it might be supposed that in the earlier and perhaps ancestral forms these teeth would be more numerous and approach more nearly to the primitive or typical number of the heterodont mammals, viz., seven on each side. This is actually the case. One European form (also recently found in America) to which Gervais has given the name of *Pseudælurus*, of Miocene age, has the dentition of *Felis* with an addition of one premolar in the lower jaw; but others have a still larger number, as *Archælurus debilis* of Cope from the American Miocene, about the size of a Panther, which has four premolars and a tubercular molar in the upper jaw, and three premolars and two molars in the lower jaw. A tubercular molar in the lower jaw, behind the sectorial, also occurs in *Ælurogale*, *Dinictis*, and *Nimravus*. Another tendency to generalization is the existence in some forms, as *Hoplophoneus*, of a posterior lobe or heel to the inferior sectorial, found in nearly all Carnivores except the existing *Felidæ*. On the other hand some of the extinct *Felidæ* show a most remarkable tendency towards a specialization not occurring in any of the surviving members of the family, viz., an enormous development of the upper canines, with which is usually associated an expansion downwards and flattening of the anterior part of the ramus of the lower jaw, on the outer side of which the canine lies, when the mouth is closed. In *Smilodon nœogeus*, the Sabre-toothed Tiger, from the caves of Brazil and also from Pleistocene deposits near Buenos Ayres, an animal about the size of a Tiger, these teeth are 7 inches in length, greatly compressed, and finely serrated on the trenchant anterior edges. Similar serrations are seen on a much fainter scale in the unworn teeth of modern Tigers. Many modifications of this commonly-called "machærodont" type have been met with both in the Old and New World to which the names of *Machærodus*, *Drepanodon*, *Smilodon*, *Hoplophoneus*, *Dinictis*, *Pogonodon*, &c., have been given. A very remarkable form, *Eusmilus*, differs from all other known Felines in having only four incisors in the lower jaw, and a pair of small canines separated by a very long diastema from the next teeth, which consist only of one premolar and one sectorial true molar. The lower jaw is enormously expanded towards the symphysis to protect the large upper canines. This animal then, although of Eocene age, appears to form the culminating development of the sabre-toothed or machærodont dentition, the most specially carnivorous type of structure known.

Cope divides all the known Feline animals into two families, *Felidæ* and *Nimravidæ*,[1] distinguished by the characters of the foramina at the base of the cranium, the former being of more modern origin than the latter, the members of which are all extinct, and which seem to connect the Cats with still more primitive types of *Carnivora*.

Family VIVERRIDÆ.

Premolars $\frac{3}{3}$ or $\frac{4}{4}$. Molars $\frac{1}{1}$ or $\frac{2}{2}$. Auditory bulla externally constricted, and divided by a septum. An alisphenoid canal (with very rare exceptions). Carotid canal distinct as a groove on the side of the bulla. Digits usually 5–5, but sometimes the pollex or hallux or both may be wanting. Dorsal vertebræ 13 or 14. Limited in distribution to the Old World.

The subfamily **Cryptoproctinæ** contains the single genus *Cryptoprocta*. Dentition: $i\ \frac{3}{3},\ c\ \frac{1}{1},\ p\ \frac{4}{4},\ m\ \frac{1}{1} = \frac{9}{9}$; total 36. The teeth generally closely resemble those of the *Felidæ*. The first premolar of both jaws is very minute and early deciduous. The upper sectorial has a very small inner lobe, quite at the anterior part of the tooth. The true molar is very small and placed transversely. The lower sectorial has a large trenchant bilobed blade, and a very minute heel, but no inner tubercle. Skull generally like that of *Felis*, but proportionately longer and narrower. Orbit widely open behind. Vertebræ: C 7, D 13, L 7, S 3, C 29. Body elongated. Limbs moderate in size. Feet subplantigrade; five well-developed toes on each, with sharp, compressed, retractile claws. Ears moderate. Tail long and cylindrical.

The only known species, *C. ferox*, the "Foussa" of the Malagasy, is peculiar to Madagascar, being the largest carnivorous animal in the island. It is about twice the size of the common Cat (5 feet from nose to end of tail), with short close fur of nearly uniform pale brown. Little is as yet known of its habits, except that it is nocturnal, frequently attacks and carries off goats, and especially kids, and shows great ferocity when wounded, on which account it is much dreaded by the natives.

The remaining numerous specific and generic modifications found in the existing animals belonging to this family seem to group themselves mainly into two tolerably distinct groups, distinguishable by the characters of the auditory bulla and neighbouring parts of the base of the skull, and by the structure of the feet. The one form has the genus *Viverra* or Civet Cats for its most typical representative, and the other *Herpestes* or the Ichneumons.

Subfamily **Viverrinæ**.—Auditory bulla oval or rather conical, broad and truncated and not everted behind, narrow in front and

[1] "On the Extinct Cats of America," *American Naturalist*, December 1880.

more or less compressed at the sides. The outer or anterior chamber very small and flat. The meatus with scarcely any inferior lip, its orifice being close to the tympanic ring. Paroccipital process triangular, its apex projecting slightly beyond the bulla. Claws strongly curved and more or less retractile.

Viverra.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{2}{2} = \frac{10}{10}$; total 40. Skull elongated; facial portion small and compressed. Orbits well-defined but incomplete behind. Vertebræ: C 7, D 13, L 7 (or D 14, L 6), S 3, C 22–30. Body elongated and compressed. Head pointed in front; ears rather small. Extremities short. Feet small and rounded. Toes short, five on each foot. First toe both on fore and hind feet much shorter than the others. Palms and soles covered with hair, except the pads of the feet and toes, and in some species a narrow central line on the under side of the sole, extending backwards nearly to the heel. Tail moderate or long. A pair of large glandular follicles situated on the perineum (in both sexes), and secreting in most species an oily substance of a peculiarly penetrating odour.

The numerous species of this genus form a large series, the two extremes of which differ considerably, but the several sections into which they may be divided blend so into one another that it is difficult to differentiate them sharply. (1) *Viverra* proper. This includes the largest species. The teeth are stouter and less compressed than in the other sections. The second upper molar especially larger. The auditory bulla smaller and more pointed in front. Body shorter and stouter; limbs longer; tail shorter, tapering. Under side of tarsus completely covered with hair. Claws longer and less retractile. Fur rather long and loose, and in the middle line of the neck and back especially elongated so as to form a sort of crest or mane. Pupil circular when contracted. Perineal glands greatly developed. These characters apply especially to *V. civetta*, the African Civet, or "Civet Cat" as it is commonly called, an animal rather larger than a common Fox, and an inhabitant of intratropical Africa. *V. zibetta*, the Indian Civet, of about equal size, approaches in many respects, especially in the characters of the teeth and feet and absence of the crest of elongated hair on the back, to the next section. It inhabits Bengal, China, the Malay Peninsula, and adjoining islands. *V. tangalunga* is a smaller but nearly allied animal from the same part of the world. From these three species and the next the civet of commerce, once so much admired as a perfume in England, and still largely used in the East, is obtained. The animals are kept in cages, and the odoriferous secretion collected by scraping the interior of the perineal follicles with a spoon or spatula. (2) *Viverricula.* This section resembles generally the next, but with the whole of the under side of the tarsus hairy. Alisphenoid canal generally absent. *V. malaccensis*, the Rasse, inhabiting India, China, Java, and Sumatra, is an elegant little animal, which affords a favourite perfume to the Javanese. (3) *Genetta.* The Genettes are smaller animals, with more elongated and slender bodies, and shorter limbs than the Civets. Skull elongated and narrow. Auditory bulla large, elongated, rounded at both ends. Teeth compressed and sharp-pointed; a lobe on the inner side of the third upper premolar not present in the previous section. Pupil contracting to a linear aperture. Tail long, slender, ringed. Fur short and soft, spotted or cloudy. Under side of the tarso-metatarsus with a narrow longitudinal bald streak. *V. genetta*, the common Genette, is found in France south of the river Loire, Spain, south-western Asia, and Africa from Barbary to the Cape. *V. felina*, *senegalensis*, *tigrina*, and *pardalis* are other named species, all African in habitat. (4) *Fossa.* *V. fossa*, from Madagascar, may belong to a distinct section or genus, but its structure is very imperfectly known. (5) In some of the smallest species the second upper molar (already reduced to very small dimensions in the Genettes) is absent; in other respects their dentition agrees with section 3. *V. gracilis* and *V. pardicolor*, both from southern Asia, constitute the genus *Prionodon* of Horsfield; *V. richardsonii*, from West Africa, the genus *Poiana* of Gray. The former has the back of the tarsus hairy, the latter has a narrow naked streak as in the Genettes.

All the animals of this genus are, for their size, extremely active, fierce, and rapacious. They feed chiefly on small mammals and birds.

Arctictis.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{2}{2} = \frac{10}{10}$; total 40. The posterior upper molar and the first lower premolar very often absent. Molar teeth generally small and rounded, with a distinct interval between every two, but formed generally on the same pattern as *Parodoxurus.* Vertebræ: C 7, D 14, L 5, S 3, C 34. Body elongated. Head broad behind, with a small pointed face. Whiskers long and numerous. Ears small, rounded, but clothed with a pencil of long hairs. Eyes small. Limbs short. Soles and palms broad, entirely naked. Tail very long and prehensile. Fur long and harsh. Cæcum extremely small. But one species is known, *A. binturong*, the Binturong, an inhabitant of southern Asia from Nepal through the Malay Peninsula to the islands of Sumatra and Java. Although structurally agreeing closely with the Paradoxures, its tufted ears, long, coarse, and dark hair, and prehensile tail give it a very different external appearance. It is slow and cautious in its movements, chiefly if not entirely arboreal, and appears to feed on vegetable as well as animal substances.

Paradoxurus.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{2}{2} = \frac{10}{10}$; total 40. The blunt and rounded form of the cusps of the hinder premolar and the molar teeth distinguishes this genus from most of the members of the family. Vertebræ: C 7, D 13, L 7, S 3, C 29–36. Head pointed in front. Ears small, rounded. Body long. Limbs moderate. Palms and soles almost entirely naked. Claws completely retractile. Tail long, non-prehensile. The Paradoxures or Palm-Civets are less strictly carnivorous than the other members of the family. They are mostly about the size of the common Cat, or rather larger, and are partly arboreal in their habits. The species are rather numerous, and present considerable variations in the details of the form and size of their molar teeth. They are restricted geographically to southern Asia and the Indo-Malayan archipelago. The best known species are *P. bondar*, *P. zeylanicus*, *P. typus*, *P. musanga*, *P. larvata*, and *P. grayi*. *P. virgata* has been separated from the others, and raised into a distinct genus, *Arctogale*, on account of the smallness of the teeth and the elongation of the bony palate. Otherwise it seems not to differ from the others.

Nandinia contains one species, *N. binotata*, a somewhat aberrant Paradoxure, from West Africa. It is rather smaller than the true Paradoxures, has smaller and more pointed molar teeth, and no cæcum. The wall of the inner chamber of the auditory bulla remains through life unossified.

Hemigalea, another modification of the Paradoxure type, contains one species, *H. hardwickii*, from Borneo, an elegant-looking animal, smaller and more slender than the Paradoxures, of light grey colour, with transverse broad dark bands across the back and loins.

Cynogale also contains one species, *C. bennettii*, Gray (described by S. Müller under the name of *Potamophilus barbatus*), from Borneo. This is a curious Otter-like modification of the Viverrine type, having semi-aquatic habits, both swimming in the water and climbing trees, living upon fish, crustacea, small mammals, birds, and fruit. The number and general arrangement of its teeth are as in *Paradoxurus*, but the premolars are peculiarly elongated, compressed, pointed, and recurved, somewhat as in the Seals, though the molars are tuberculated. The head is elongated, the muzzle broad and depressed. Whiskers very long and abundant. Ears small and rounded. Toes short and slightly webbed at the base. Tail short, cylindrical, covered with short hair. Fur very dense and soft, of a dark brown colour, mixed with black and grey.

Subfamily **Herpestinæ.**—Auditory bulla very prominent, and somewhat pear-shaped, the posterior chamber being large, rounded, and generally with its greatest prominence to the outer side. The anterior chamber considerably dilated, and produced into a short inferior wall to the auditory meatus, in which is a depression or vacuity just below the centre of the opening of the meatus. Sometimes this vacuity is continued into the meatus, forming a narrow fissure. The paroccipital process does not project beyond the bulla, but is spread out and lost (in adult animals) on its posterior surface. Toes straight; claws lengthened, exserted, non-retractile.

Herpestes.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, sometimes $\frac{3}{3}$, $m\ \frac{2}{2}$; 40 or 36. Teeth of molar series generally with strongly-developed, sharply-pointed cusps. Skull elongated, constricted behind the orbits. Face short and compressed. Frontal region broad and arched. Post-orbital processes of frontal and malar bones well-developed, generally meeting so as to complete the circle of the orbit behind. Vertebræ: C 7, D 13, L 7, S 3, C 21–26. Head pointed in front. Ears short and rounded. Body very long and slender. Extremities short. Five toes on each foot, the first, especially that on the hind foot, very short. Toes free, or but slightly palmated. Palms naked. Distal portion of soles naked, under surface of tarsus and metatarsus clothed with hair. Tail long or moderate, generally thick at the base, and sometimes covered with more or less elongated hair. The longer hairs covering the body and tail almost always annulated. This genus contains a very large number of animals commonly called Ichneumons, or in India Mongooses, varying in size from that of a large Cat down to a Weasel. They are widely distributed over the African continent and the southern parts of Asia, especially India and the Indo-Malayan archipelago, one species occurring also in Spain. They are mostly terrestrial in their habits, feeding on small mammals and birds, reptiles, especially snakes, eggs of birds and reptiles, and also insects. Some species are partially domesticated, being used to keep houses clear of rats, mice, and snakes. *H. ichneumon* was a sacred animal to the ancient Egyptians. They vary considerably in appearance, some, as *H. galera* (also called *paludinosus* and *robustus*), are larger and heavier, with stouter body, longer limbs, and stronger teeth. Others are small, with very elongated bodies and short legs. The tail also varies somewhat in length, and in the amount of hair with which it is covered. These trivial differences have given rise to the formation by some zoologists of very numerous genera, the characters of which are by no means clearly defined, but the following are the most distinct and generally recognized.

Helogale, premolars $\frac{3}{3}$, contains two small South-African species, *H. parvula* and *H. undulata*.

Bdeogale contains also two small Ichneumon-like animals, *B. crassicauda* and *puisa*, differing from *Herpestes* proper in having only four toes on each foot, both pollex and hallux being absent. The orbit is nearly complete, the tail of moderate length and rather bushy.

Cynictis.—Pollex present, but hallux absent. Skull shorter and broader than in *Herpestes*, rather contracted behind the orbits, which are large and complete behind. Face short. Anterior chamber of the auditory bulla very large. Front claws elongated. *C. penicillata*, from South Africa.

All the foregoing Herpestines have the nose short, with its under surface flat, bald, and with a median longitudinal groove. The remaining forms have the nose more or less produced, with its under side convex, and a space between the nostrils and the upper lip covered with close adpressed hairs, and without any median groove.

Rhinogale.—Toes 5–5. Claws of fore feet short, compressed, acute. Under surface of tarsus hairy. Founded on a single specimen from East Africa, *R. melleri*.

Crossarchus.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{2}{2}$; total 36. Snout elongated. Toes 5–5. Claws on fore feet long and curved. Hallux very short. Under surface of tarsus naked. Tail shorter than the body, tapering. Fur harsh. Species: *C. obscurus*, the Kusimanse, a small burrowing animal from West Africa, of uniform dark-brown colour; *C. fasciatus*; *C. zebra*; *C. gambianus*.

Suricata.—A more distinct genus than any of the above. The dental formula as in the last, but the teeth of the molar series remarkably short in the antero-posterior direction, corresponding with the shortness of the skull generally. Orbits complete behind. Vertebræ: C 7, D 15, L 6, S 3, C 20. Though the head is short and broad, the nose is pointed and rather produced and movable. Ears very short. Body shorter and limbs longer than in *Herpestes*. Toes 4–4, the pollex and hallux being absent. Claws on fore feet very long and narrow, arched, pointed, and subequal. Hind feet with much shorter claws, soles hairy. Tail rather shorter than the body. One species only is known, the Suricate, *S. tetradactyla*, a small grey-brown animal, with dark transverse stripes on the hinder part of the back, from South Africa.

Galidictis, *Galidea*, and *Hemigalidia* are names of three slight generic modifications of the Viverrine type, allied to the *Herpestinæ*, but placed by Mivart in a distinct subfamily, *Galidictinæ*. They are all inhabitants of Madagascar. The best-known, *Galidia elegans*, is a lively Squirrel-like little animal with soft fur and a long bushy tail, which climbs and jumps with agility. It is of a chestnut-brown colour, the tail being annulated with darker brown. *Galidictis vittata* and *striata* chiefly differ from the Ichneumons in their coloration, being grey with parallel longitudinal stripes of dark brown.

Eupleres is another form, also from Madagascar, which has been placed in a subfamily apart. It differs remarkably from all the other *Viverridæ* in the weak development of the jaws and the small

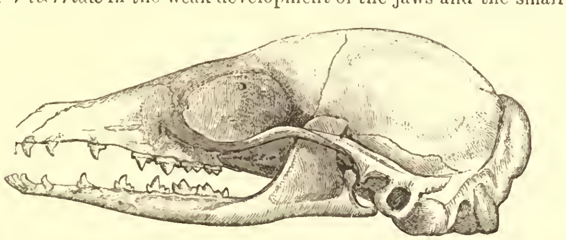


FIG. 118.—Skull of *Eupleres goudoti*. $\frac{4}{5}$ nat. size. Mus. Roy. Coll. Surgeons.

size of the teeth, in consequence of which it was, when first discovered, placed inthe order *Insectivora*. Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{2}{2} = 40$. Vertebræ: C 7, D 13, L 7, S 3, C 20. But one species is known, *E. goudoti*.

Family HYÆNIDÆ.

No alisphenoid canal. Dorsal vertebræ 15. Molars $\frac{1}{1}$. Limited to the Old World.

Subfamily **Protelidæ.**—Auditory bulla divided into two distinct chambers. Premolar and molar teeth very small and simple in character.

This group contains but a single species, belonging to the genus *Proteles*, *P. cristatus*, the Aard-Wolf or Earth-Wolf of the Dutch colonists of the Cape, an animal nearly allied to the Hyænas, but remarkably modified in its dentition, the molar teeth being very small, placed far apart, and almost rudimentary in character (see fig. 119). The canines are long and rather slender. The dental formula is $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, p and $m\ \frac{4}{3\text{ or }4} = \frac{8}{7\text{ or }8}$; total 30 or 32. Vertebræ: C 7, D 15, L 5, S 2, C 24. The fore feet with five toes; the pollex, though short, with a distinct claw. The hind feet with four subequal toes. Claws all strong, blunt, subcompressed, and non-retractile. The general external appearance is very like that of a small striped Hyæna, but the muzzle is more pointed and the ears larger. It has a copious mane of long hair, capable of being

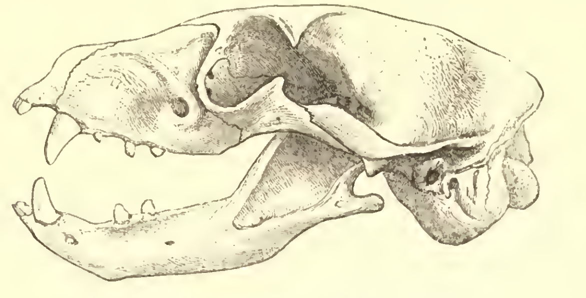


FIG. 119.—Skull and Dentition of *Proteles cristatus*. × $\frac{1}{2}$. Mus. Roy. Coll. Surgeons.

erected, when the animal is excited, along the middle line of the neck and back. It is a native of South Africa, and is a burrowing nocturnal animal, feeding on decomposing animal substances, larvæ, and termites. Observations upon specimens in captivity indicate that it has neither inclination nor power to attack or feed upon living vertebrated animals.

Subfamily **Hyænidæ.**—Auditory bulla not divided by a septum into two chambers.

Hyæna.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{3}$, $m\ \frac{1}{1} = \frac{9}{8}$; total 34. Teeth, especially canines and premolars, very large, strong, and conical. Upper sectorial with a very large, distinctly trilobed blade and a moderately developed inner lobe placed at the anterior extremity of the blade. Molar very small, and placed transversely close to the hinder edge of the last, as in the *Felidæ*. Lower sectorial consisting of little more than the bilobed blade. Zygomatic arches of cranium very wide and strong. Sagittal crest high, giving attachment to very powerful biting muscles. Orbits incomplete behind. Vertebræ: C 7, D 15, L 5, S 4, C 19. Limbs rather long, especially the anterior pair, digitigrade, four subequal toes on each, with stout non-retractile claws. Pollex and hallux only represented by rudimentary metacarpal and metatarsal bones. Tail rather short. A large post-anal median glandular pouch, into which the largely developed anal scent glands pour their secretion.

The three existing species of Hyæna (see HYÆNA) are divisible into two sections to which some zoologists assign generic rank.

1. Upper molar moderately developed and three-rooted. An inner tubercle and heel more or less developed on the lower molar. Ears large, pointed. Hair long, forming a mane on the back and shoulders. *H. striata*, the Striped Hyæna, of northern Africa and southern Asia. *H. brunnea*, of south Africa, in some respects intermediate between this and the next section. 2. Genus *Crocuta*. Upper molar extremely small, two- or one-rooted, often deciduous. Lower molar without trace of inner tubercle, and with an extremely small heel. Ears moderate, rounded. Hair not elongated to form a mane. *H. crocuta* or *Crocuta maculata*, the Spotted Hyæna, from Africa south of the Sahara. In dental characters the first section inclines more to the *Viverridæ*, the second to the *Felidæ*; or the second may be considered as the more specialized form, as it certainly is in its visceral anatomy, especially in that of the reproductive organs of the female.[1]

Extinct Hyænidæ.—Hyænas abounded in Europe from the Upper Miocene to the Pleistocene epoch, and a series of transitional forms from ancient generalized types merging into *Viverridæ*, as *Ictitherium* and *Hyænictis* (with additional tubercular molars), leading by gradual modifications during successive geological ages to the species now existing, have been traced by Gaudry. The Cave Hyæna (*H. spelæa*), once so abundant in Britain and other parts of Europe, is scarcely distinguishable specifically from the existing *H. crocuta* of Africa; and extinct forms found in France, described under the names of *H. prisca* and *H. arvernensis*, are probably the ancestors of *H. striata*. The existing *H. brunnea* seems to have preserved the characters of *H. eximia* of the Upper Miocene of Pikermi in Greece with little modification. There is at present no evidence of the existence of this group in America.

Section CYNOIDEA.

This section contains a single family, *Canidæ*, or Dog-like animals, which appear to hold an intermediate position between the other two sections, retaining also many of the more generalized characters of the ancient members of the order. The structure of the auditory bulla and adjacent parts of the bones of the skull is

[1] The anatomical peculiarities of *Hyæna crocuta* have been fully elucidated in a series of papers by Morrison Watson, in the *Proceedings of the Zoological Society* for 1877, 1878, 1879, and 1881, in which references to previous authors on the subject will be found.

quite intermediate between that of the Æluroid and Arctoid forms. In the number and arrangement of the teeth they more nearly approach the primitive heterodont type than any other existing *Carnivora*. A cæcum is always present, sometimes short and simple, but when long it is folded upon itself in a characteristic manner.

The Dogs form a very compact group, composed of numerous species which closely resemble each other in essential characters, though differing considerably externally. The most marked differences are a slight variation in the number of the true molar teeth, which exceed the usual number in the Cape Long-eared Fox (*Otocyon*), and fall short of it in some other less aberrant forms to which the names of *Icticyon* and *Cyon* have been given, and a diminution in the number of toes in the Cape Hunting Dog (*Lycaon*), which has 4–4, instead of 5–4 as in the remainder of the family. After taking these away, there remain a great number of animals called Dogs, Wolves, Jackals, and Foxes, varying from one another only in the characters of the tail, ears, fur, form of the pupil, and some trifling peculiarities of skull and teeth, upon which some authors have divided them into many genera. These divisions are, however, extremely difficult, if not impossible, to define, on account of the numerous gradual transitions from one form to the other.

Canis.—Pending further investigation, it will perhaps be safest to retain all the species, with the exceptions of *Otocyon* and *Lycaon* mentioned above, in the old genus *Canis*, the most prominent characters of which are the following. Teeth, usually $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{2}{3} = \frac{10}{11}$; total 42. The absence of the last upper molar ($\underline{m\ 3}$), alone distinguishes this from the generalized dentition of heterodonts (see p. 353), and this tooth is occasionally present in one species (*C. cancrivorus*). In certain Asiatic species (*C. primævus* and its allies), which on this account have been separated to form the genus *Cyon* of Hodgson, the last lower molar ($\overline{m\ 3}$) appears to be constantly absent, and in *C. venaticus* (genus *Icticyon*, Lund) not only this but also $\underline{m\ 2}$ is usually not developed. The milk dentition is $di\ \frac{3}{3}$, $dc\ \frac{1}{1}$, $dm\ \frac{3}{3} = \frac{7}{7}$; total 28,—the first permanent premolar having no predecessor. The teeth of both permanent and milk or temporary series are figured at p. 353 (fig. 3). The upper sectorial $\underline{p\ 4}$ consists of a stout blade, of which the anterior cusp is almost obsolete, the middle cusp large, conical, and pointed backwards, and the posterior cusp in the form of a compressed ridge; the inner lobe is very small, and placed quite at the fore part of the tooth. The first molar is more than half the antero-posterior length of the sectorial, and considerably wider than it is long; its crown consists of two prominent conical cusps, of which the anterior is the larger, and a low broad inward prolongation, supporting two more or less distinct cusps and a raised inner border. The second molar resembles the first in general form, but is considerably smaller. The lower sectorial $\overline{m\ 1}$ is a very large tooth, with a strong compressed bilobed blade, the hinder lobe being considerably the larger and more pointed, a small but distinct inner tubercle placed at the hinder margin of the posterior lobe of the blade, and a broad, low, tuberculated heel, occupying about one-third of the whole length of the tooth. The second molar is less than half the length of the first, with a pair of cusps placed side by side anteriorly, and a less distinct posterior pair. The third is an extremely small and simple tooth with a subcircular tuberculated crown and single root.

The cranium is more or less elongated, the facial portion tapering forwards and compressed. The jaws elongated. The zygomata moderately strong. The post-orbital processes of the frontal short, leaving the orbit widely open posteriorly. Vertebræ: C 7, D 13, L 7, S 3, C 17–22. Clavicles present, but very rudimentary. Limbs of moderate proportions, digitigrade. Feet short; five toes on the fore foot, the pollex much shorter than the others, and not reaching to the ground. Four toes on the hind foot, the hallux being represented by a rudiment of the metatarsal.[1] All the toes are provided with exserted non-retractile slightly curved and blunt claws, which, being exposed, become worn at the tips. Tail moderate, or rather long, generally somewhat bushy. The pupil of the eye, when contracted, is in some species round, in others elliptical and vertical.

This extensive genus may be considered as truly cosmopolitan. One or more species are found throughout the American continent from Greenland to Patagonia and the Falkland Isles; and similarly, in the Old World, Europe, Africa, and Asia, with most of the large islands adjacent, and even Australia, have their wild Dogs, though in the last case they probably belong to a feral race, introduced originally by man. They are generally sociable animals, hunting their prey in packs. Many species burrow in the ground; none habitually climb trees. Though mostly carnivorous, feeding chiefly on animals they have chased and killed themselves, many, especially among the smaller species, eat garbage, carrion, insects, and also fruit, berries, and other vegetable substances. The species are very numerous, and, as in most other large genera, very ill-defined, few zoologists agreeing as to which of the many slightly different modifications may be considered as local varieties and which true species. Perhaps the best cranial character by which the different members of the genus can be distinguished is that pointed out by Burmeister, viz., that in the animals generally called Dogs, Wolves, and Jackals the post-orbital process of the frontal bone is regularly smooth and convex above, with its extremity bent downwards, whereas in Foxes the process is hollowed above, with its outer margin (particularly of the anterior border) somewhat raised. This modification coincides in the main with that upon which Professor Huxley has recently[2] based his division of the group into two parallel series, the Thooids or Lupine forms and Alopecoids or Vulpine forms, which he characterizes by the presence of frontal air-sinuses in the former, which not only affects the external form but to a still greater degree the shape of the anterior part of the cranial cavity, and the absence of such sinuses in the latter. The pupil of the eye when contracted is round in most members of the first group, and vertically elliptical in the others, but more observations are required before this character can be absolutely relied upon. The form and length of the tail is often used for the purposes of classification, but its characters do not coincide with those of the cranium, as many of the South American *Canidæ* have the long bushy tails of Foxes and the skulls of Wolves. Taking into account various combinations of these and other minor characters, the species may be arranged in the following groups, which some authors have considered as of generic importance.

A. *Thooid or Lupine Series.*

(1) *Canis* proper contains the largest members of the genus, the true Wolves of the northern parts of both Old and New Worlds (*C. lupus*, &c.), the Jackals of southern Asia and Africa (*C. aureus*, *mesomelas*, &c.), and the various breeds of the domestic Dog (*C. familiaris*), the origin of which is still involved in obscurity. Some naturalists believe it to be a distinct species, descended from one that no longer exists in a wild state; others have sought to find its progenitors in some one of the wild or feral races, either of true Dogs, Wolves, or Jackals; while others again believe that it is derived from the mingling of two or more wild species or races. It is probably the earliest animal domesticated by man, and few if any other species have undergone such an extraordinary amount of variation in size, form, and proportion of limbs, ears, and tail, variations which have been perpetuated and increased by careful selective breeding. See DOG. The Dingo or Australian Dog is met with wild, and also as the domestic companion of the aboriginal people. Dogs were also in the possession of the natives of New Zealand and other islands of the Pacific, where no placental mammals exist naturally, on their discovery by Europeans in the last century. (2) *Cyon*, wild Dogs of the south-east of Asia, distinguished by slight modifications as *C. primævus*, *C. dukhenensis*, and *C. sumatrensis*, differ from the above in wanting the small last lower tubercular molar. (3) *Lycalopex* is a group formed of certain South-American *Canidæ*, distinguished from *Canis* proper by their longer tails and Fox-like aspect:—*C. cancrivorus*, *C. brasiliensis*, *C. melampus*, *C. vetulus*, *C. fulvicaudus*, *C. azaræ*, *C. megellanicus*, *C. griscus*. The last three have been further separated (under the name of *Pseudalopex*) on account of slight differences in the relative size of the molar teeth, and of their pupil being elliptical when contracted. (4) *Nyctereutes* (one species, *C. procyonides*, from Japan and north-east Asia) has no claims to generic distinction but such as are founded upon its long loose fur, short ears, and short bushy tail, which give it some superficial resemblance to a Raccoon. (5) *Icticyon*, with one small species, *C. venaticus*, the Bush Dog, from Guiana and Brazil, with close hair, and short legs and tail, has more reason to be regarded as a distinct form, as it is distinguished from all other Dogs by the reduction of its molar teeth to $\frac{1}{2}$, and their comparatively small size. In consequence of this, and its general external characters, it was formerly placed among the *Mustelidæ*, but its Canine affinities have now been thoroughly established.

B. *Alopecoid or Vulpine Series.*

(6) *Vulpes*, true Foxes. The species or varieties are numerous and widely spread over North America, Eurasia, and Africa:—*C. vulpes*, the common Fox of Europe; *C. niloticus*, *adustus*, and *variegatus*, Africa; *C. flavescens*, *montanus*, *bengalensis*, *japonicus*, *corsæ*, Asia; *C. fulvus*, *macrourus*, *velox*, North America. The tail of the above is clothed with soft fur and long hair, uniformly mixed; from them Baird distinguishes, under the name of *Urocyon*, other species which have a concealed erect mane of stiff hairs along the upper line of the tail. These have also a shorter muzzle and a wide space between the temporal crests; they are *C. virginianus* and *C. littoralis*, both from North America. The Arctic Fox (*C. lagopus*, genus *Leucocyon*, Gray) has the tail very full and bushy and the soles of the feet densely furred below. Its colour changes according to season from bluish-grey to pure white. (7) *Fenneccus*. Certain small elegant African Foxes (*C. cerdo*, *famelicus*, and *chama*), with very

[1] In Domestic Dogs a hallux is frequently developed, though often in a rudimentary condition, the phalanges and claw being suspended loosely in the skin, without direct connexion with the other bones of the foot; it is called by dog-fanciers the "dew claw."

[2] *Proc. Zool. Soc. Lond.*, 1880, p. 238.

large ears and corresponding large auditory bullæ, have been separated under the above name.

Lycaon.—This resembles in most of its characters the Dogs of the Lupine series, but the teeth are rather more massive and rounded, the skull shorter and broader, and it has but four toes on each limb, as in *Hyæna*. The one species, *L. pictus*, the Cape Hunting Dog (fig. 120) from south and east Africa, is very distinct exter-

FIG. 120.—Cape Hunting Dog (*Lycaon pictus*).

nally from all the other *Canidæ*. It is nearly as large as a mastiff, with large, broadly ovate erect ears, and singularly coloured, being not only variable in different individuals, but unsymmetrically marked with large spots of white, yellow, and black. It presents some curious superficial resemblances to *Hyæna crocuta*, perhaps a case of mimetic analogy. It hunts its prey in large packs.

Otocyon.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{3 \text{ or } 4}{4} = \frac{11 \text{ or } 12}{12}$; total 46 or 48. The molar teeth are thus in excess of any other known heterodont mammal. They have the same general characters as in *Canis*, with very pointed cusps. The lower sectorial shows little of its typical characters, having five cusps on the surface; these can, however, be identified as the inner tubercle, the two greatly reduced and obliquely placed lobes of the blade, and two cusps on the heel. The skull generally resembles that of the smaller Foxes, particularly the Fennecs. The auditory bullæ are very large. The hinder edge of the mandible has a very peculiar form, owing to the great development of an expanded, compressed, and somewhat inverted subangular process. Vertebræ: C 7, D 13, L 7, S 3, C 22. Ears very large. Limbs rather long. Toes 5–4. One species, *O. megalotis*, from South Africa, rather smaller than a common Fox.

Professor Huxley looks upon this as the least differentiated or most primitive existing form of *Canis*, regarding the presence of the four molar teeth as a survival of a condition of the dentition exhibited by the common ancestors of the existing *Canidæ* and the existing carnivorous Marsupials. There is, however, at present no palæontological proof of this, as none of the numerous fossil forms of *Canidæ* yet discovered have more than the normal number of molars. One of the best known of these is *Amphicyon*, from the Miocene strata of Europe and America, formerly supposed to have affinities with the Bears, having five toes on each foot, and being possibly plantigrade, but, as the structure of the skull and teeth clearly show, only a generalized Dog, in which the true molars are fully developed. Another genus, *Cynodictis*, of which many modifications have been described by Filhol from the south of France, approaches the *Viverridæ*, and may be a common ancestor of the Cynoid and Æluroid *Carnivora*.

Section ARCTOIDEA.

The section *Arctoidea* includes a considerable number of forms which agree in the essential characteristics of the structures of the base of the cranium and reproductive organs, and in the absence of a cæcum to the intestinal canal. They have no Cowper's glands, and have a rudimentary prostate and a large cylindrical penial bone. All the members of this group have five completely developed toes on each foot.

Family MUSTELIDÆ.

True molars $\frac{1}{2}$ (or $\frac{1}{1}$ in *Mellivora*). No alisphenoid canal. A large group widely diffused, especially in the northern temperate regions of the earth. The different genera are very difficult to arrange in any natural order. They are rather artificially divided, chiefly according to the characters of their feet and claws, into the Otter-like (Lutrine), Badger-like (Meline), and Weasel-like (Musteline) forms.

Subfamily **Lutrinæ.**—Feet short, rounded (except the hind feet of *Enhydra*). Toes webbed. Claws small, curved, blunt. Head broad and much depressed. Upper posterior molars large and quadrate. Kidneys conglomerate. Habits aquatic.

Lutra.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{3}$, $m\ \frac{1}{2}$; total 36. Upper sectorial with a trenchant tricusped blade, and a very large inner lobe, hollowed on the free surface, with a raised sharp edge, and extending along two-thirds or more of the length of the blade. True molar large, with a quadricuspidate crown, broader than long. Skull broad and depressed, contracted immediately behind the orbits. Facial portion very short; brain case large. Vertebræ: C 7, D 14–15, L 6–5, S 3, C 20–26. Body very long. Ears short and rounded. Limbs short. Feet completely webbed, with well developed claws on all the toes. Tail long, thick at the base and tapering, rather depressed. Fur short and close.

The Otters are all more or less aquatic, living on the margins of rivers, lakes, and in some cases the sea, are expert divers and swimmers, and feed chiefly on fish. They have a very extensive geographical range, and so much resemble each other in outward appearance, especially in the nearly uniform brown colouring, that the species are by no means well-defined. See OTTER.

L. sandbachii, a very large species from Demerara and Surinam, with a prominent ridge along each lateral margin of the tail, constitutes the genus *Pteronura* of Gray.

Aonyx.—Feet only slightly webbed; claws exceedingly small or altogether wanting on some of the toes. First upper premolar very small, sometimes wanting. True molars very broad and massive, presenting an approach to the form of the next genus. *A. inunguis*, South Africa; *A. leptonyx*, Java, Sumatra.

Enhydriodon.—*E. sivalensis* is a large extinct Otter-like animal described by Dr Falconer from the Pliocene strata of the Subhimalayan mountains.

Enhydra.—Dentition: $i\ \frac{3}{2}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{1}{2}$; total 32. Differs from all other known *Carnivora* in having but two incisors on each side of the lower jaw, the one corresponding to the first (very small in the true Otters) being constantly absent. Though the molar teeth generally resemble those of *Lutra* in their proportions, they differ very much in the exceeding roundness and massiveness of their crowns and bluntness of their cusps. Feet webbed. Fore feet short, with five subequal toes, with short compressed claws. Hind feet very large, depressed, and fin-like. The phalanges flattened as in the Seals. The fifth toe the longest and stoutest, the rest gradually diminishing in size to the first, all with moderate claws. Tail moderate, cylindrical.

One species, *E. lutris*, the Sea-Otter. It is larger than any of the true Otters, and is found only on the coasts and islands of the North Pacific, where it was formerly very abundant, but is gradually becoming more and more rare, on account of the numbers killed annually for their valuable fur. It is said to live on molluscs and crabs as well as fish, and the massive mill-like structure of the grinding teeth, so unlike that of all the known purely piscivorous mammals, would seem to indicate some such diet.

Subfamily **Melinæ.**—Feet elongated. Toes straight. Claws non-retractile, slightly curved, subcompressed, blunt; those of the fore foot especially large. Upper posterior molar variable. Kidneys simple. Habits mostly terrestrial and fossorial.

Mephitis.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{2 \text{ or } 3}{3}$, $m\ \frac{1}{2}$; total 32–34. Upper molar larger than the sectorial, subquadrate, rather broader than long. Lower sectorial with heel less than half the length of the whole tooth. Bony palate terminating posteriorly opposite the hinder border of the last molar tooth. Facial portion of skull short and somewhat truncated in front. Vertebræ: C 7, D 16, L 6, S 2, C 21. Head small. Body elongated. Limbs moderate, subplantigrade. Ears short and rounded. Tail long, abundantly clothed with very long fine hair. Anal glands largely developed; their secretion, which can be discharged at the will of the animal, has an intolerably offensive odour, which circumstance has rendered the Skunks, as they are commonly called, proverbial. They are strictly nocturnal animals, terrestrial and burrowing, feeding chiefly on small mammals, birds, reptiles, insects, worms, roots, and berries. All the known species have a prevalent black colour, varied by white stripes or spots on the upper part. They generally carry the body much arched, and the tail erect, the long loose hair of which waves like a plume over the back. There are many species, all inhabitants of the American continent, over which they have an extensive range. See SKUNK. The South-American species, which have only two upper premolars, and differ in some other characters, have been generically separated under the name of *Conepatus*.

Arctonyx.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{1}{2}$; total 38. Incisor line curved, the outer teeth being placed posteriorly to the others. Lower incisors proclivous. First premolars often rudimentary or absent. Upper molar much larger than the sectorial, longer in the antero-posterior direction than broad. Lower sectorial with a very large, low, tuberculated heel. Cranium elongated and depressed; face long, narrow, and concave above. Bony palate extending as far backwards as the level of the glenoid fossa. Palatal bones dilated. Suborbital foramina very large. Vertebræ: C 7, D 16, L 4, S 4, C 20. Snout long, naked, mobile, and truncated, with large terminal nostrils, much like those of a Pig. Eyes small. Ears very small and rounded. Body compressed, rather than depressed. Limbs of moderate length and digitigrade in walking. Tail moderate, tapering. A full soft under fur, with longer, bristly hairs interspersed. The best-known species is *A. collaris*, the Sand-Bear or *Bhalú-soor* (*i.e.*, Bear-Pig) of the natives, found in the mountains of the north-east of Hindustan and Assam. It is rather larger than the English Badger, higher in its legs, and very Pig-like in general aspect, of a light grey colour, with flesh-coloured snout and feet; nocturnal and omnivorous. Other species or local varieties have been described by A. Milne-Edwards from North China and Tibet.

Mydaus.—Dentition as the last, but the cusps of the teeth more acutely pointed. Cranium elongated, face narrow and produced. Suborbital foramen small, and the palate, as in all the succeeding genera of this group, produced backwards about midway between the last molar tooth and the glenoid fossæ. Vertebræ: C 7, D 14–15, L 6–5, S 3, C 12. Head pointed in front; snout produced, mobile, obliquely truncated, the nostrils being inferior. Limbs rather short and stout. Tail extremely short, but clothed with rather long bushy hair. Anal glands largely developed, and emitting an odour like that of the American Skunks (*Mephitis*). One species, *M. meliceps*, the Teledu, a small burrowing animal, found in the mountains of Java, at an elevation of 7000 or more feet above the sea-level.

Meles.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{1}{2}$; total 38. The first premolar in both jaws extremely minute and often deciduous. Upper molar very much larger than the sectorial, subquadrate, as broad as long. Lower sectorial with a broad, low, tuberculated heel, more than half the length of the whole tooth. The postglenoid processes of the skull are so strongly developed, and the glenoid fossa is so deep, that the condyle of the lower jaw is firmly held in its place even after all the surrounding soft parts are removed. Vertebræ: C 7, D 15, L 5, S 3, C 18. Muzzle pointed. Ears very short. Body stout, broad. Limbs short, strong, subplantigrade. Tail short. The best-known species is the common Badger (*M. taxus*) of Europe and northern Asia, still found in many parts of England, where it lives in woods, is nocturnal, burrowing, and very omnivorous, feeding on mice, reptiles, insects, fruit, acorns, and roots. Other nearly allied species, *M. leucurus* and *M. chinensis*, are found in continental Asia, and *M. anakuma* in Japan.

Taxidea.—Dental formula as in *Meles*, except that the rudimentary anterior premolars appear to be always wanting in the upper jaw. The upper sectorial much larger in proportion to the other teeth. Upper molar about the same size as the sectorial, triangular, with the apex turned backwards. Heel of lower sectorial less than half the length of the tooth. Skull very wide in the occipital region; the lambdoidal crest very greatly developed, and the sagittal but slightly, contrary to what obtains in *Meles*. Vertebræ: C 7, D 15, L 5, S 3, C (?). Body very stoutly built and depressed. Tail short. The animals of this genus are peculiar to North America, where they represent the Badgers of the Old World, resembling them much in appearance and habits. *T. americana* is the common American Badger of the United States. *T. berlandieri*, the Mexican Badger, is perhaps only a local variety.

Mellivora.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{1}{1}$; total 32. Upper sectorial large, with its inner cusp quite at the anterior end of the blade, as in the following genera; molar much smaller and transversely extended, having a very small outer and a larger rounded inner lobe. Heel of lower sectorial very small, scarcely one-fourth of the whole length of the tooth, and with but one cusp. Tubercular molar absent. Vertebræ: C 7, D 14, L 4, S 4, C 15. Body stout, depressed. Limbs short, strong. Head depressed, nose rather pointed. External ears rudimentary. Tail short. The animals of this genus are commonly called Ratels. *M. indica*, from India, and *M. ratel* and *M. leuconota* from South and West Africa, have nearly the same general appearance and size, being rather larger than a common Badger. Their coloration is peculiar, all the upper surface of the body, head, and tail being ash-grey, while the lower parts, separated by a distinct longitudinal boundary line, are black. They live chiefly on the ground, into which they burrow, but can also climb trees. They feed on small mammals, birds, reptiles, and insects, and are said to be very partial to honey.

Helictis.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{1}{2}$; total 38. Upper sectorial with a large bicusped inner lobe. Molar smaller, wider transversely than in the antero-posterior direction. Lower sectorial with heel about one-third the length of the tooth. Skull elongated, rather narrow and depressed. Facial portion especially narrow. Infraorbital foramen very large. Head rather small and produced in front, with an elongated, obliquely truncated, naked snout. Ears small. Body elongated. Limbs short. Tail short or moderate, bushy. Several species are described (*H. orientalis*, *moschata*, *nipalensis*, *subaurantiaca*), all from eastern Asia, small animals compared with the other members of the subfamily, climbing trees with agility and living much on fruit and berries as well as on small mammals and birds.

Ictonyx.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{1}{2}$; total 34. In general characters the teeth much resemble those of the Polecats (*Mustela*), being more delicately cut and sharply cusped than in most of the foregoing. Upper molar smaller than the sectorial, narrow from before backwards. Lower sectorial with a small narrow heel and distinct inner tubercle. General form of body musteline. Limbs short. Fore feet large and broad, with five stout, nearly straight, blunt, and non-retractile claws, of which the first and fifth are considerably shorter than the others. Tail moderate, with longer hairs towards the end, giving it a bushy appearance. Hair generally long and loose. The best-known species of this genus, *I. zorilla*, the Cape Polecat, was placed by Cuvier in the genus *Mustela*, by Lichtenstein in *Mephitis*, and in many characters it forms a transition between these genera. It is about the size of an English Polecat, but conspicuous by its coloration, having broad, longitudinal bands of dark brown, alternating with white. Its odour is said to be as offensive as that of the American Skunks. From the Cape of Good Hope it ranges as far north as Senegal. Another species, *I. frenata*, from Sennaar, has been described.

Subfamily **Mustelinæ.**—Toes short, partially webbed; claws short, compressed, acute, curved, often semiretractile. Upper posterior molar of moderate size, wide transversely. Kidneys simple. Terrestrial and arboreal in habits.

Galictis.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{1}{2}$; total 34. Molars small but stout; upper sectorial with the inner lobe near the middle of the inner border of the tooth. Lower sectorial with heel small, and inner tubercle small or absent. Body long. Limbs short; claws non-retractile. Palms and soles naked. Head broad and depressed. Tail of moderate length. The best-known species, *G. vittata*, the Grison (genus *Grisonia*, Gray), and *G. barbara*, the Tayra (genus *Galera*, Gray), are both South-American; *G. allamandi* is an intermediate form.

Mustela.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{1}{2}$; total 38. Upper sectorial with inner lobe close to the anterior edge of the tooth. Molar nearly as large as sectorial. Lower sectorial with small inner tubercle. Vertebræ: C 7, D 14, L 6, S 3, C 18–23. Body long and slender. Limbs short, digitigrade. Feet rounded; toes short, with compressed, acute, semiretractile claws. Tail moderate or long, more or less bushy. One species is British, *M. martes*, the Pine Marten; the remainder inhabit the northern regions of Europe, Asia, and America. Many of the species, as the Sable (*M. zibellina*), yield fur of great value. See MARTEN.

Putorius.—The dentition differs from that of *Mustela* chiefly in the absence of the anterior premolars of both jaws. The teeth are more sharply cusped, and the lower sectorial wants the inner tubercle. External characters generally similar to those of the Martens, but the body is longer and more slender, and the limbs even shorter. They are all small animals, of very active, bloodthirsty and courageous disposition, living chiefly on birds and small mammals, and are rather terrestrial than arboreal, dwelling among rocks, stones, and outbuildings. Some of the species, as the Stoat or Ermine (*P. ermineus*), inhabiting cold climates, undergo a seasonal change of colour, being brown in summer and white in winter, though the change does not affect the whole of the fur, the end of the tail remaining black in all seasons. This is a large genus, having a very extensive geographical range throughout the Old and New Worlds, and includes the animals commonly known as Weasels, Polecats, Ferrets, and Minks.

Gulo.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{1}{2}$; total 38. Crowns of the teeth very stout. Upper molar very much smaller than the sectorial. Lower sectorial large, with very small heel and no inner tubercle. The dentition, though really but a modification of that of the Weasels, presents a great general resemblance to that of Hyæna. Vertebræ: C 7, D 15, L 5, S 3, C 15. Body and limbs stoutly made. Feet large and powerful, subplantigrade, with large, compressed, much curved, and sharp-pointed claws. Soles of the feet (except the pads of the toes) covered with thick bristly hairs. Ears very small, nearly concealed by the fur. Eyes small. Tail short, thick, and bushy. Fur full, long, and rather coarse. The one species, the Wolverene or Glutton, *G. luscus*, an inhabitant of the forest regions of northern Europe, Asia, and America, much resembles a small Bear in appearance. It is a very powerful animal for its size, climbs trees, and lives on squirrels, hares, beavers, reindeer, and is said to attack even horses and cows.

Family PROCYONIDÆ.

True molars $\frac{2}{2}$, obtusely tuberculated. No alisphenoid canal. Habitat exclusively American.

Procyon.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{2}{2}$; total 40. The molar teeth broad and tuberculated. The upper sectorial with three cusps along the outer margin, and a very broad bicusped inner lobe, giving an almost quadrate form to the crown. First molar with a large tuberculated crown, rather broader than long. Second considerably smaller, with transversely oblong crown. Lower sectorial with an extremely small and ill-defined blade, placed transversely in front, and a large inner tubercle and heel. Second molar as long as the first, but narrower behind, with five obtuse cusps. Vertebræ: C 7, D 14, L 6, S 3, C 16–20. Body stout. Head broad behind, but with a pointed muzzle. Limbs plantigrade, but in walking the entire sole is not applied to the ground as it is when the animal is standing. Toes, especially of the fore foot, very free, and capable of being spread wide apart. Claws compressed, curved, pointed, and non-retractile. Tail moderately long, cylindrical, thickly covered with hair, annulated, non-prehensile. Fur long, thick, and soft. The well-known Raccoon (*Procyon lotor*) of North America is the type of this genus. It is replaced in South America by *P. cancrivorus*.

Bassaris.—A form closely allied to *Procyon*, but of more slender and elegant proportions, with sharper nose, longer tail, and more digitigrade feet, and with teeth otherwise like, but smaller, and more sharply denticulated. It was formerly, but erroneously, placed among the *Viverridæ*. Two species:—*B. astuta*, from the southern parts of the United States and Mexico, and *B. sumichrasti*, from Central America.

Bassaricyon.—This name has recently (1876) been given to a distinct modification of the Procyonine type of which at present only two examples are known, one from Costa Rica and the other from Ecuador, which, appearing to be different species, have been named *B. gabbi* and *B. alleni*. They much resemble the Kinkajou (*Cercoleptes*) in external appearance, but the skull and teeth are more like those of *Procyon* and *Nasua*.

Nasua.—Dentition as in *Procyon*, but the upper canines are larger and more strongly compressed, and the molars smaller. The facial portion of the skull is more elongated and narrow. Vertebræ: C 7, D 14, L 6, S 3, C 22–23. Body elongated and rather compressed. Nose prolonged into a somewhat upturned, obliquely truncated, mobile snout. Tail long, non-prehensile, tapering, annulated. These animals, commonly called Coatis or Coati-Mundis, live in small troops of eight to twenty, are chiefly arboreal, and feed on fruits, young birds, eggs, insects, &c. Recent researches have reduced the number of supposed species to two, *N. narica* of Mexico and Central America, and *N. rufa* of South America from Surinam to Paraguay.

Cercoleptes.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{2}{2} = 36$. Molars with low flat crowns, very obscurely tuberculated. Skull short and rounded, with flat upper surface. Vertebræ: C 7, D 14, L 6, S 3, C 26–28. Clavicles present, but in a very rudimentary condition. Head broad and round. Ears short. Body long and musteline. Limbs short. Tail long, tapering, and prehensile. Fur short and soft. Tongue long and very extensile. But one species of this somewhat aberrant genus is known, *C. caudivolvulus*, the Kinkajou, found in the forests of the warmer parts of South and Central America. It is about the size of a Cat, of a uniform pale, yellowish-brown colour, nocturnal and arboreal in its habits, feeding on fruit, honey, eggs, and small birds and mammals, and is of a tolerably gentle disposition and easily tamed.

Family AILURIDÆ.

Formed for the reception of one genus, resembling the *Procyonidæ* in the number of true molar teeth, but differing in some cranial characters, especially the presence of an alisphenoid canal, and in its Asiatic habitat.

Ailurus.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{4}$, $m\ \frac{2}{2}$; total 38. First lower premolar very minute and deciduous. Molars remarkable for their great transverse breadth, and the numerous cusps of their crowns. Vertebræ: C 7, D 14, L 6, S 3, C 18. Skull high and compressed. Facial portion short. Ascending ramus of mandible extremely high. Head round. Face short and broad. Ears large, erect, pointed. Limbs stout, plantigrade, with large blunt non-retractile claws. Tail nearly as long as body, cylindrical, clothed with long hairs. Fur long and thick. One species, *A. fulgens*, the Panda, rather larger than a Cat, found in the south-east Himalayas, at heights of from 7000 to 12,000 feet above the sea, among rocks and trees, and chiefly feeding on fruits and other vegetable substances. Its fur is of a remarkably rich reddish-brown colour, darker below.

Family URSIDÆ.

True molars $\frac{2}{3}$, with broad, flat, tuberculated crowns. The three anterior premolars of both jaws rudimentary and often deciduous. Fourth upper premolar (sectorial) with no third or inner root. No alisphenoid canal (except in *Ailuropus*). Kidneys conglomerate. Geographical distribution extensive.

Ailuropus.—An interesting annectant form connecting the true Bears with *Ailurus* and with several extinct genera. Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{3}$, $m\ \frac{2}{3}$; total 40. Premolars increasing in size from first to last, and two-rooted except the first. First upper molar with quadrate crown, broader than long. Second larger than the first. Cranium with zygomatic arches and sagittal crest immensely developed, and ascending ramus of mandible very high, giving greater spaces for attachments of temporal muscle than in any other existing member of the order. Facial portion short. Bony palate not extending behind the last molar tooth. An alisphenoid canal. Feet bear-like, but soles more hairy, and perhaps less completely

FIG. 121. *Ailuropus melanoleucus*. From A. Milne-Edwards.

plantigrade. Fur long and thick. Tail very short. One extremely rare species, *A. melanoleucus* (fig. 121), discovered by Père David in 1869, in the most inaccessible mountains of eastern Tibet. Said to feed principally on roots, bamboos, and other vegetables. It is of the size of a small Brown Bear, of a white colour, with ears, spots round the eyes, shoulders, and limbs black.

Ursus.—Dentition: $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{2}{3} = 42$. The three anterior premolars above and below one-rooted, rudimentary, and frequently wanting. Usually the first (placed close to the canine) is present, and after a considerable interval the third, which is situated close to the other teeth of the molar series. The second is very rarely present in the adult state. The fourth (upper sectorial) differs essentially from the corresponding tooth of other Carnivores in wanting the inner lobe supported by a distinct root. Its sectorial characters are very slightly marked. The crowns of both the true molars are longer than broad, with flattened, tuberculated, grinding surfaces. The second has a large backward prolongation or heel. The lower sectorial has a small and indistinct blade and greatly developed tubercular heel. The second molar is of about the same length, but with a broader and more flattened tubercular crown. The third is smaller. The milk teeth are comparatively small, and shed at an early age. Skull more or less elongated. Orbits small and incomplete behind. Palate prolonged considerably behind the last molar tooth. Vertebræ: C 7, D 14, L 6, S 5, C 8–10. Body heavy. Feet broad, completely plantigrade. The five toes on each foot all well-developed, and armed with long compressed and moderately curved, non-retractile claws. Palms and soles naked. Tail very short. Ears moderate, erect, rounded, hairy. Fur generally long, soft, and shaggy.

The Bears are all animals of considerable bulk, and include among them the largest members of the order. Though the species are not numerous, they are widely spread over the earth's surface (but absent from the Ethiopian and Australian regions, and only represented by one species in the Neotropical region), and differ much among themselves in their food and manner of life. They are mostly omnivorous or vegetable feeders, and even the Polar Bear, usually purely carnivorous or piscivorous, devours grass with avidity in summer. The various species may be grouped in the following sections. (1) *Thalassarctos*. Head comparatively small, molar teeth small and narrow. Soles more covered with hair than in the other sections. *U. maritimus*, the Polar or White Bear of the Arctic regions. (2) *Ursus* proper. *U. arctos*, the common Brown Bear of Europe and Asia, a very variable species, to which *U. syriacus* and *isabellinus*, if distinct, are nearly related; *U. horribilis*, the Grizzly Bear, an American representative form; *U. tibetanus*, *japonicus*, and *americanus*, the Black Bears of the Himalayas, Japan, and North America; *U. ornatus*, the Spectacled Bear of the Peruvian Andes. (3) *Helarctos*. Head short and broad. Molar teeth comparatively broad (but the length still exceeding the breadth). Tongue very long and extensile. Fur short and smooth. *U. malayanus*, the Malay Bear or Sun Bear. See BEAR.

Melursus. This differs from the true Bears in the first upper incisor being absent or shed at a very early age, in the very small size of the other teeth, in the very large extensile lips, and in other minor characters. The one species, *M. labiatus*, the well-known Sloth Bear of India, feeds chiefly on black ants, termites, beetles, fruit, honey, &c.

The great Cave Bear, the remains of which are found so abundantly in caves of Pleistocene age in Europe, was a true *Ursus*, and as much or more specialized as any existing species, as it had lost its three anterior premolars in the adult state, but in *Ursus arvernensis* and older species from the Pliocene they were all retained. Still more generalized forms of Bears, presenting various degrees of transition towards a common Carnivorous type, are represented by the genera *Arctotherium* from South America and *Hyænarctos* of Miocene strata of Europe and Asia, and others which are not far removed (at least in dental characters) from such primitive Dog-like types as *Amphicyon*.

Extinct Carnivora of Doubtful Position.

The discovery of fossil remains in Eocene and early Miocene formations both in Europe and North America, shows that numerous species of terrestrial carnivorous animals existed upon the earth during those periods, which cannot be referred to either of the sections into which the order has now become broken up. By some zoologists these have been supposed to be Marsupials, or at least to show transitional characters between the Didelphous and Monodelphous subclasses. By others they are looked upon as belonging altogether to the latter group, and as the common ancestors of existing Carnivores and Insectivores, or perhaps rather as descendants or relatives of such common ancestors, retaining more of the generalized characters than any of the existing species. They shade off almost insensibly into numerous other forms less distinctly carnivorous, to the whole of which, including the modern *Insectivora*, Cope (to whom we are indebted for our principal knowledge of the American extinct species) gives the name of Bunotheria, those more specially related to the existing *Carnivora* forming the suborder *Creodonta*, which is divided into the five families, *Arctocyonidæ*, *Miacidæ*, *Oxyænidæ*, *Amblyctonidæ*, and *Meronychidæ*. These are cases, however, in which the application of the principles of classification adopted in the case of existing species, of which the entire structure is known, and which have become divided into isolated groups by the extinction of intermediate forms, is really impossible. If the generally accepted view of evolution is true, and the extreme modifications pass insensibly into each other by minute gradations (a view the palæontological proof of which becomes strengthened by every fresh discovery), there must be many of these extinct forms which cannot be assigned to definitely characterized groups. There are, however, some which stand out prominently from the others as formed on distinct types, having no exact representatives at present living on the earth. Of these the best-known is that named *Hyænodon*, of which, with the nearly allied *Pterodon*, many species

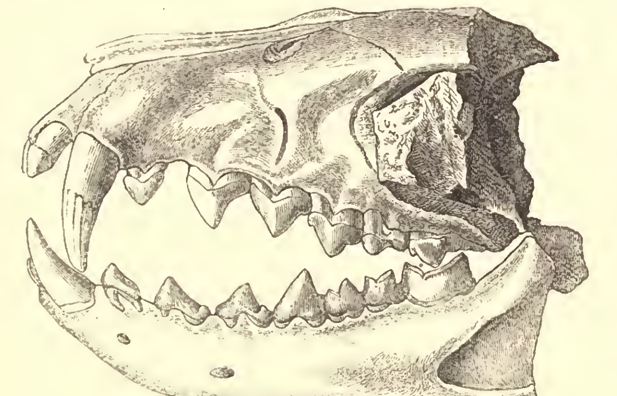


Fig. 122.—Dentition of *Hyænodon leptorhynchus* (Lower Miocene, France). The posterior molar is concealed behind the penultimate tooth.

have been found both in Europe and America. They had the full number of forty-four teeth, grouped in the usual manner, and the incisors, canines, and premolars were formed upon the ordinary Carnivorous type as now seen in the *Canidæ*, the fourth premolar above and the first true molar below being formed upon the "sectorial" plan, but the teeth behind these, instead of being tuberculated as in all existing *Carnivora*, repeated the characters of the sectorial, and also increased in size, especially in the lower jaw, from before backwards. They thus present some resemblance to the teeth of such carnivorous Marsupials as the *Dasyuridæ*; but, as the researches of Filhol have demonstrated, their milk dentition follows precisely the rule of existing placental heterodont mammals, and not that characteristic of the Marsupials. They show, moreover, none of the essential cranial modifications which distinguish true Marsupials. The curious American genus *Oxæna* seems to have been a specialized form of this type, and the European *Proviverra* or *Cynohyænodon* of Filhol) forms a complete transition between it and the *Viverridæ*. In *Arctocyon primævus*, the oldest known Tertiary mammal, from the lowest Eocene beds of La Fère, department of Aisne, France, on the other hand, all the molars were tuberculated, and have been compared with those of the *Procyonidæ* and also *Gymnura*, among the *Insectivora*. The small size of the brain of these early forms is not, as has been supposed, a special Marsupial character, but is common to the primitive forms of all groups of vertebrates. *Mesonyx*, from the Eocene of North America, seems to have been a very generalized form, with flat blunt claws, and long and slender tail. Cope makes the interesting suggestion that this may have been in the ancestral line of the Pinnipeds, but his statement that the scaphoid and lunar bones of the carpus were distinct offers a decided difficulty to the acceptance of this view.

Suborder *PINNIPEDIA*.

These differ from the rest of the *Carnivora* mainly in the structure of their limbs, which are modified for aquatic progression,—the two proximal segments being very short and partially enveloped in the general integument of the body, while the third segment, especially in the hinder extremities, is elongated, expanded, and webbed. There are always five well-developed digits on each limb. In the hind limb the two marginal digits (first and fifth) are stouter and generally larger than the others. The teeth also differ from those of the more typical *Carnivora*. The incisors are always fewer than $\frac{3}{3}$. The molar series consists generally of four premolars and one molar of very uniform characters, with never more than two roots, and with conical, more or less compressed, pointed crowns, which may have accessory cusps, placed before or behind the principal one, but are never broad and tuberculated. The milk teeth are very small and simple, and are shed or absorbed at a very early age, usually either before or within a few days after birth. The brain is relatively large, the cerebral hemispheres broad in proportion to their length, and with numerous and complex convolutions. There is a very short cæcum. The kidneys are divided into numerous distinct lobules. There are no Cowper's glands. Mammæ two or four, abdominal. No clavicles. Tail always very short. Eyes very large and exposed, with flat cornea. The nostrils close by the elasticity of their walls, and are opened at will by muscular action.

The animals of this group are all aquatic in their mode of life, spending the greater part of their time in the water, swimming and diving with great facility, feeding mainly on fish, crustaceans, and other marine animals, and progressing on land with difficulty. They always come on shore, however, for the purpose of bringing forth their young. They are generally marine, but they occasionally ascend large rivers, and some inhabit inland seas and lakes, as the Caspian and Baikal. Though not numerous in species, they are widely distributed over the world, but occur most abundantly on the coasts of lands situated in cold and temperate zones. The suborder is divisible into three well-marked families:—the *Otariidæ* or Sea Bears, which form a transition from the Fissiped *Carnivora* to the Seals; the *Trichechidæ*, containing the Walrus; and the *Phocidæ* or typical Seals.

Family Otariidæ.

When on land the hind feet are turned forwards under the body, and aid in supporting and moving the trunk as in ordinary quadrupeds. A small external ear. Testes suspended in a distinct external scrotum. Skull with post-orbital processes and alisphenoid canal. Palms and soles of feet naked.

Otaria.—Dentition: $i\ \frac{3}{2}$, $c\ \frac{1}{1}$, $p\ \frac{4}{4}$, $m\ \frac{1 \text{ or } 2}{1}$; total 34 or 36. First and second upper incisors small, with the summits of the crowns divided by a deep transverse groove into an anterior and a posterior cusp of nearly equal height; the third large and canine-like. Canines large, conical, pointed, recurved. Molars and premolars, usually $\frac{5}{5}$, of which the second, third, and fourth are preceded by milk teeth shed a few days after birth; sometimes (as in fig. 123) a sixth upper molar (occasionally developed on one side and not the other); all with similar characters, generally uniradicular; crown moderate, compressed, pointed, with a single principal cusp, and sometimes a cingulum, and more or less developed anterior and posterior accessory cusps. Vertebræ: C 7, D 15, L 5, S 4, C 9-10. Head rounded. Eyes large. Pinna of ear small, narrow, and pointed. Neck long. Skin of all the feet extended far beyond the nails and ends of the digits, with a deeply-lobed margin. The nails small and often quite rudimentary, especially those of the first and fifth toes of both feet; the best-developed and most constant are the three middle claws of the hind foot, which are elongated, compressed, and curved.

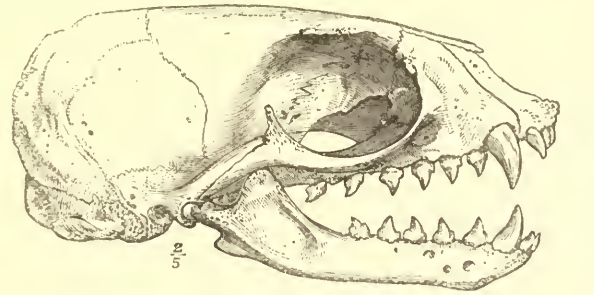


FIG. 123.—Skull and Dentition of *Otaria forsteri*. From Gray, *Proc. Zool. Soc.*, 1872, p. 660.

The *Otariæ*, or Eared Seals, commonly called Sea Bears or Sea Lions, are widely distributed, especially in the temperate regions of both hemispheres, though absent from the coasts of the North Atlantic. As might be inferred from their power of walking on all fours, they spend more of their time on shore, and range inland to greater distances, than the true Seals, especially at the breeding time, though they are obliged always to return to the water to seek their food. They are gregarious and polygamous, and the males are usually much larger than the females, a circumstance which has given rise to some of the confusion existing in the specific determination of the various members of the genus. Some of the species possess, in addition to the stiff, close, hairy covering common to all the group, an exceedingly fine, dense, woolly under fur. The skins of these, when dressed and deprived of the longer harsh outer hairs, constitute the "sealskin" of commerce, so much valued for wearing apparel, which is not the product of any of the true Seals. The best-known species are *O. stelleri*, the Northern Sea Lion, the largest of the genus, from the North Pacific, about 10 feet in length; *O. jubata*, the Southern Sea Lion, from the Falkland Islands and Patagonia; *O. californiana*, from California, frequently exhibited alive in menageries in Europe; *O. ursina*, the common Sea Bear or Fur Seal of the North Pacific, the skins of which are imported in immense numbers from the Prybiloff Islands; *O. pusilla*, from the Cape of Good Hope; *O. forsteri* and others, from the coasts of Australia and various islands scattered over the southern hemisphere. These have been grouped by some zoologists into many genera, founded upon very trivial modifications of teeth and skull.

Family TRICHECHIDÆ.

In many characters the single genus comprising this family is intermediate between the *Otariidæ* and *Phocidæ*, but it has a completely aberrant dentition. It has no external ears, as in the *Phocidæ*; but when on land the hind feet are turned forwards and used in progression, though less completely than in the *Otariidæ*. The upper canines are developed into immense tusks, which descend a long distance below the lower jaw. All the other teeth, including the lower canines, are much alike, small, simple and one-rooted, the molars with flat crowns. The skull is without post-orbital process, but has an alisphenoid canal.

Trichechus, Linn.; *Odobænus*, Brisson (which some modern zoologists have revived).—Dentition of young: $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, p and $m\,\frac{5}{4}$. Many of these teeth are, however, lost early or remain through life in a rudimentary state, concealed by the gums. The teeth which are usually developed functionally are $i\,\frac{1}{0}$, $c\,\frac{1}{1}$, $p\,\frac{3}{3}$, $m\,\frac{0}{0}$; total 18. Vertebræ: C 7, D 14, L 6, S 4, C 9. Head round. Eyes rather small. Muzzle short and broad, with on each side a group of long, very stiff, bristly whiskers. The remainder of the hair covering very short and adpressed. Tail very rudimentary. Fore feet with subequal toes, with five minute flattened nails. Hind feet with subequal toes, the fifth slightly the largest, with cutaneous lobes projecting beyond the ends as in *Otaria*; first and fifth with minute flattened nails; second, third, and fourth with large, elongated, subcompressed pointed nails.

The Walrus or Morse (*T. rosmarus*) is found throughout the circumpolar regions, those of the North Atlantic and North Pacific being considered by some zoologists as distinct species, by others as local varieties. It is gregarious, but, owing to the destruction by the sealers for the sake of its tusks, oil, and hide, it is far less abundant than formerly. The use of the great tusks (which are developed in both sexes, though in the female they are more slender than in the male) appears to be for scraping and digging among the sand and shingle for the molluscs and crustaceans which form its principal sustenance; they are also formidable weapons of defence.

Family PHOCIDÆ.

The true Seals are the most completely adapted for aquatic life of all the Pinnipeds. When on land the hind limbs are extended behind them and take no part in progression, which is effected by a series of jumping movements produced by the muscles of the trunk, in some species aided by the fore limbs only. The palms and soles of the feet are hairy. There is no pinna to the ear, and no scrotum, the testes being abdominal. The upper incisors have simple, pointed crowns, and vary in number in the different groups. All have well developed canines and $\frac{5}{5}$ teeth of the molar series. In those species of which the milk dentition is known, there are three milk molars, which precede the second, third, and fourth permanent molars; the dentition is therefore $p\,\frac{4}{4}$, $m\,\frac{1}{1}$, the first premolar having as usual no milk predecessor. The skull has no post-orbital process and no alisphenoid canal. The fur is stiff and adpressed, without woolly under fur.

Subfamily **Phocinæ**.—Incisors $\frac{3}{2}$. All feet with five well-developed claws. The toes on the hind feet subequal, the first and fifth not greatly exceeding the others in length, and with the interdigital membrane not extending beyond the toes.

Halichœrus.—Dentition: $i\,\frac{3}{2}$, $c\,\frac{1}{1}$, $p\,\frac{4}{4}$, $m\,\frac{1}{1}$; total 34. Molars with large, simple, conical, recurved, slightly compressed crowns, with sharp anterior and posterior edges, but without accessory cusps, except sometimes the two hinder ones of the lower jaw. With the exception of the last one or two in the upper jaw and the last in the lower jaw they are all uniradicular. Vertebræ: C 7, D 15, L 5, S 4, C 14.

One species, *H. grypus*, the Grey Seal of the coasts of Scandinavia and the British Isles.

Phoca.—Dental formula as the last. Teeth smaller and more pointed. Molars with two roots (except the first in each jaw). Crowns with accessory cusps. Vertebræ: C 7, D 14-15, L 5, S 4, C 11-14. Head round and short. Fore feet short, with five very strong, subcompressed, slightly curved, rather sharp claws, subequal in length. On the hind feet the claws much narrower and less curved. The species of this genus are widely distributed throughout the northern hemisphere, and include *P. barbata*, the Bearded Seal; *P. grœnlandica*, the Greenland Seal; *P. vitulina*, the Common Seal; and *P. hispida*, the Ringed Seal of the North Atlantic; *P. caspica*, from the Caspian and Aral Seas; and *P. siberica*, from Lake Baikal. See SEAL.

Subfamily **Stenorhynchinæ**.—Incisors $\frac{2}{2}$. Molars two-rooted, except the first. On the hind feet the first and fifth toes greatly exceeding the others in length, with nails rudimentary or absent.

Monachus.—Dentition: $i\,\frac{2}{2}$, $c\,\frac{1}{1}$, $p\,\frac{4}{4}$, $m\,\frac{1}{1}$; total 32. Crowns of molars strong, conical, compressed, hollowed on the inner side, with a strongly-marked lobed cingulum, especially on the inner side, and slightly developed accessory cusps before and behind. The first and last upper and the first lower molar considerably smaller than the others. Vertebræ: C 7, D 15, L 5, S 2, C 11. All the nails of both fore and hind feet very small and rudimentary. One species, *M. albiventer* (*Pelagius monachus* of some authors), the Monk Seal of the Mediterranean and adjacent parts of the Atlantic.

The other genera of this section have the same dental formula, but are distinguished by the characters of the molar teeth and the feet. They are all inhabitants of the shores of the southern hemisphere.

Stenorhynchus (*Ogmorhinus*, Peters).—All the teeth of the molar series with three distinct pointed cusps, deeply separated from each other; of these the middle or principal cusp is largest and slightly recurved; the other two (anterior and posterior) are nearly equal in size, and have their apices directed towards the middle one. Skull much elongated. One species, *S. leptonyx*, the Sea Leopard, widely distributed in the Antarctic and southern temperate seas.

Lobodon.—Molars with much-compressed elongated crowns, with a principal recurved cusp, rounded and somewhat bulbous at the apex, and with one anterior, and one, two, or three posterior, very distinct accessory cusps. One species, *L. carcinophaga*.

Leptonyx.—Molars small, with simple, subcompressed, conical crowns, with a broad cingulum, but no distinct accessory cusps. *L. weddellii*.

Ommatophoca.—All the teeth very small; those of the molar series with pointed recurved crowns, and small posterior and still less developed anterior accessory cusps. Orbits very large. Nails quite rudimentary on front and absent on hind feet. The skull bears a considerable resemblance to that of the members of the next subfamily, towards which it may form a transition. There is one species, *O. rossii*, of which very little is known.

Subfamily **Cystophorinæ**.—Incisors $\frac{2}{1}$. Teeth of molar series generally one-rooted. Nose of males with an appendage capable of being inflated. First and fifth toes of hind feet greatly exceeding the others in length, with prolonged cutaneous lobes, and rudimentary or no nails.

Cystophora.—Dentition : $i\,\frac{2}{1}$, $c\,\frac{1}{1}$, $p\,\frac{4}{4}$, $m\,\frac{1}{1}$; total 30. The last molar has generally two distinct roots. Beneath the skin over the face of the male, and connected with the nostrils, is a sac capable of inflation, when it forms a kind of hood covering the upper part of the head. Nails present, though small on the hind feet. *C. cristata*, the Hooded or Bladder-Nose Seal of the Polar Seas.

Macrorhinus.—Dentition as the last, but molars of simpler character, and all one-rooted. All the teeth, except the canines, very small relatively to the size of the animal. Hind feet without nails. Vertebræ: C 7, D 15, L 5, S 4, C 11. Nose of adult male produced into a short tubular proboscis, ordinarily flaccid, but capable of dilatation and elongation under excitement. One species, *M. leonina*, the Elephant Seal, or "Sea Elephant" of the whalers, the largest of the whole family, attaining the length of nearly 20 feet. Formerly abundant in the Antarctic Seas, and also found on the coast of California.

EXTINCT PINNIPEDS.

Remains of animals of this group have been found in late Miocene and Pliocene strata in Europe and America, the most abundant and best preserved being those of the Antwerp Crags, the subject of a recent illustrated monograph by Van Beneden. Nothing has, however, yet been discovered which throws any light upon the origin of the group, as all the extinct forms at present known come within the definition of the existing families; and, though annectant forms between these occur, there are as yet no transitions to a more generalized type of mammal. Indeed, all those of which the characters are best known belong to the completely developed Phocine or Trichechine, not to the Otarine, type. The structure of the Pinnipeds is so clearly a modification of that of the terrestrial Carnivores, especially of the Arctoid type, that it is difficult to imagine that they can have had any other origin but one in common with that group; but the separation must have taken place early in the Tertiary epoch, if not before.

Bibliography of Pinnipedia.—J. A. Allen, *History of North American Pinnipeds*, 1880; P. J. Van Beneden, *Ossements fossiles d'Anvers*, pt. i., 1877.

ORDER PRIMATES.

This order in the system of Linnæus includes Man, all the Monkeys, the Lemurs, and the Bats. By common consent of all zoologists the last-named animals have been removed into a distinct order. With regard to the association of the others, there has been, and still is, much difference of opinion.

That all the Monkeys, from the highest Anthropoid Apes to the lowest Marmosets, form a natural and tolerably homogeneous group seems never to have been questioned; but whether the Lemurs on the one hand and Man on the other should be united with them in the same order are points of controversy. With regard to the first, the question has already been referred to in the article LEMUR, in which an account has been given of the characters and the principal modifications of the type. If, in accordance with the traditional views of zoologists, they are still considered to be members of the order *Primates*, they must form a suborder apart from all the others, with which they have really very little in common except the opposable hallux of the hind foot, a character also met with in the Opossums, and which is therefore of very secondary importance.

The history of all the various forms of true Monkeys is very fully given in the article APE. The position of Man alone remains to be considered. In the *Systema Naturæ* of Linnæus he was separated only generically from the Apes, but in the next great work which exercised a widespread influence over the progress of zoological science, the *Règne Animal* of Cuvier, he forms a distinct order under the name of *Bimana*, the Monkeys and Lemurs being associated together as *Quadrumana*. This has been the prevailing arrangement in the zoological systems of the present century, though in the classification of Owen his position is still farther removed from that of the Monkeys, as in it the genus *Homo* forms one of the four primary divisions or subclasses of the *Mammalia*, called *Archencephala*, the *Quadrumana* being united with the *Carnivora*, *Ungulata*, and others in another division called *Gyrencephala*. On the other hand the tendency of most modern systematists, for reasons which have been fully stated by Professor Huxley,[1] is to revert towards the Linnæan position. Considering solely the facts of Man's bodily structure, it can be clearly demonstrated that the points in which he differs from the most nearly resembling Ape are not of greater importance than those by which that Ape differs from other universally acknowledged members of the group; and therefore, in any natural system, if Man is to be made a subject of zoological classification upon the same principles as those applied elsewhere, he must be included in the order which comprises the Monkeys. We say upon the same principles as are applied elsewhere, as zoological classification has never taken into consideration the psychological characteristics which distinguish the subjects of its investigations, but only their tangible and physical structure, otherwise endless confusion would result, at all events with our very imperfect knowledge of animal psychology. The essential attributes which distinguish Man, and give him a perfectly isolated position among living creatures, are not to be found in his bodily structure, and therefore should either be left entirely out of consideration or have such weight given to them as would remove him completely out of the region of zoological classification. To profess to classify Man as if he were one of the animals, as in all points of the structure and functions of his organs he undoubtedly is, to place him in the class *Mammalia*, and then to allow other considerations to influence the judgment as to the particular position he should occupy in the class, is most illogical.

Man, therefore, considered from a zoological point of view, must be included in the order *Primates*, even if the Lemurs are removed from it, as his structural affinities with the Monkeys are far closer than are those of the so-called "Half-Apes." We may, without treading upon debateable ground, go farther, and say that the differences between Man and the Anthropoid Apes are really not so marked as those which separate the latter from the American Monkeys. Perhaps the best exposition of the facts relating to the present condition of the order will be a division into five sections, which may be considered as families, of course without intending to imply that they are exactly equivalent, or that the intervals which separate them are of precisely the same importance, but that they are five distinct groups, all branches from a common stem, and unconnected in the present condition of nature by any intermediate forms. These are—(1) *Hominidæ*, containing Man alone; (2) *Simiidæ*, containing the four genera of Man-like Apes: *Troglodytes*, *Gorilla*, *Simia*, and *Hylobates*; (3) *Cercopithecidæ*, containing all the remaining Old-World Monkeys; (4) *Cebidæ*, containing the American Monkeys having three true molar teeth on each side of each jaw; and (5) *Hapalidæ*, the American Monkeys with two molar teeth, or Marmosets.

The distinctions between *Hominidæ* and *Simiidæ*, of which alone we have to treat at present, as the characters of the other families are given in the article APE, are chiefly relative, being greater size of brain and of brain case as compared with the facial portion of the skull, smaller development of the canine teeth of the males, more complete adaptation of the structure of the vertebral column to the vertical position, greater length of the lower as compared with the upper extremities, and greater length of hallux or great toe, with almost complete absence of the power of bringing it in opposition to the other four toes. The last

[1] *Man's Place in Nature*, 1863, and *Anatomy of Vertebrated Animals*, 1871. See also the more recent investigations of Broca into the comparative structure of Man and the higher Apes, published mostly in the *Revue d'Anthropologie*.

and the small size of the canine teeth are perhaps the most marked and easily defined distinctions that can be drawn between the two groups.

Man is universally admitted to form a single genus, *Homo* of Linnæus, but a question of considerable importance in treating of him from a zoological point of view, and one which has been a subject of much controversy, is whether all men should be considered as belonging to one or to several species. This question is perhaps of less importance now than formerly, when those who maintained a plurality of species associated with the hypothesis plurality of origin. One of the strongest arguments against the view that the various races of Man represent more than one species is that none of those who have maintained it have been able to agree as to how many distinct specific modifications can be defined, almost every number from three to twenty or more having been advocated by different authors. If the distinguishing characters of the so-called species had been so marked, there could not be such a remarkable diversity of opinion upon them. Again, the two facts—(1) that, however different the extremes of any two races may be in appearance (and it must be admitted that, as advocated by many polygenists, the differences are greater than many which are considered specific among other animals), every intermediate gradation can be found through which the one passes into the other, and (2) that all races are fertile *inter se*—are quite conclusive in favour of considering Man as representing a single species in the ordinary sense in which the word is now used, and of treating of all his various modifications as varieties or races.

The great problem at the root of all zoology, the discovery of a natural classification which shall be an expression of our knowledge of the real relationship or consanguinity of different forms, is also applicable to the study of the races of Man. When we can satisfactorily prove that any two of the known groups of mankind are descended from the same common stock, a point is gained. The more such points we have acquired the more nearly shall we be able to picture to ourselves, not only the present, but the past distribution of the races of Man upon the earth, and the mode and order in which they have been derived from one another. But the difficulties in the way of applying zoological principles to the classification of Man are vastly greater than in the case of most animals. When groups of animals become so far differentiated from each other as to represent separate species, they remain isolated; they may break up into further subdivisions—in fact, it is only by further subdivision that new species can be formed; but it is of the very essence of species, as now universally understood by naturalists, that they cannot recombine, and so give rise to new forms. With the varieties of Man it is otherwise. They have never so far separated as to answer to the physiological definition of species. All races, as said above, are fertile with one another, though perhaps in different degrees. Hence new varieties have constantly been formed, not only by the segmentation of portions of one of the old stocks, but also by various combinations of those already established.

Without entering into the difficult question of the method of Man's first appearance upon the world, we must assume for it vast antiquity,—at all events as measured by any historical standard. Of this there is now ample proof. During the long time he existed in a savage state—a time compared to which the dawn of our historical period is as yesterday—he was influenced by the operation of those natural laws which have produced the variations seen in other regions of organic nature. The first Men may very probably have been all alike; but, when spread over the face of the earth, and become subject to all kinds of diverse external conditions,—climate, food, competition with members of his own species or with wild animals,—racial differences began slowly to be developed through the potency of various kinds of selection acting upon the slight variations which appeared in individuals in obedience to the tendency planted in all living things. These differences manifested themselves externally in the colour of the skin, the colour, quality, and distribution of the hair, the form of the head and features, and the proportions of the limbs, as well as in the general stature.

Geographical position must have been one of the main elements in determining the formation and permanence of races. Groups of Men isolated from their fellows for long periods, such as those living on small islands, to which their ancestors may have been accidentally drifted, would naturally, in course of time, develop a new type of features, of skull, of complexion, or hair. A slight set in one direction, in any of these characters, would constantly tend to intensify itself, and so new races would be formed. In the same way, different intellectual or moral qualities would be gradually developed or transmitted in different groups of Men. The longer a race thus formed remained isolated, the more strongly impressed and the more permanent would its characteristics become, and less liable to be changed or lost when the surrounding circumstances were altered, or under a moderate amount of intermixture from other races—the more "true" in fact, would it be. On the other hand, on large continental tracts, where no mountain ranges or other natural barriers form obstacles to free intercourse between tribe and tribe, there would always be a tendency towards uniformity, from the amalgamation of races brought into close relation by war or by commerce. Smaller or feebler races would be destroyed or absorbed by others impelled by superabundant population or other causes to spread beyond their original limits; or sometimes the conquering race would itself disappear by absorption into the conquered.

Thus, for untold ages, the history of Man has presented a shifting, kaleidoscopic scene: new races gradually becoming differentiated out of the old elements, and, after dwelling a while upon the earth, either becoming suddenly annihilated or gradually merged into new combinations; a constant destruction and reconstruction; a constant tendency to separation and differentiation, and a tendency to combine again into a common uniformity—the two tendencies acting against and modifying each other. The history of these processes in former times, except in so far as they may be inferred from the present state of things, is a difficult study, owing to the scarcity of evidence. If we had any approach to a complete palæontological record, the history of Man could be reconstructed; but nothing of the kind is forthcoming. Evidence of the anatomical characters of Man, as he lived on the earth during the time when the most striking racial characteristics were being developed, during the long ante-historic period in which the Negro, the Mongolian, and the Caucasian were being gradually fashioned into their respective types, is entirely wanting, or if any exists it is at present safely buried in the earth, perhaps to be revealed at some unexpected time and in some unforeseen manner. Even the materials from which a history of the modifications of the human species as known to our generation must be constructed are rapidly passing away, as the age in which we live is an age in which, in a far greater degree than any previous one, the destruction of races, both by annihilation and absorption, is going on. Owing to the rapid extension of maritime discovery and commerce, changes such as have never been witnessed before are now taking place in the ethnology of the world, changes especially affecting the island populations among which, more than elsewhere, the solution of many of these problems may be looked for. The subject is, however, attracting the attention of observers of all countries to a greater degree than it ever has before, with the usual result of bringing distrust upon, and dissatisfaction with, the old systems, without as yet establishing anything in their place which meets with universal acceptance. The difficulty of finding distinctive characters capable of strict definition by which races or groups may be differentiated may be inferred from what has been said above. It is rather by the preponderance of certain characters in a large number of members of a group than by the exclusive or even constant possession of these characters in each of its members that the group must be distinguished. Hence, in all cases in which the characters can be expressed by the numerical method, as in the dimensions and proportions of different parts of the body, averages are now largely used by anthropologists. Provided the data upon which these averages are based have been obtained from a sufficient number of individuals, they can be absolutely relied upon to express the prevailing or most characteristic development of each particular feature in any group, and permit satisfactory comparisons between the conditions of that feature in different groups. Great progress is now being made in perfecting the methods of investigation of racial characteristics, and as we are beginning to learn what lines of research are profitable and what are barren, we may hope that the time is not far distant when we may get some clear insight into the knowledge of the natural classification and relationships of the races of Man. (W. H. F.)

INDEX.

MAMMOTH, a name commonly given to one of the numerous extinct forms of Elephant, *Elephas primigenius* of Blumenbach and most subsequent authors.[1] Probably no animal which has not survived to the historic period has left such abundant and well-preserved evidence of its former existence. The discovery of immense numbers, not only, as in the case of most extinct creatures, in the form of fragmentary bones and teeth, but often as more or less entire carcases, or "mummies" as they may be called, with the flesh, skin, and hair *in situ*, in the frozen soil of the tundras of northern Siberia, has for a long time given great interest to the species, and been the cause of many legendary stories among the natives of the lands in which they occur. Among these one of the most prevailing is that the Mammoth was, or still is, an animal which passes its life habitually in burrows below the surface of the ground, and which immediately dies if by any chance it comes into the upper air.

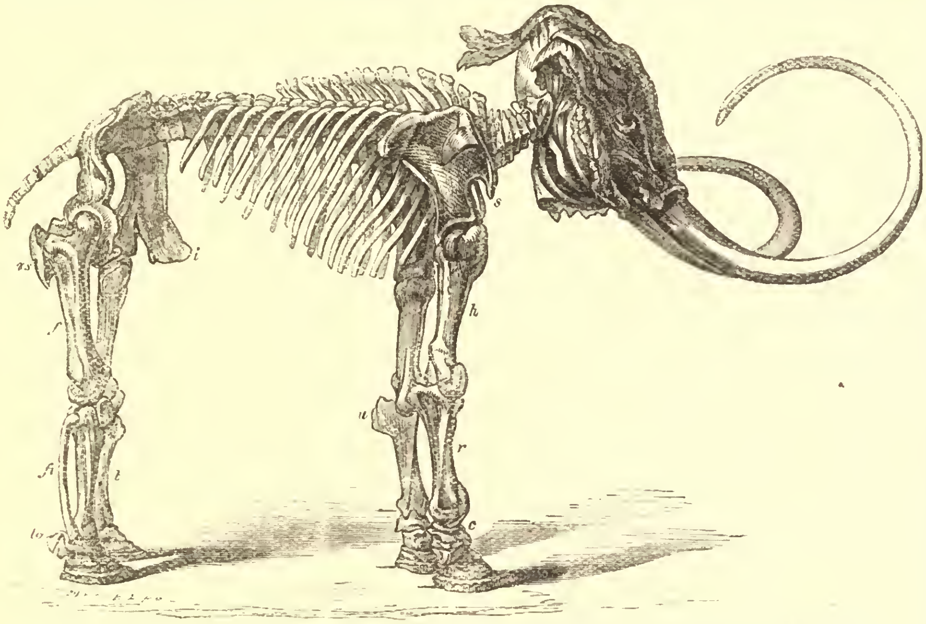


FIG. 1.—Restored Skeleton of Mammoth (*Elephas primigenius*). From Tilesius in *Mém. Acad. Imp. Sc. St Pétersbourg*, t. v. (1815).

The general characteristics of the animals of the order *Proboscidea*, to which the Mammoth belongs, are given in the article MAMMALIA (p. 423). Its position is also there indicated as a member of the most highly specialized section of the group of Elephants, that called by Falconer *Euelephas*, which also contains the modern Asiatic species. Of the whole group it is in many respects, as in the size and form of the tusks, and especially the characters of the molar teeth, the farthest removed from the primitive Mastodon-like type, while its nearest surviving relative, *E. indicus*, has retained the slightly more generalized characters of the Mammoth's contemporaries of more southern climes, *E. columbi* of America, and *E. armeniacus* of the Old World, if, indeed, it can be specifically distinguished from them.

The tusks or upper incisor teeth were doubtless present in both sexes, but probably of smaller size in the female. In the adult males they often attained the length of from 9 to 10 feet measured along the outer curve. Upon leaving the head they were directed at first downwards and outwards, then upwards and finally inwards at the tips, and generally with a tendency to a spiral form not seen in other species of Elephant. Different specimens, however, present great variations in curve, from nearly straight to an almost complete circle.

It is chiefly by the characters of the molar teeth that the various extinct modifications of the Elephant type are distinguished. Those of the Mammoth (see fig. 2) differ from the corresponding organs of allied species in (1) great breadth of the crown as compared with the length, (2) the narrowness and crowding or close approximation of the ridges, (3) the thinness of the enamel and its straightness, parallelism, and absence of "crimping" as seen on the worn surface, or in a horizontal section of the tooth. The molars, as in other Elephants, are six in number on each side above and below, succeeding each other from before backwards. Of these Dr Falconer gave the prevailing "ridge-formula" (or number of complete enamelled ridges in each tooth) as 4, 8, 12, 12, 16, 24, as in *E. indicus*. Dr Leith Adams, working from more abundant materials, has shown that the number of ridges of each tooth, especially those at the posterior end of the series, is subject to very great individual variation, ranging in each tooth of the series within the following limits: 3 to 4, 6 to 9, 9 to 12, 9 to 15, 14 to 16, 18 to 27,—excluding the small plates called "talons" at each end of the tooth. Besides these variations in the number of ridges or plates of which each tooth is composed, the thickness of the enamel varies so much as to have given rise to a distinction between a "thick-plated" and a "thin-plated" variety,—the latter being most prevalent among the specimens from the Arctic regions, and most distinctively characteristic of the species. From the specimens with thick enamel plates the transition to the other species or varieties mentioned above, including *E. indicus*, is almost imperceptible.

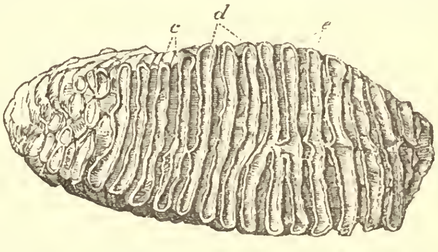


FIG. 2.—Grinding Surface of Upper Molar Tooth of the Mammoth (*Elephas primigenius*). From Owen. *c*, cementum; *d*, dentine; *e*, enamel.

The bones of the skeleton generally more resemble those of the Indian Elephant than of any other known species, but the skull differs, in the narrower summit, narrower temporal fossæ, and more prolonged incisive sheaths, required to support the roots of the enormous tusks. Among the external characters by which the Mammoth was distinguished from either of the existing species of Elephant was the dense clothing, not only of long coarse outer hair, but also of close under woolly hair, of a reddish-brown colour, evidently in adaptation to the colder climate which it inhabited. This character, for a knowledge of which we are indebted to the well-preserved remains found in northern Siberia, is also represented in the rude but

[1] The word Mammoth was introduced into the languages of western Europe about two centuries ago from the Russian, and is thought by Pallas and Nordenskiöld to be of Tartar origin, but others, as Witzen, Strahlenburg, and Howorth have endeavoured to prove that it is a corruption of the Arabic word *Behemoth*, or great beast.

graphic drawings of prehistoric age, found in caverns in the south of France.[1] In size different individuals varied considerably, but the average height does not appear to have exceeded that of either of the existing species of Elephant.

The geographical range of the Mammoth was very extensive. There is scarcely a county in England in which some of its remains have not been found either in alluvial deposits of gravel or in caverns, and numbers of its teeth are from time to time dredged up from the bottom of the sea by the fishermen who ply their trade in the German Ocean, having been washed out of the water-worn cliffs of the eastern counties of England. In Scotland and Ireland its remains are less abundant, but they have been found in vast numbers at various localities throughout the greater part of central Europe (as far south as Santander in Spain and Rome), northern Asia, and the northern part of the American continent, though the exact distribution of the Mammoth in the New World is still a question of debate. It has not hitherto been met with in any part of Scandinavia or Finland.

In point of time, the Mammoth belongs exclusively to the post-Tertiary or Pleistocene epoch of geologists, and it was undoubtedly contemporaneous with man in France, and probably elsewhere. There is evidence to show that it existed in Britain before, during, and after the glacial period.

As before indicated, it is in the northern part of Siberia that its remains have been found in the greatest abundance, and in quite exceptional conditions of preservation. For a very long period there has been from that region a regular export of Mammoth ivory in a state fit for commercial purposes, both eastward to China and westward to Europe. In the middle of the 10th century an active trade was carried on at Khiva in fossil ivory, which was fashioned into combs, vases, and other objects, as related by Abú 'l Kásim, an Arab writer of that period. Middendorff reckoned that the number of tusks which have yearly come into the market during the last two centuries has been at least a hundred pairs, and Nordenskiöld from personal observation considers this calculation as probably rather too low than too high. They are found at all suitable places along the whole line of the shore between the mouth of the Obi and Behring's Straits, and the farther north the more numerous do they become, the islands of New Siberia being now one of the most favourite collecting localities. The soil of Bear Islands and of Liachoff Islands is said to consist only of sand and ice with such quantities of Mammoth bones as almost to compose its chief substance. The remains are not only found around the mouths of the great rivers, as would be the case if the carcases had been washed down from more southern localities in the interior of the continent, but are imbedded in the frozen soil in such circumstances as to indicate that the animals had lived not far from the localities in which they are now found, and they are exposed either by the melting of the ice in unusually warm summers or by the washing away of the sea cliffs or river banks by storms or floods. In this way the bodies of more or less perfect animals, often standing in the erect position, with the soft parts and hairy covering entire, have frequently been brought to light.

References to the principal recorded discoveries of this kind, and to the numerous speculations to which they have given rise, both among the ignorant peasants and learned academicians, will be found in Nordenskiöld's *Voyage of the Vega* (English translation, vol. i. 1881, p. 398 *sq.*) and a series of papers in the *Geological Magazine* for 1880 and 1881, by H. H. Howorth. For the geographical distribution and anatomical characters, see Falconer's *Palæontological Memoirs*, vol. ii., 1868; Boyd Dawkins, "*Elephas primigenius*, its range in space and time," *Quart. Jour. Geol. Soc.*, xxxv. p. 138 (1879); and Leith Adams, "Monograph of British Fossil Elephants," part ii., *Palæontographical Society*, 1879. (W. H. F.)

[1] The best-known of these is the etching upon a portion of tusk found in the cave of La Madelaine in the Dordogne, figured in Christy and Lartet's *Reliquiæ Aquitanicæ*, and in many other works bearing on the subject of the antiquity of man.

MAMMOTH CAVE, in Edmondson county, Kentucky, United States, 37° 14′ N. lat. and 86° 12′ W. long., by rail 85 miles south-south-west of Louisville, was discovered, in 1809, by a hunter named Hutchins, while in pursuit of a wounded bear. Its mouth is in a forest ravine, 194 feet above Green river, and 600 feet above the sea. This aperture is not the original mouth, the latter being a chasm a quarter of a mile north of it, and leading into what is known as Dixon's Cave. The two portions are not now connected, though persons in one can make themselves heard by those in the other. Saltpetre was formerly made from the nitrous earth in which the cave abounded; but it is now mainly turned to account as a place of exhibition.

The cavernous limestone of Kentucky covers an area of 8000 square miles, is massive and homogeneous, and belongs to the Subcarboniferous period. It shows few traces of dynamic disturbance, but has been carved, since the Miocene epoch, into many caverns, of which the Mammoth Cave is the noblest specimen known. The region is undulating, but its valleys are mostly funnel-shaped depressions emptying through fissures into subterranean streams, which feed rivers, often of navigable size, and whose waters are never frozen over, even in severe winters. Such valleys are called sink-holes.

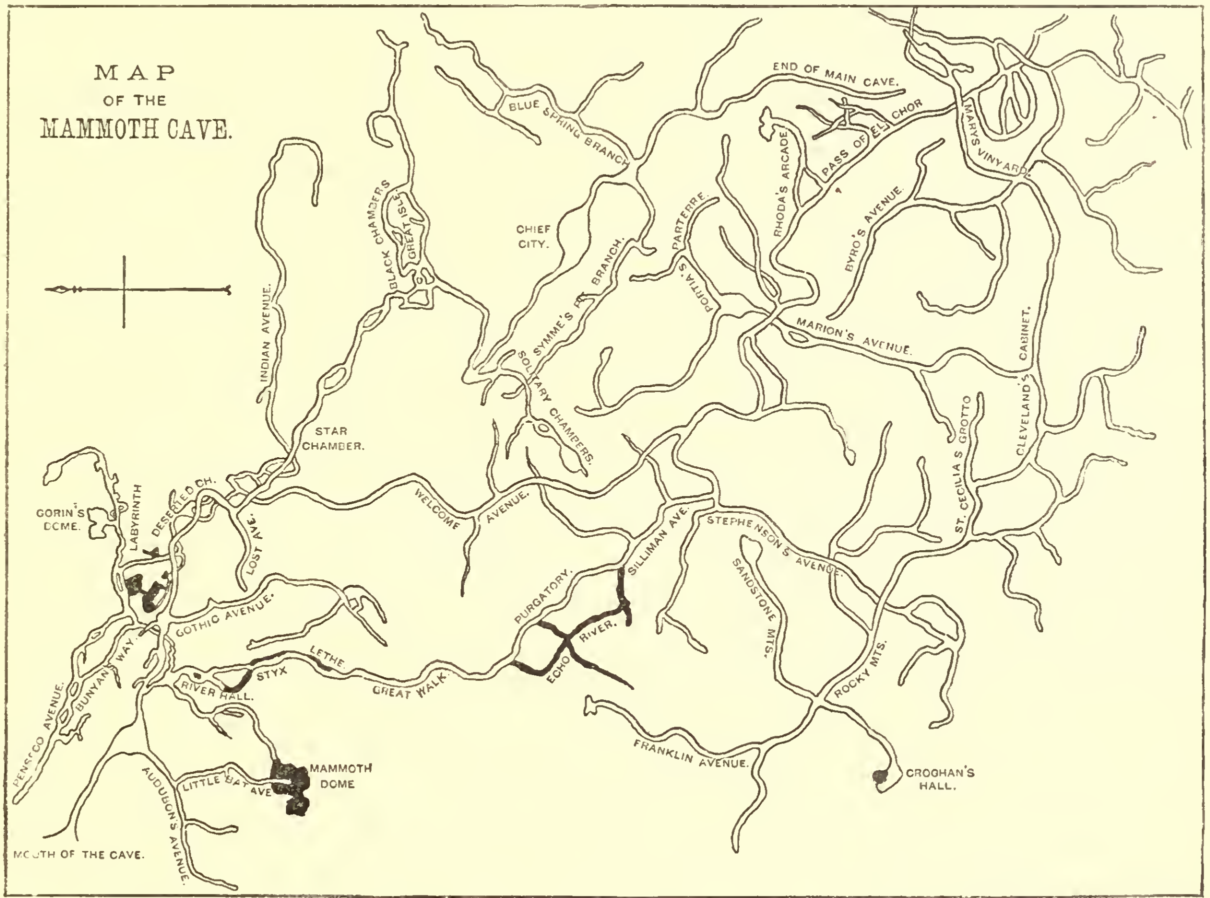
The natural arch that admits one to Mammoth Cave has a span of 70 feet, and from a ledge above it a cascade leaps 50 feet to the rocks below, where it disappears. A winding flight of stone steps leads the way down to a narrow passage, through which the air rushes with violence, outward in summer, and inward in winter. The temperature of the cave is uniformly 54° Fahr. throughout the year, and the atmosphere is both chemically and optically of singular purity. While the lower levels are moist from the large pools that have secret connexion with Green river, the upper galleries are extremely dry. These conditions led, at one time, to the erection of thirteen cottages, at a point about 1 mile under ground, for the use of invalids, especially consumptives. The experiment ended in failure, and only two cottages now remain.

The Main Cave, from 40 to 300 feet wide, and from 35 to 125 feet high, has several vast rooms, *e.g.*, the Rotunda, where are the ruins of the old saltpetre works; the Star Chamber, where the protrusion of white crystals through a coating of the black oxide of manganese creates an optical illusion of great beauty; the Chief City, where an area of 2 acres is covered by a vault 125 feet high, and the floor is strewn with rocky fragments, among which are found numerous half-burnt torches made of canes, and other signs of prehistoric occupancy. Two skeletons were exhumed near the Rotunda; but no other bones of any description have been found. The so-called Mammoth Cave "mummies" (*i.e.*, bodies kept by being inhumed in nitrous earth), with accompanying utensils, ornaments, braided sandals, and other relics, were found in Short and Salt caves near by, and removed to Mammoth Cave for exhibition. The Main Cave, which abruptly ends 4 miles from the entrance, is joined by winding passages, with spacious galleries on different levels; and, although the diameter of the area of the whole cavern is less than 10 miles, the combined length of all accessible avenues is supposed to be about 150 miles.[2]

[2] The present manager, Mr F. Klett, has undertaken the difficult task of a thorough survey, the results of which, so far as completed, are presented in the accompanying map. The portion beyond River Hall is supplemented from an older survey by Stephen, the guide.

The chief points of interest are arranged along two lines of exploration, besides which there are certain side excursions. The "short route" requires about four hours, and the "long route" nine. Audubon's Avenue, the one nearest the entrance, is seldom visited, except by the bats that hang from the walls in clusters like swarms of bees. The Gothic Avenue contains numerous large stalactites and stalagmites, and an interesting place called the Chapel, and ends in a small double dome and cascade. Among the most surprising features of cave scenery are the vertical shafts that pierce through all levels, from the uppermost galleries, or even from the sink-holes, down to the lowest floor. These are styled pits or domes, according to the position occupied by the observer. A crevice behind a block of stone 40 feet long by 20 wide, called the Giant's Coffin, admits the explorer to a place where six pits, varying in depth from 65 feet to 220 feet, exist in an area of 600 yards. This includes Gorin's Dome, which is viewed from a point midway in its side, and is by many regarded as the finest room in the cavern. Others admire more the Mammoth Dome, at the termination of Spark's Avenue, where a cataract falls from a height of 250 feet amid walls wonderfully draped with stalactitic tapestry. The Egyptian Temple, which is a continuation of the Mammoth Dome, contains six massive columns, two of them quite perfect, and 80 feet high and 25 feet in diameter. The combined length of these contiguous chambers is 400 feet. By a crevice above they are connected with an arm of Audubon's Avenue. Lucy's Dome, about 300 feet high, is supposed to be the loftiest of all these vertical shafts. A pit called "the Maelstrom," in Croghan's Hall, is the spot most remote from the mouth of the cave; a son of Prentice, the poet, permitted himself to be lowered 190 feet by a rope to the bottom, in 1859. There are some fine stalactites near this pit, and others in the Fairy Grotto and in Pensico Avenue; but, considering the magnitude of Mammoth Cave, its poverty of stalactitic ornamentation is remarkable. The wealth of crystals is, however, surprising. These are of endless variety and fantastic beauty. Besides the sparkling vault of the Star Chamber (300 feet long and 80 high), there are halls canopied by fleecy clouds, or studded with mimic snowballs, and others displaying various grotesque resemblances on the walls and ceiling.

Cleveland's Cabinet and Marion's Avenue, each a mile long, are adorned by myriads of gypsum rosettes and curiously twisted crystals, called "oulopholites." These cave flowers are unfolded by pressure, as if a sheaf were forced through a tight binding, and



Typographic Etching Co., del. et sc.

the crystal fibres curl outward from the centre of the group. Thus spotless arches of 50 feet span are embellished by floral clusters and garlands, hiding nearly every foot of the grey limestone. The botryoidal formations hanging by thousands in Mary's Vineyard resemble mimic clusters of grapes, as the oulopholites resemble roses. Again there are chambers with drifts of snowy crystals of the sulphate of magnesia, the ceilings so thickly covered with their efflorescence that a loud concussion of the air will cause them to fall like the flakes of a snow storm.

Many small rooms and tortuous paths, where nothing of special interest can be found, are avoided as much as possible on the regular routes; but certain disagreeable experiences are inevitable. There is peril also in the vicinity of the deep pits. The one known as the Bottomless Pit was for many years a barrier to all further exploration, but is now crossed by a wooden bridge. Long before the shaft had been cut as deep as now, the water flowed away by a channel gradually contracting to a serpentine way, so extremely narrow as to be called the Fat Man's Misery. The walls, only 18 inches apart, change direction eight times in 105 yards, while the distance from the sandy path to the ledge overhead is but 5 feet. The rocky sides are finely marked with waves and ripples, as if running water had suddenly been petrified. This winding way conducts one to River Hall, beyond which lie the crystalline gardens that have been described. It used to be said that, if this narrow passage were blocked up, escape would be impossible; but lately an intricate web of fissures, called the Corkscrew, has been discovered, by means of which a good climber, ascending only a few hundred feet, lands 1000 yards from the mouth of the cave, and cuts off one or two miles.

The waters, entering through numerous domes and pits, and falling, during the rainy season, in cascades of great volume, are finally collected in River Hall, where they form several extensive lakes, or rivers, whose connexion with Green river is known to be in two deep springs appearing under arches on its margin. Whenever there is a freshet in Green river the streams in the cave are joined in a continuous body of water, the rise sometimes being 60 feet above the low-water mark. The subsidence within is less rapid than the rise; and the streams are impassable for about seven months in each year. They are navigable from May to October, and furnish interesting features of cave scenery. The first approached is called the Dead Sea, embraced by cliffs 60 feet high and 100 feet long, above which a path has been made, whence a stairway conducts us down to the banks of the River Styx, a body of water 40 feet wide and 400 feet long, crossed by a natural bridge. Lake Lethe comes next—a broad basin enclosed by walls 90 feet high, below which a narrow path leads to a pontoon at the neck of the lake. A beach of the finest yellow sand extends for 500 yards to Echo river, the largest of all, being from 20 to 200 feet wide, 10 to 40 feet deep, and about three-quarters of a mile long. It is crossed by boats. The arched passage-way is very symmetrical, varying in height from 10 to 35 feet, and famous for its musical reverberations,—not a distinct echo, but an harmonious prolongation of sound for from 10 to 30 seconds after the original tone is produced. The long vault has a certain keynote of its own, which, when firmly struck, excites harmonics, including tones of incredible depth and sweetness.

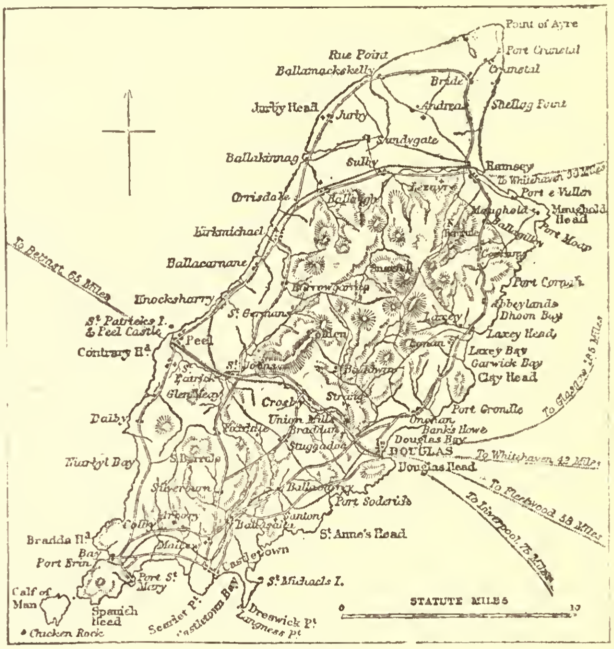
The fauna of Mammoth Cave has been classified by Putman, Packard, and Cope, who have catalogued twenty-eight species truly subterraneous, besides those that may be regarded as stragglers from the surface. They are distributed thus:—*Vertebrata*, 4 species; *Insecta*, 11; *Arachnida*, 6; *Myriapoda*, 2; *Crustacea*, 2; *Vermes*, 3. Ehrenberg adds a list of 8 Polygastric *Infusoria*, 1 fossil infusorian, 5 *Phytolitharia*, and several microscopic fungi. A bed of *Agaricus* was found by the writer near the River Styx; and upon this hint an attempt has been made to propagate edible fungi in this locality. The most interesting inhabitants of Mammoth Cave are the blind, wingless grasshoppers, with extremely long antennæ; blind, colourless crayfish (*Cambarus pellucidus*, Telk.); and the blind fish, *Amblyopsis spelæus*, colourless and viviparous, from 1 inch to 6 inches long. The *Cambarus* and *Amblyopsis* have wide distribution, being found in many other caves, and also in deep wells, in Kentucky and Indiana. Fish not blind are occasionally caught, which are apparently identical with species existing in streams outside. The true subterranean fauna may be regarded as chiefly of Pleistocene origin; yet certain forms are possibly remnants of Tertiary life. The strongly marked divergence of these animals from those found outside convinced the elder Agassiz that they were specially created for the limits within which they dwell. But the opinion now held is that they are modified from allied species existing in the sunlight, and that their peculiarities may all be accounted for on principles of evolution,—the process being accelerated (or retarded) by their migration from the outer world to a realm of absolute silence and perpetual darkness.

The literature of Mammoth Cave is extensive, though scattered through many periodicals, volumes of travels, and scientific reports. See especially Bullitt, *Rambles by a Visitor*, 1844; Collins, *History of Kentucky*, 1847; Forwood, *The Mammoth Cave*, 1870; Packard and Putnam, *Inhabitants of Mammoth Cave*, 1872; Shaler, *Memoirs of Geological Survey of Kentucky*, 1876; Hovey, "In Mammoth Cave," *Scribner's Magazine*, 1880; *Celebrated Caverns*, 1882. (H. C. H.)

MAN. See ANTHROPOLOGY (vol. ii. p. 107 *sq.*) and the articles on the various contributory sciences there referred to. Compare also MAMMALIA, above, p. 444.

MAN, ISLE OF, a dominion of the crown of England, situated in the Irish Sea, almost equidistant from England on the east, Scotland on the north, and Ireland on the west. It lies between 54° 2′ and 54° 25′ N. lat., and between 4° 18′ and 4° 50′ W. long., Douglas on the east coast of the island being distant 58 miles west-north-west from Fleetwood, while Peel on the west coast is 65 miles south-east of Belfast. The greatest length of the island is about 33 miles, and its greatest breadth about 12 miles. The total area is 145,325 acres, or about 227 square miles.

A mountain range occupies the larger portion of the island, extending from Maughold Head to the Calf Islet; the highest summits—Snaefell (2024 feet), North Barrule (1842), and Slieu Chairw (1808)—are in the north-west. These mountains rise abruptly from the narrow tract of almost level ground which forms the extreme northern boundary of the island; and between their lofty chasms are the lovely and picturesque recesses of Ravensdale, Sulby Glen, Glen Aldyn, and Ballure. The fine scenery of the mountains has been made more accessible by the construction of a series of roads, commanding at many points views unsurpassed in the United Kingdom for picturesqueness and variety. In the south-western portion of the mountain range only one summit, that of South Barrule (1585 feet), rises above 1500 feet. From Peel southwards along the western shore the mountains stretch to the very edge of the coast-line, and at the south-western extremity the shore is wildly precipitous, especially at Cronk-ny-Irree-Lhaa, which rises abruptly from the sea to the height of 1449 feet; at Brada Head, near which Brada Hill forms an almost precipitous wall over 700 feet in height; at Calf Islet, surrounded by rugged broken rocks; and at Spanish Head (said to take its name from the destruction which there overtook a portion of the Spanish Armada). Towards the south-eastern shore the mountains slope more gradually towards the sea, the coast of which is generally low and sandy, being indented by several finely rounded bays, including Castletown Bay and Derby Haven. From Derby Haven to Maughold Point the coast is frequently bold and rocky, and the numerous creeks and bays, the largest of which are Douglas Bay and Laxey Bay, greatly add to the charm and variety of the scenery. From Maughold Head round to Peel the coast presents little of special interest, being formed in great part of sand and gravel cliffs, although along the western side the bold clay-slate formation again appears.



Isle of Man.

The largest river in the island is the Sulby, which rises near Snaefell, and, after flowing northwards through a rugged glen to Sulby village, winds eastwards through a level and well-cultivated country to the sea at Ramsey. The Neb or Great River, which is formed by the junction near Slieuwhallin of a stream rising near South Barrule and flowing north by the Foxdale Glen, and of another flowing south from Sartfell by Rhenass, passes west to the Irish Sea at Peel. The Silverburn flows southwards from South Barrule to the Castletown Bay. The Dhu and Glass flowing eastwards unite before entering the sea at Douglas, which takes its name from their union. The streams abound with trout, and fishing is generally permitted without restriction. There are no lakes.

Geology.—The greater part of the island is formed of slaty Silurian rocks of identical formation with the mountainous regions of Cumberland and Westmoreland. No characteristic fossils, however, exist to determine their exact age except one, *Palæochorda major*, found in the Skiddaw slates. The line of strike is from south-west to north-east, and the strata are highly inclined. The mountains for the most part present a smooth rounded appearance, superinduced by prolonged subaerial waste. The clay-slate formation is sometimes broken through by intrusions of granite and other eruptive rocks. The "greenstones" are especially visible at Brada Head, Castletown, Langness, and other points along the coast. A large mass of granite, containing silvery mica, red and white felspar, and gray quartz, rests on the eastern slope of South Barrule mountain, and valuable masses of the same rock appear at the Dhoon river to the north-east of the Laxey lead-mines. Upper Old Red Sandstone and conglomerate occur at Peel on the west coast, and on the south coast, in the neighbourhood of Castletown Bay, chiefly at the peninsula of Langness. It rests on the upturned edges of the slates, and passes imperceptibly into the beds of limestone. The Carboniferous or Mountain Limestone is the only representative of the Carboniferous strata in the island. The limestone contains numerous fossils. At Poolvash it assumes the character of black marble, which is much used for chimneypieces. At Scarlet Point, and thence to Poolvash, interesting evidence exists of volcanic eruptions during the accumulation of the Carboniferous rocks. A great blank in the geological record occurs at the top of the limestone series, for the next strata that appear are the clays and gravels of the Glacial period. These strata occupy the greater portion of the low ground of the island, and consist of boulder clay, drift gravel, and sands. They occasionally reach as far up the mountains as 500 feet, and in the southern districts erratic boulders are sometimes to be observed on the very highest summits. Boulders of granite, for example, have been carried across South Barrule Hill (1585 feet) and dropped on the top of Crook-ny-Irree-Lhaa (1449 feet). The whole of the plain in the north of the island is occupied by Drift deposits, which occasionally form hills above 300 feet in height. Numerous depressions in the plain at one time occupied by lakes are now filled by beds of peat.

Minerals.—The most important minerals are lead, copper, and zinc. The principal mines are those of Laxey, near the Laxey river, which produce lead, copper, and especially sulphide of zinc, which forms more than two-thirds of the total quantity of ore raised from those mines. The galena obtained is very rich in silver. The Foxdale mines, between Castletown and St John's, are also very largely wrought. The amount of copper ore is comparatively small. The mines are rented from the queen as lady of the manor, the lessees paying one-tenth of the produce. In 1852 the total quantity of lead ore obtained was 2415 tons, of lead 1834¼ tons, and of silver 36,700 oz., the value of which was £7646. In 1871 the total quantity of lead ore obtained was 4645 tons, producing 3335 tons of lead and 176,631 oz. of silver; 5768 tons of zinc were also obtained, valued at £19,015, and 267 tons of copper ore, producing 18 tons of copper, valued at £1074. In 1881 Brada Head copper-mine yielded 78 tons of ore, producing 6 tons 5 cwts. of fine copper, valued at £562, 13s.; and at Great Laxey 7567 tons of zinc were raised, giving 3480 tons of the metal, valued at £28,701. The following table gives the produce of the lead-mines in 1881.

Mine.	Lead Ore.	Lead.		Silver.	Value of Ore.		
	Tons.	Tons.	Cwts.	Oz.	£	*s.*	*d.*
Foxdale	3,419	2,500	0	9,080	39,145	10	0
Laxey	1,700	1,275	0	5.250	30,487	0	0
Foxdale, East	400	292	0	9.600	5,362	0	0
Rushen	101	75	7	810	1,050	15	0
Kirk Michael	40	30	0	125	338	0	0
Great Laxey	15	11	5	...	129	15	0
Total	5,675	4,183	12	84,865	76,513	0	0

Rotten-stone and ochre are obtained in the south at Malew and Arbory, the total amount raised in 1881 being 207 tons, valued at £636. Iron is found in small quantities at Foxdale, but the total quantity obtained in 1881 was only 120 tons, valued at £60. Limestone is extensively quarried in the southern districts, both for building purposes and for agriculture. Dolomite occurs in large quantities in the mines at Laxey. There is a valuable granite quarry at Foxdale. Gold in minute particles lies in the bed of a small stream near Barrule. A considerable number of other minerals are found, but the quantity of each is unimportant. The total number of persons employed in the mines in 1881 was 1258.

Climate.—The mean annual temperature is higher than that of any other district occupying the same parallel of latitude, and the variation according to the seasons is remarkably small. The mean annual temperature is a little less than 49° Fahr., the mean temperature of summer less than 59°, and that of winter nearly 42°, giving a difference of only 17°. Rain is frequent but seldom heavy, the annual fall being 41·71 inches, about the same as in the adjacent parts of England and Scotland, but less than in those of Ireland. Thunderstorms are very rare. Many plants, even palms, which in England require artificial heat, grow in some parts of the island throughout winter in the open air, while fuchsias under the same conditions attain to great size and perfection. The air is unusually clear and pure.

Agriculture.—Owing originally to the enterprise of Scotch and English farmers, the land where arable has been brought into a state of high cultivation. Through the use of seaweed in large quantities in the northern districts of the island the sandy and gravelly soil has been greatly enriched, and it now possesses remarkable fertility, its productiveness being increased by the fine climate. The lime obtained in the neighbourhood of Castletown in the south has also been found highly beneficial for the soil in that vicinity. The best land is in these two districts, but even in the mountainous regions in the centre of the island great improvements have taken place. The farms are principally held on lease, and of late years many small holdings have been combined into large farms cultivated on modern principles.

According to the agricultural returns of 1882, the cultivated area comprehended 97,494 acres, 67 per cent. of the whole. The commons and uncultivated lands on the mountains are, moreover, utilized for the pasturage of horses, cattle, and sheep, the evergreen furze forming the principal food of these animals during the winter season. The area under corn crops was 25,211 acres, under green crops 12,046, rotation grasses 37,094, permanent pasture (exclusive of heath or mountain land), 22,836, and fallow 307. Oats occupy about one-half of the total area under corn crops, barley about one-third, and wheat about one-sixth. The wheat, which is of a very fine quality, is cultivated chiefly in the north of the island. The white and red clover and the common grasses grow in great luxuriance, and on account of the good pasturage in winter the supply much exceeds the needs of the island, large quantities being shipped to the neighbouring districts of England. Turnips, which in 1882 occupied 8432 acres, are also largely exported. The dry sandy soil of the island is very favourable for the growth of potatoes, the area planted in 1882 being 3373 acres. The most common rotation of crops is corn, green crop, corn, clover and hay, and pasture.

The total number of horses in 1882 was 5249, of which 3551 were used solely for purposes of agriculture. The native breed of horses is similar to that of North Wales. They are small, but hardy, active, and patient of labour. In 1882 cattle numbered as many as 19,780, an average of nearly 21 to every 100 acres under cultivation, considerably above that of Great Britain, which was 18·4. Of the cattle, 6862, or more than one-third, were cows and heifers in milk or in calf. On account of the large number of summer visitors, dairy farming is specially profitable. The native breed of cattle has very much degenerated, but an improved stock is now general through the importation chiefly of Ayrshires and shorthorns. Sheep in 1882 numbered 55,690, not a very large number considering the mountainous nature of the country, but cattle feeding is generally more profitable than sheep rearing, partly owing to the fine climate. The principal sheep runs are those which have been enclosed by the crown from the common lands. The native breed of sheep, small hardy animals, is gradually being superseded by crosses, and by the introduction of English sheep in the low grounds. The fleece of the native sheep is not valuable, but the mutton is of very fine quality. Pigs are largely kept, the number in 1882 being 4685. The old breed called "purrs" is now nearly extinct.

In 1882 there were 237 acres under orchards, 142 under market gardens, and 6 under nursery grounds. The acreage under woods is not given, but it is very small. Apples, for which the island was at one time famed, are still grown in considerable quantities, and gooseberries, currants, strawberries, and other smaller fruits are largely cultivated. The botany of the island is not specially interesting. The variety of species is not great, although there are a few rare plants.

Fauna.—Like Ireland, the Isle of Man is exempt from venomous reptiles and toads, a circumstance traditionally attributed to the agency of St Patrick, the patron saint of both islands. Frogs are, however, found, and both the sand lizard and the common lizard are met with. Moles are absent, badgers are unknown, and foxes are now extinct. Fossil bones are frequently found of the

Irish elk; and the red deer, as is proved by the references to it in old laws, and the representations of it on Runic monuments, was at one time common, although the species had almost disappeared about the beginning of the 18th century. Hares are less plentiful than formerly, and rabbits are not numerous except on the Calf Islet. Snipe are abundant. There are a few partridges, grouse, and quail, but neither pheasants nor black game. Various species of waterfowl visit the island, including wild geese, wild ducks, plover, widgeon, and teal. The Manx puffin (*Procellaria anglorum*) is becoming scarce, but still frequents the Calf Islet. The peregrine falcon breeds in the precipitous rocks in the neighbourhood of the Calf Islet, and at Maughold Head. The red-legged crow is common, the kingfisher scarce. The cuckoo is a yearly visitant, as is also the lapwing. Wild pigeons and seabirds of great variety frequent the rocks.

A variety of the domestic cat, remarkable for the absence or stunted condition of the tail, is common in the island.

Manufactures and Trade.—Partly perhaps on account of the absence of coal, the manufactures of the island have not attained any importance, the principal being Manx cloth, canvas, nets, ropes, and twine. There is, however, a large export of all kinds of agricultural produce, horses, cattle, and sheep, as well as of lead, lime, and black marble. Much of the trade is still carried on by means of small coasting vessels, but these are being gradually superseded by steamers which ply between Douglas and Liverpool, Barrow, Fleetwood, Silloth, Dublin, Belfast, Whitehaven, and Glasgow. The imports consist principally of provisions from England, timber from Norway, and lean cattle from Ireland. In 1881 the number of vessels engaged in the foreign and colonial trade that entered the ports of the island was 26 of 4885 tons, while 14 of 2916 tons cleared. The number engaged in the coasting trade was—entered, 2288 of 440,158 tons; cleared, 2328 of 436,107 tons. There is daily communication between Douglas and Liverpool.

There are very valuable fishing grounds, especially for herring and cod, round the southern half of the island from Peel to Douglas, and mackerel fishing is also largely prosecuted by the islanders off the coast of Ireland. The Manx fishing boats, decked and undecked, number upwards of seven hundred, employing more than four thousand men. Peel and Port St Mary alone have about three hundred and fifty-seven boats, manned by two thousand five hundred men, the capital invested in boats and nets being for these ports alone about £100,000.

The prosperity of the island, apart from its fishing and agriculture, is mainly dependent on its yearly influx of summer visitors, the annual number being now about 120,000. The season lasts from the middle of May to the middle of September.

Internal Communication.—The roads, which of late years have been greatly improved and extended, are excellent. They are maintained by a system of licences on innkeepers, grocers, and hawkers, and by an impost on carriages, carts, and dogs, and a rate on real property. The highways are under the management of a board appointed by the Tynwald court, a surveyor-general, and parochial surveyors.

The first railway in the Isle of Man was that between Douglas and Peel, opened in 1873. There is now communication by rail between the various towns of the island, and a proposal has also been made for a direct line between Douglas and Ramsey *via* Laxey. The insular government has assisted one of the railway companies by a guarantee. The railways are single narrow-gauge lines, and are worked on the baton system.

Government and Administration.—The government of the island is vested in a governor appointed by the crown, a council which acts as an upper chamber of the legislature, and the House of Keys. The governor and council and the House of Keys together constitute the court of Tynwald; but the approval of the queen of Great Britain in council is essential to every legislative enactment. Acts of the British legislature do not affect the island except it be specially named in them. For the purposes of civil jurisdiction the island is divided into a northern and a southern district, and each of these is again subdivided into three "sheadings," which are analogous to counties.

The governor, who is the representative of the sovereign, is captain-general of the military forces. He presides in the council and in all courts of Tynwald, and is *ex officio* sole judge of the chancery and exchequer courts. The council consists of the lord bishop of the diocese, the attorney-general, the two deemsters, the clerk of the rolls, the water-bailiff, the receiver-general, the archdeacon, and the vicar-general, all of whom are appointed by the crown, except the vicar-general, who is appointed by the bishop. No act of the governor and council is valid unless it is the act of the governor and at least two members of the council. The House of Keys, the representative branch of the legislature of the island, is one of the most ancient legislative assemblies in the world. It consists of twenty-four members elected by male owners or occupiers, and female owners of property. Each of the six sheadings elects three members, the towns of Castletown, Peel, and Ramsey one each, and Douglas, the chief town, three. There is a property qualification required of the members, and the house sits for seven years unless previously dissolved. The Keys were at one time self-elected, but in 1866 they consented to popular election in exchange for the privilege of controlling the expenditure of the surplus revenue of the island, agreeing, however, to pay into the imperial exchequer a fixed sum of £10,000 annually as the island's contribution towards the expenses of the army and navy of the United Kingdom.

In matters of property the court of chancery has the most extensive jurisdiction of any in the island, and is a court both of law and of equity. The governor presides, and is assisted by the clerk of the rolls and the deemsters. The exchequer court takes cognizance of all matters connected with the revenue, and also determines the right of tithe. The common law courts for the southern division are held at Douglas and Castletown alternately, and those for the northern division at Ramsey, once in three months. They are presided over by the deemsters, and take cognizance of all actions, real, personal, and mixed, and of civil matters that require to be determined by a jury. Courts of general jail delivery are held at Castletown, for the trial of prisoners indicted for criminal offences; the governor presides, attended by the deemsters, the clerk of the rolls, and the water-bailiff.

The deemsters or judges of the island (supposed by some to be the successors of the Druidical priests) until the 15th century acted according to unwritten laws, called "breast laws," of which they were the depositaries. They have concurrent jurisdiction over the whole island. Their advice is taken by the governor on all difficult points of law. Each has now a salary of £1000 per annum. Deemster courts are held weekly, alternately at Douglas and Castletown by the deemster for the southern division, and at Ramsey and Peel or Kirk Michael by the deemster of the northern division. They take cognizance in a summary manner of matters of debt, and have jurisdiction in criminal cases. The herring fishery, and the boats employed in it, are placed under the charge of the water-bailiff, who holds courts to redress grievances and enforce the regulations of the fishery. He appoints with a small salary two fishermen, called admirals, to preserve order. The water-bailiff has also civil jurisdiction in questions of salvage, and takes cognizance of suits in maritime matters. The high bailiff's courts are held weekly in Douglas, Castletown, Ramsey, and Peel for the recovery of debts under 40s., and daily for the punishment of drunkenness and offences against public order. The magistrates hold regular courts in each of the towns for the summary trial of breaches of the peace and minor offences. They are appointed by commission under the great seal of England, but their powers are regulated by insular acts of Tynwald. The members of the council and the four high bailiffs are also *ex officio* magistrates. The coroner of the sheading, who is appointed annually by the governor, is a kind of sheriff. Inquests of death are held by the high bailiff and jury. There are about thirty legal practitioners, called advocates, who combine the functions of barrister and solicitor.

The laws of the island still retain much of their ancient peculiarity of character, though modified by acts of Tynwald, and rendered in some respects more in unison with those of England. The criminal law was consolidated and amended by the criminal code of 1872.

The general tenure is a customary freehold devolving from each possessor to his next heir-at-law. The descent of land follows the same rules as the descent of the crown of England. The right of primogeniture extends to females in default of males in the direct line. The interest of a widow or widower, being the first wife or husband of a person deceased, in a life estate is one-half of the lands which have descended hereditarily, and is forfeited by a second marriage; a second husband or second wife is only entitled to a life interest in one-fourth, if there be issue of the first marriage. Of the land purchased by the husband the wife surviving him is entitled to a life interest in one moiety. By a statute of the year 1777 proprietors of land are empowered to grant leases for any term not exceeding twenty-one years in possession without the consent of the wife.

Previous to the Act of Revestment in 1765, the commerce of the island consisted principally in the importing and exporting of contraband goods, the average return of which exceeded half a million sterling per annum, the loss to the British revenue being estimated at £300,000. After this period the customs of the island were regulated by the imperial parliament. The various loans to the insular government were consolidated in 1882, and the funded debt now amounts to £230,000.

For the year ending March 31, 1882, the net revenue of the customs of the island was £70,906, and the expenditure £50,558, leaving a balance of £20,348, which is disposed of thus:—

One-ninth part of the quarter's revenue to 31st March 1882		£1,091
Due exchequer	£10,000	
Less abatement on account of loss on importation of goods	2,000	
		8,000
Expended by War Department, 1881–82		278
Do. Board of Works, 1881–82		846
Unappropriated surplus due Isle of Man		10,133
		£20,348

Religion and Education.—Christianity is said to have been introduced into the island by St Patrick about the middle of the 5th century. The bishopric of Sodor (*i.e.*, Sudreys, the southern Hebrides) was formerly united with that of Man; and the union continued till the 14th century, the Manx bishops even now retaining the joint title Sodor and Man. Some indeed affirm, but with small evidence to support the statement, that the title of Sodor was derived from the little island off Peel, said to have been at one time called Sodor, now known as St Patrick's Isle, and the seat of the cathedral of St German. The diocese is in the province of York; its bishop has a seat but not a vote in the House of Lords. The bishop is assisted in ecclesiastical matters by an archdeacon, a vicar-general, a registrar, and a sumner-general.

The ecclesiastical courts are the consistory, chapter, and the vicar-general's summary court. The livings of the clergy arise chiefly from tithes; the patronage, from the bishopric downwards, with the exception of four in the gift of the diocesan, is vested in the crown.

Besides King William's College, opened in 1833, providing an education equal to that obtainable at the highest class schools of England, and possessing a considerable number of exhibitions to the universities, there are in the island several other good secondary schools. The parochial schools are also well taught, and there are now board schools, under the insular Education Act, established throughout the island.

Population.—The following table shows the population of each parish and town from 1726 to 1881.

Sheadings, Parishes, and Towns.		Population.					
		1726.	1757.	1821.	1851.	1871.	1881.
Rushen.	Malew, (P.)	890	1,466	2,649	3,232	2,466	2,595
	Castletown, (T.)	785	915	2,036	2,501	2,318	2,274
	Arbory, (P.)	661	1,785	1,155	1,593	1,350	1,272
	Rushen, (P.)	813	1,007	2,568	3,262	3,665	3,509
Middle.	Santon, (P.)	376	507	800	714	628	588
	Braddan, (P.)	780	1,121	1,754	2,407	2,215	2,071
	Douglas, (T.)	810	1,814	6,054	9,653	13,846	15,725
	Onchan, (P.)	370	434	1,457	3,478	1,620	1,500
Glenfaba.	Marown, (P.)	499	658	1,201	1,363	1,121	983
	German, (P.)	510	925	1,849	2,168	1,762	1,692
	Peel, (T.)	475	805	1,909	2,329	3,496	3,822
	Patrick, (P.)	745	954	2,031	2,923	2,888	2,625
Garff.	Lonan, (P.)	547	869	1,846	2,605	3,741	3,275
	Maughold, (P.)	529	759	1,514	1,764	1,433	1,147
	Ramsey, (T.)	460	882	1,523	2,660	3,861	4,214
Ayre.	Lezayre, (P.)	1,309	1,481	2,209	2,455	1,620	1,478
	Bride, (P.)	612	629	1,001	1,053	880	759
	Andreas, (P.)	967	1,057	2,229	2,165	1,757	1,477
Michael.	Jurby, (P.)	483	467	1,108	983	788	659
	Ballaugh, (P.)	806	773	1,467	1,392	1,077	971
	Michael, (P.)	643	826	1,427	1,416	1,231	1,102
Total		14,070	20,134	40,087	52,116	53,763	53,738

In 1880 the death-rate was 21·9 per 1000, and the birth-rate 28·6.

The principal towns of the island are Douglas, Castletown, Ramsey, and Peel. Douglas, the chief town and seat of government, is noticed in vol. vii. p. 376. Castletown, the ancient capital of the island, was until a recent period the residence of the governor. It possesses a good harbour, barracks, and a custom-house. Ramsey, on account of its fine sandy beach and beautiful situation, is a favourite watering-place, and it has also a large shipping trade. Peel, adjoining St Patrick's Islet, is the principal seat of the herring fishery.

Language.—The Manx language is a subdialect of the ancient Celtic, and a dialect of the Irish branch, to which the Scottish Gaelic also belongs. The differences in pronunciation of these languages are not so great as to prevent a native of either country conversing with one of the other, although the differences in orthography perplex even the most learned linguists. The Manx is now spoken only in the north-western parishes and at a few localities along the western coast. The natives generally converse in the English language. Manx is not taught in any of the schools, and it is very probable that it will shortly become utterly extinct. See CELTIC LITERATURE, vol. v. p. 298.

History and Antiquities.—It admits of nearly absolute demonstration that Anglesey and not Man was the *Mona* of Cæsar. By ancient writers the island is called Eubonia. The English name Man is derived from the Manx *Mannin.* Many explanations have been given of the origin of the word, but none of them are better than conjectures.[1] It is inherently probable that the island was occupied by the Romans, and this is confirmed by the discovery of a Roman altar, which is still preserved in Castle Rushen, and of Roman coins in the same vicinity. A cist and urn found in 1852 near Tynwald Hill are supposed to belong to the aboriginal pagan period; another memorial of this period is probably St Patrick's chair, consisting of five upright stones on a stone platform forming a seat. Two of the stones are marked by a cross, but this in all likelihood was done at a period long subsequent to their erection. According to tradition the island was for a considerable period one of the chief seats of the Druids. By the peasantry nearly all the old monuments are attributed to the Druids, but the Runic crosses belong of course to a later period. One of the principal Druidical stone circles is that on the eminence called Mull, near the Calf Islet.

The earliest personage mentioned by tradition and history is Mannanan-Beg-Mac-y-Lheirr, who is described in the statute-book of the island as a paynim, who "kept the land *under mist* by his necromancy." In 517 Maelgwyn, king of North Wales, and nephew of King Arthur, expelled the Scots, and annexed the island to his Welsh dominions. He was succeeded by his son Rhun-ap-Maelgwyn in 560, from whom in 581 the island was reconquered by Aydun M'Gabhran, king of Scotland, who appointed his sister's son Brennus "thane of Man." The Welsh king appears to have recovered it from the Scots about 611, and to have retained possession of it until 630, when it was conquered by Edwin, king of Northumbria. Shortly afterwards it again fell under the dominion of the Welsh, till towards the close of the 9th century it was subdued by Harold Haarfager of Norway. The jarls of Harold for some time threw off his rule, and held independent sway. Of these Jarl Orry succeeded in establishing his rule over Man. His descendants continued to rule till 1077, when Godred Crovan, son of Harold the Black of Iceland, routed the islanders and slew their king, Fingal II. On the death of Godred in 1093, Magnus Barefoot succeeded in obtaining possession of Man, over which he placed the Norwegian jarl Oettar as governor. The inhabitants of the southern district, becoming displeased with Oettar, elected Macmanus in his place; a battle in consequence ensued at Santwart (or Sainthill), in the parish of Jurby, and victory was inclining to the party of Macmanus, when the women of the north, rushing to the scene of action, totally changed the issue of the fight, although not till both leaders were slain. On the death of Magnus, the right of Godred Crovan's line to the kingdom of the Isles was recognized, and Lagman, the son of that conqueror, succeeded to the government. He at length abdicated, and undertook a pilgrimage to Palestine, whence he never returned. Olave II., surnamed the Dwarf, the only surviving son of Godred Crovan, being then a minor, a regent was appointed, who was expelled from the kingdom in the third year of his government. Olave ascended the throne in 1114. He entered into alliance with the kings of England, Ireland, and Scotland, but his reign was disturbed by the pretensions of three natural sons of his brother Harold, by one of whom he was treacherously slain in 1154. On this Godred the Black, Olave's only legitimate son, was recalled from Norway, and the sons of Harold were delivered to condign punishment. During his reign Somerled, thane of Argyll, obtained possession of the island, and Godred had to take refuge in Norway, where he remained till the death of the usurper, on which he regained possession of his throne. His death took place in 1187. Olave III., his only legitimate son, being then a minor, Reginald, another son, was appointed to the government during his minority. The latter endeavoured to secure to himself the throne by doing homage to John of England, and afterwards by acknowledging the supremacy of the pope; a series of struggles was the consequence, till at length Reginald was slain in 1226. In 1237 Olave died in Peel Castle, leaving three sons,—Harold, Reginald, and Magnus; he was succeeded by his son Harold II., who was drowned, with his queen and a numerous retinue of nobility, in 1248, on their return from Norway, where they had been celebrating his marriage with Cecilia, daughter of Haco. His brother Reginald II. assumed the government, but was afterwards slain by Ivar, brother of Reginald the usurper, in 1249. On the death of Reginald II. his brother Magnus was chosen king. John of the Isles landed with an army at Ronaldsway to dispute his claims, but was driven from the island.

From this time the power of the Norwegian kings began to decline, and that of the Scottish sovereigns to revive. Magnus did homage to Alexander III. of Scotland, and held the island from the crown of Scotland. He died in 1265, without issue. In the meantime Magnus VI. of Norway, as the legitimate sovereign of Man, ceded in 1266 to Alexander III. all his claims and interest in the sovereignty and episcopacy of Man for the sum of 4000 marks, and an annual pension of 100 marks. The widow of Magnus (the late king of Man) succeeded, however, in getting Ivar, the assassin of her brother-in-law Reginald, placed on the vacant throne; and Alexander in 1270 sent an army to reduce the island to obedience. After a decisive battle at Ronaldsway, in which Ivar was slain, the kingdom was annexed to the dominions of Alexander. This monarch, in token of his conquest, substituted the quaint device of "the three legs," which still constitutes the national emblem, for the ancient armorial ensign of the island—a ship in full sail, with the motto, "*Rex Manniæ et Insularum.*"

[1] See "Man, its Names and their Origin," by J. M. Jeffcott, in *Manx Society Publications*, 1878.

He placed the island under the government of his nobles or thanes, whose repeated acts of tyrannical oppression at length inspired the inhabitants to throw off the Scottish yoke. Bishop Mark (Marcus Galvadiensis), a Scotchman, however, being informed of their determination, obtained their mutual consent to decide the contest by thirty champions selected from each party. The Manx champions were all killed, and twenty-five of the Scottish warriors shared the same fate. This victory confirmed the conquest of the Scots; the ancient regal government was abolished, and a military despotism established.

The most important relics of the Northmen are the Runic crosses, of which there are about forty, either whole or fragmentary. Nearly one half of these contain Scandinavian inscriptions in the ancient Norse language and in Runic character. There are a very large number at Kirk Michael, but some of the most perfect are those in the churchyards of Ballaugh, Maughold, and Braddan.

During the contentions of Bruce and Baliol, Edward I. of England took possession of the island for a period, while two rival claimants for the throne appeared. One of these was Mary, the daughter of Reginald II.; the other her aunt Affrica or Alfrida, a daughter of Olave II., and sister of Magnus. The latter in 1305 conveyed her right in the island to her husband, Sir Simon de Montacute, whose son Sir William afterwards mortgaged its revenues to Anthony Beck, bishop of Durham and patriarch of Jerusalem. In 1313 Bruce made a descent on the island, and granted it to his nephew Randolph, earl of Murray.

In the reign of Edward III. Mary Waldebeof, daughter of the previous claimant, solicited the assistance of that monarch. The king allowed her title, and by giving her in marriage to William Montacute, earl of Salisbury (the grandson of Sir Simon Montacute and Alfrida), thus united in their persons the rights of the two lines of descendants of Olave the Black to the kingdom of Man. With the aid of the English king, the earl was enabled to expel the Randolphs from the island; and in the year 1344 he was crowned king of Man. In the year 1393 the earl of Salisbury sold to Sir William le Scroop, afterwards earl of Wiltshire, "the Isle of Man, with the title of king, and the right of being crowned with a golden crown." On his attainder for high treason, the island in 1399 was bestowed on Henry Percy, earl of Northumberland, but, he having been attainted and banished, Henry IV. made a grant of it to Sir John Stanley for life. This grant was cancelled, and a new patent passed the Great Seal in 1406, bestowing the island on him and his heirs, to be held of the crown of Great Britain, by presenting to the king a cast of falcons at his coronation. Sir John died in 1414.

The lords of the house of Stanley governed the island chiefly by lieutenants, who occupied the castles of Peel and Rushen. Various tumults arose; and in 1422 fourteen persons were drawn by wild horses, quartered, and beheaded. Eventually authority was delegated by Sir John Stanley the second to Henry Byron, who remodelled the House of Keys, and rendered his regency one of the most popular in the insular history. Sir John died in 1432, and was succeeded by his son Thomas, who was created Baron Stanley by Henry VI., and died in 1460. Thomas his son was created earl of Derby by Henry VII. He died in 1505. This nobleman's son Thomas, the second earl of Derby, relinquished the title of king of Man, as he preferred "being a great lord to being a petty king." Edward, the third earl, son of the last-named Thomas, was a great favourite with Henry VIII. On his death in 1572 he was succeeded by his son Henry, the fourth earl of Derby. He died in 1594, leaving two sons, Ferdinand and William, who in time became lords of Man. The title of William was disputed by the three daughters of Ferdinand; with these, however, he effected a compromise; and in 1610 he obtained an "act for assuring and establishing the Isle of Man in the name and blood of William, earl of Derby," but in 1627 resigned his dignities to his son James, celebrated in history as "the great earl of Derby."

After the execution of this earl in 1651, for bringing aid to Charles II. before the battle of Worcester, the defence of the island was undertaken by the heroic Lady Derby, who was then in Castle Rushen; but William Christian, the receiver-general, on the appearance of a hostile fleet, surrendered the castle without resistance. The island was then granted to General Lord Fairfax, who held it until the Restoration, when it was restored to Charles, the eighth earl (the son of Earl James), in 1660. On the death of Earl Charles in 1672 he was succeeded by his son William, the ninth earl, who took but little interest in his Manx property, and, dying without issue in 1702, was succeeded by his brother James (a younger son of Charles, the eighth earl). At this time the lordship of Man was approaching dissolution. The leases, which had been granted for three lives, having nearly expired, and no provision having been made relative to their renewal, the neglect of agriculture became general, and the people were wholly given up to the fisheries and the pursuit of the contraband trade. In 1703, however, the earl conferred on his Manx subjects the Act of Settlement (very justly called the Manx Magna Charta), by which the lessees of estates were finally established in their possession, and their descent secured in perpetuity, on the payment of certain fines, rents, and dues to the lords. James died in 1736 without issue.

The lordship of Man then devolved on James, second duke of Athole, a descendant of the Lady Amelia Anna Sophia Stanley (youngest daughter of the seventh earl of Derby). In 1725, in order to put an end to the contraband trade of the island, an Act of Parliament was passed authorizing the purchase of all the royalties and revenues of the island; but no result followed till 1765, when proposals for the purchase were revived and the sovereignty and its revenues were surrendered to the crown for £70,000. The duke and duchess reserved the manorial rights, the patronage of the see, and other emoluments and perquisites. By the Act of Revestment the island was more closely united to the crown of England, although its independent form of government has never experienced any material change. An annuity of £2000 had also been granted to the duke and duchess, but, on the ground of inadequate compensation, the fourth duke presented petitions to parliament and the privy council in 1781 and 1790. He did not succeed, however, until the year 1805, when an Act was passed assigning to him and his heirs, as an additional grant, a sum equal to one-fourth of the revenues of the island, which was afterwards commuted for £3000 per annum for ever.

In 1825 an Act passed both houses of parliament, at the instance of the lords of the treasury, authorizing the lords of the treasury to treat with the duke for the purchase of his remaining interest in the island, and in 1829 he was awarded a further sum of £417,144 for his rights in and over the soil as lord of the manor, as follows:—

For the annuity	£150,000
Rents and alienation fines	34,000
Tithes, mines, and quarries; Patronage of the bishopric, with fourteen advowsons, the aggregate value of which was £6000	233,144
Total	£417,144

The ecclesiastical buildings of Man have never been remarkable for architectural beauty. The most important ecclesiastical ruin is St German's cathedral on St Patrick's Isle. The present building, which is roofless and in a very dilapidated condition, dates from 1245, but is supposed to occupy the site of an older building. It is a rude cruciform structure 110 feet long by 70 feet broad. The tower, 68 feet in height, is still entire. The crypt of the cathedral was made use of for an ecclesiastical prison, among its more important captives being Eleanor, wife of Humphrey, duke of Gloucester, uncle of Henry VI. She is alluded to by Shakespeare as living in banishment "with Sir John Stanley in the Isle of Man." St Patrick's church on the same islet is supposed to have been erected in the time of St Patrick. Adjoining it is a round tower similar to those so common in Ireland. Most of the other old churches in Man have been replaced by modern structures, but another very ancient one is Lonan old church, now partly roofless, a very unpretending structure, but said to date from the 6th century. St Trinian's church, also in ruins, is said never to have been roofed, a circumstance accounted for by an interesting legend. Of Rushen Abbey, a house of the Cistercians, founded by Olave, king of Man, in 1134, there now only remain the tower, refectory, and dormitory. The Franciscan friary of Bimakin, founded in 1373, has been partly rebuilt in a rude manner, and is used as a barn. Of the nunnery of Douglas, said to have been founded by Matilda, daughter of Ethelbert, king of the West Saxons, there are now very slight remains, chiefly of the chapel.

The principal castles are Castle Rushen, in Castletown, the ancient residence of the kings of Man, dating probably from the 13th century, and still quite entire; Peel Castle, the ancient stronghold of the island; and Castle Mona, Douglas, erected in 1801 as a residence by the duke of Athole, and now used as a hotel.

The chief sources of the early history of Man are the Norse and Erse Sagas, and the record kept by the monks of Rushen Abbey entitled *Chronicon Manniæ*, which has been edited with learned notes by P. A. Munch, Christiania, 1860. The best general history is that of Train, 2 vols., 1845. Among other works may be mentioned J. G. Cumming, *Isle of Man, its history, physical, ecclesiastical, civil, and legendary*, 1848; Id., *Runic and other Remains of the Isle of Man*, 1857; J. O. Halliwell, *Roundabout Notes on the Isle of Man*, 1863. The publications of the Manx Society are of great value and interest.

MANACOR, a town in the island of Majorca, stands on a slight eminence in a fertile plain, 30 miles east of Palma (40 miles by rail, by way of Inca). It is substantially built, with wide streets and several squares; it has the usual buildings (a parish church, a hospital, schools, and the like), and the former palace of the independent kings of Majorca is pointed out. The neighbourhood produces cereals, fruits, an inferior quality of wine, and some oil; and there is some trade in these, as well as in sheep and cattle The population in 1877 was 14,894.

MANAGUA, the capital of Nicaragua, Central America, lies on the south shore of Lake Managua in 12° 7′ N. lat.

and 86° 12′ W. long. Steamboat communication with Old Leon was opened in 1881, and a railway (32 miles) is in course of construction to Granada. It was mainly owing to the rivalry between Leon and Granada that Managua was chosen as the seat of the national assembly, and apart from the administrative buildings there is little of interest in the place. The population is about 12,000.

MANAKIN, from the Dutch word *Manneken*, applied to certain small birds, a name apparently introduced into English by Edwards (*Nat. Hist. Birds*, i. p. 21) in or about 1743, since which time it has been accepted generally, and is now used for those which form the Family *Pipridæ* of modern ornithologists. The Manakins are peculiar to the Neotropical Region, and are said to have many of the habits of the Titmouse Family (*Paridæ*), living, says Swainson, in deep forests, associating in small bands, and keeping continually in motion, but feeding almost wholly on the large soft berries of the different kinds of *Melastoma*. However, as with most other South American Passerine birds, little is really known of their mode of life; and it is certain that the *Pipridæ* have no close affinity with the *Paridæ*,[1] but belong to the other great division of the Order *Passeres*, to which Garrod assigned the name *Mesomyodi*, and in that division, according to the same authority, constitute, with the *Cotingidæ*,[2] the group *Heteromeri* (*Proc. Zool. Society*, 1876, p. 518). The Manakins are nearly all birds of gay appearance, generally exhibiting rich tints of blue, crimson, scarlet, orange, or yellow in combination with chestnut, deep black, black and white, or olive green; and among their most obvious characteristics are their short bill and feeble feet, of which the outer toe is united to the middle toe for a good part of its length. The tail, in most species very short, has in others the middle feathers much elongated, and in one the outer rectrices are attenuated and produced into threads. They have been divided by various authors into upwards of twenty so-called genera; but Messrs Sclater and Salvin (*Nomenclator*, pp. 53–55) recognize only fifteen, though admitting sixty species, of which fifteen belong to the genus *Pipra* as now restricted, the *P. leucocilla* of Linnæus being its type. This species has a wide distribution from the isthmus of Panama to Guiana and the valley of the Amazon; but it is one of the most plainly coloured of the Family, being black with a white head. The genus *Machæropterus*, consisting of four species, is very remarkable for the extraordinary form of some of the secondary wing-feathers in the males, in which the shaft is thickened and the webs changed in shape, as described and illustrated by Mr Sclater (*Proc. Zool. Society*, 1860, p. 90; *Ibis*, 1862, p. 175[3]) in the case of the beautiful *M. deliciosus*, and it has been observed that the wing-bones of these birds are also much thickened, no doubt in correlation with this abnormal structure. A like deviation from the ordinary character is found in the allied genus *Manacus* or *Chiromachæris*, comprehending six species, and that gentleman believes it enables them to make the singular noise for which they have long been noted (see BIRDS, vol. iii. p. 770), described by Mr Salvin (*Ibis*, 1860, p. 37) in the case of one of them, *M. candæi*, as beginning "with a sharp note not unlike the crack of a whip," which is "followed by a rattling sound not unlike the call of a landrail"; and it is a similar habit that has obtained for another species, *M. edwardsi*, the name in Cayenne, according to Buffon (*Hist. Nat. Oiseaux*, iv. p. 413), of *Casse-noisette*. This view is supported by Mr Layard, who, writing of the last species, says (*Ibis*, 1873, p. 381)—"They make a curious rattling noise (I suspect, by some movement of the oddly shaped wing-feathers), which constantly betrays their presence in the forests," while of the congeneric *M. gutturosus*, Mr J. F. Hamilton remarks (*Ibis*, 1871, p. 305)—"The first intimation given of the presence of one of these birds is a sharp whirring sound very like that of a child's small wooden rattle, followed by two or three sharp snaps." The same observer adds (*loc. cit.*) of a member of the kindred genus *Chiroxiphia*, containing five species, that *C. caudata* is known to the Brazilians as the Fandango-bird from its "habit of performing a dance." They say that "one perches upon a branch and the others arrange themselves in a circle round it, dancing up and down on their perches to the music sung [?] by the centre one." Exception must be taken to this story so far as regards the mode in which the "music" is produced, for these birds have no true song-muscles; but the effect is doubtless as described by Mr Hamilton's informant. (A. N.)

[1] Though Edwards called the species he figured (*ut supra*) a Titmouse, he properly remarked that there was no genus of European birds to which he could liken it.

[2] Excluding, however, the genus *Rupicola*—the beautiful orange-coloured birds well known as the "Cocks of the Rock"—which has usually been placed among the *Cotingidæ*.

[3] The figures are repeated by Mr Darwin (*Descent of Man*, &c., ii. p. 66).

MÁNANTADI, or MANANTODDY, a town in Malabar district, Madras, the trading centre of the Wainád coffee district (11° 48′ N. lat., 76° 2′ 55″ E. long.). The population in 1871, including numerous European coffee planters, with their families, in the neighbourhood, was 10,959. Besides several Government offices, it contains a good club. Early in the century it was a military outpost, and in 1802 the garrison was massacred by the Kotiote rebels.

MANASSEH. The tribe of JOSEPH (*q.v.*), the northern and stronger half of the "sons of Rachel," was divided into two branches, so considerable as themselves to bear the name of tribes, which referred their origin to Manasseh and Ephraim, the two sons of Joseph by his Egyptian wife Asenath. Of the two Manasseh was held to be the elder, but the patriarchal story relates how Jacob predicted the superiority of the younger branch (Gen. xlviii.), which in fact played far the greater part in history, occupying in the early days of the settlement in Canaan the part of the central mountain land (Mount Ephraim) where the head-quarters of armed Israel and the sanctuary of the ark stood (at Shiloh), and in later times holding the kingship, and greatly excelling Manasseh in numerical strength (Deut. xxxiii. 17). During the conquest, perhaps, the separation of the two branches of Joseph was not so well marked as it afterwards became, for the ancient narrative of Josh. xvii. 14 *sq.* represents the whole house of Joseph as acting together, establishing itself in the uncleared forests of the central mountains till it had strength to contend with the iron chariots of the Canaanites about Bethshean, and in the cities of the rich plain of Jezreel. These cities probably were not all subdued till the days of David or Solomon (Jud. i. 27; 1 Sam. xxxi. 10; 1 Kings ix. 15); they ultimately fell to Manasseh, which held the northern part of the hill country of Joseph, overlooking the plain, and finally encroached on lands once reckoned to the less warlike tribes of Asher and Issachar (Josh. xvii. 11). But the line of division between Ephraim and Manasseh was not always the same, and in the time of Gideon, the great hero of Manasseh, and the man under whom the seniority of the tribe had a real meaning, Shechem itself was a Manassite dependency (Jud. viii. 31, ix.; comp. Num. xxvi. 31; Josh. xvii. 2). Besides their western settlements in the fertile glades of northern Samaria, running out into the great plain, the Manassites had broad territories east of the Jordan in the pasture land of Bashan and Gilead, mainly occupied by a clan named Machir, and reckoned as the first-born of Manasseh. On the probability that these territories were colonies from the west see vol. xiii. p. 401.

The outlying Manassites had many struggles with their foreign neighbours; 1 Chron. ii. 23 speaks of the loss of sixty cities to Geshur and the Aramæans (A. V. mistranslates). After suffering much at the hands of Damascus, they were carried into captivity by Tiglath Pileser (734 B.C.). The captivity of their brethren in the west followed some thirteen years later.

The name Manasseh (מְנַשֶּׁה, he who causes to forget) is referred in Gen. xli. 51 to Joseph's joy at the birth of the son who caused him to forget his sorrows and cease to long for his home. Unlike the other tribal names, it occurs as a personal name before the captivity, being that borne by the son and successor of Hezekiah, the godless king whose sins are designated as the decisive cause of the rejection of the kingdom of Judah.

MANATEE, an animal belonging to the order *Sirenia*, for the general characters and position of which see MAMMALIA (p. 389). The name *Manati* was apparently first applied to it by the early Spanish colonists of the West Indies, in allusion to the hand-like use which it frequently makes of its fore limbs; by English writers from the time of Dampier (who gives a good account of its habits) downwards it has been generally spelt "Manatee." It was placed by Linnæus in his heterogeneous genus *Trichechus*, but Storr's name *Manatus* is now generally accepted for it by zoologists. The question of the specific distinction of the African and American Manatees will be treated of further on, but it will be chiefly to the latter and better known form that the following description applies.

The size of the Manatee has been much exaggerated, as there is no trustworthy evidence of its attaining a greater length than 8 or perhaps 9 feet. Its general external form may be seen in the figure at p. 390 of the present volume, taken from a living example in the Brighton Aquarium. The body is somewhat fish-like, but depressed and ending posteriorly in a broad flat shovel-like horizontal tail, with rounded edges. The head is of moderate size, oblong, with a blunt, truncated muzzle, and divided from the body by a very slight constriction or neck. The fore limbs are flattened oval paddles, placed rather low on the sides of the body, and showing externally no signs of division into fingers, but with a tolerably free motion at

FIG. 1.—Front View of Head of American Manatee, showing the eyes, nostrils, and mouth. A, with the lobes of the upper lip divaricated; B, with the lip contracted. From Murie, *Trans. Zool. Soc.*, vol. xi.

the shoulder, elbow, and wrist joints, and with three diminutive flat nails near their extremities. No traces of hind limbs are discernible either externally or internally; and there is no dorsal fin. The mouth is very peculiar, the tumid upper lip being cleft in the middle line into two lobes, each of which is separately movable, as will be described in speaking of its manner of feeding. The nostrils are two semilunar valve-like slits, at the apex of the muzzle. The eyes are very minute, placed at the sides of the head, and with a nearly circular aperture with wrinkled margins. The external ear is a minute orifice situated behind the eye, without any trace of pinna. The skin generally is of a dark greyish colour, not smooth or glistening, like that of the *Cetacea*, but finely wrinkled. At a little distance it appears naked, but a close inspection, at all events in young animals, shows a scanty covering of very delicate hairs, and both upper and under lips are well supplied with short, stiff bristles.

The skeleton is remarkable for the massiveness and extreme density of most of the bones of which it is composed, especially the skull and ribs. The cervical region of the vertebral column is short, and presents the great peculiarity of containing only six bones instead of seven, the number usual in the *Mammalia*,—the only other case being that of one species of Sloth (*Cholœpus hoffmanni*). Another great peculiarity (which, however, seems to be characteristic of all the *Sirenia*) is that the flat ends of the bodies of the vertebræ do not ossify separately, so as to form disk-like epiphyses in the young state. None of the vertebræ are united together to form a sacrum, the rudimentary pelvic bones having no direct connexion with the vertebral column. The number of rib-bearing vertebræ appears to vary in different individuals from fifteen to eighteen, and those of the lumbar and caudal region from twenty-five to twenty-nine. The skull (fig. 2) is exceed-

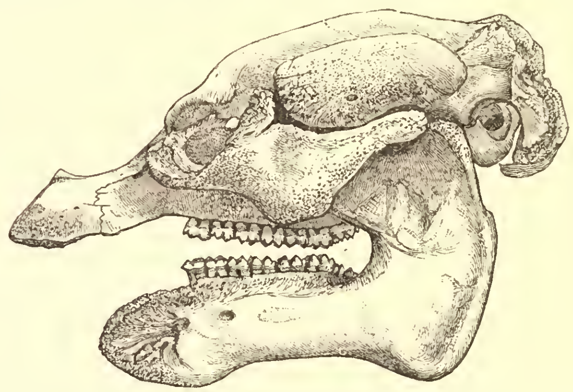


FIG. 2.—Skull of African Manatee (*Manatus senegalensis*). × ⅕. From Mus. Roy. Coll. Surgeons.

ingly different from that of any of the Whales or Dolphins (order *Cetacea*), with which the Manatee was formerly supposed to be allied. The cerebral cavity is rather small as compared with the size of the animal, and of oblong form; its roof is formed of the parietal bones as in ordinary mammals. The squamosal has an extremely large and massive zygomatic process, which joins the largely developed malar bone in front. The orbit is small, but prominent and nearly surrounded by bone. The anterior nares taken together form a lozenge-shaped aperture, which looks upwards and extends backwards considerably behind the orbits. Their sides are formed by the ascending processes of the premaxillæ below, and by the supraorbital processes of the frontals above, no traces of nasals being found in most skulls, though these bones are occasionally present in a most rudimentary condition, attached to the edges of the frontals, far away from the middle line, a position quite unique among the mammalia. In front of the narial aperture the face is prolonged into a narrow rostrum, formed by the premaxillæ, supported below and at the sides by the maxillæ. The under surface of this is very rugous, and in life covered by a horny plate. The rami of the mandible are firmly united together at the symphysis, which is compressed laterally, deflected, and has a rugous upper surface; to this another horny plate is attached, which with that of the upper jaw functionally supplies the place of teeth in the anterior part of the mouth. In the young state there are rudimentary teeth concealed beneath these horny plates, which never penetrate through them, and must therefore be quite functionless, and altogether disappear before the animal is full-grown. There is besides, on each side of the hinder part of both upper and lower jaws, a parallel row of molar teeth, similar in characters from the beginning to the end of the series, with square enamelled crowns raised into tuberculated transverse ridges, something like those of the Tapir and Kangaroo. The upper teeth have two ridges and three roots; the lower teeth have an additional posterior small ridge or talon, and but two roots. These teeth succeed each other from before backwards, as in the *Proboscidea*, those at the front of the mouth being worn out and shed before those at the back are fully developed. There are altogether about eleven on each side of each jaw, but rarely more than six are present at one time. The brain is remarkably simple in structure, its hemispheres exhibiting none of the richness of convolution so characteristic of the *Cetacea*. The stomach is compound, being divided by a valvular constriction into two principal cavities, the first of which is provided with a singular glandular pouch near the cardiac end, and the second with a pair of elongated, conical cæcal sacs or diverticula, the use of which is by no means obvious. The cæcum is bifid. The kidneys are simple. The heart is broad and flat, with the apex deeply cleft between the ventricles. The principal blood-vessels form very extensive and complex *retia mirabilia*. The lungs are remarkably long and narrow, as owing to the very oblique position of the diaphragm the thoracic cavity extends very far back over the abdomen. The mammary glands of the female are two in number, situated just behind and to the inner side of the origin of the pectoral limb. The red corpuscles of the blood are among the largest of those of any members of the class, averaging in diameter, according to Gulliver, $\frac{1}{2400}$ of an inch.

Manatees pass the whole of their life in the water, inhabiting bays, lagoons, estuaries, and large rivers, but the open sea, so congenial to the *Cetacea*, is quite unsuited to their peculiar mode of life. As a general rule they prefer shallow water, in which, when not feeding, they lie near the bottom, supporting themselves on the extremity of the tail, or slowly moving about by the assistance of the fore limbs, the tips of which are just allowed to touch the ground, and only raising the top of the head above the surface for the purpose of breathing at intervals of two or three minutes. In deeper water they often float, with the body much arched, the rounded back close to the surface, and the head, limbs, and tail hanging downwards. The air in the lungs obviously assists them to maintain this position, acting in the same manner as that in the air-sac of fishes. Their food consists exclusively of aquatic plants, on which they browse beneath the water much as terrestrial Ungulates do on the green pastures on shore. They are extremely slow and inactive in their movements, and perfectly harmless and inoffensive, but are subject to a constant persecution from the inhabitants of the countries in which they dwell for the sake of their oil, skin, and flesh. Frequent attempts have of late been made to keep specimens alive in captivity, and sometimes with considerable success, one having lived in the Brighton Aquarium for upwards of sixteen months. It was fed chiefly on lettuce and endives, but would also eat leaves of the dandelion, sow-thistle, cabbage, turnip, and carrot. From this and other captive specimens some interesting observations upon the mode of life of the animal have been made. One of these is the free use it makes of its fore-limbs. From the shoulder-joint they can be moved in all directions, and the elbow and wrist permit of free extension and flexion. In feeding they push the food towards their mouths by means of one of the hands, or both used simultaneously, and any one who has seen these members thus employed can readily believe the stories of their carrying their young about under their arms. Still more interesting and quite unique among Mammals is the action of the peculiar lateral pads formed by the divided upper lip, thus described by Professor Garrod:—"These pads have the power of transversely approaching towards and receding from one another simultaneously (see fig. 1, A and B). When the animal is on the point of seizing (say) a leaf of lettuce, the pads are diverged transversely in such a way as to make a median gap of considerable breadth. Directly the leaf is within grasp the lip-pads are approximated, the leaf is firmly seized between their contiguous bristly surfaces, and then drawn inwards by a backward movement of the lower margin of the lip as a whole." The animal is thus enabled by the unaided means of the upper lip to introduce food placed before it without the assistance of the comparatively insignificant lower lip, the action greatly recalling to the observer that of the mouth of the silkworm and other caterpillars in which the mandibles diverge and converge laterally during mastication. When out of water the Manatee is an extremely helpless animal; and, although statements are frequently met with in books of its voluntarily leaving the water for the purpose of basking or feeding on shore, all trustworthy observations of those acquainted with it, either in a state of nature or in captivity, indicate that it has not the power of doing so. None of the specimens in confinement have been observed to emit any sound.

Manatees, though much less numerous than formerly, are still occasionally found in creeks, lagoons, and estuaries in some of the West India Islands, and at various spots on the Atlantic coast of America from Florida as far south as about 20° S. lat., and in the great rivers of Brazil, almost as high as their sources. They are also met with in similar situations on the opposite African coast, from about 16° N. to 10° S. lat., and as far into the interior as Lake Tchad. Its range may even extend, if native reports obtained by Schweinfurth are correctly interpreted, to the river Keebaly, 27° E. long.

The American Manatee (*M. australis*, Tilesius) was thought by Dr Harlan to be divisible into two species, one inhabiting Brazil and the other the West Indies and Florida. To the northern form he gave the name of *M. latirostris*, but the distinction is not now generally recognized. On better grounds the African Manatee was separated by Desmarest, under the name of *M. senegalensis*, and there are certainly constant although not very important cranial characters by which it can be distinguished from its American congener, among which the following may be cited:—the anterior part of the rostrum is shorter, shallower, and altogether smaller; the orbit is smaller; the zygomatic process is more deep and massive; the malar bone is deeper from above downwards; the upper margin of the anterior nares is narrower and with a smooth and rounded instead of a thin and serrated edge; the upper surface of the frontal is flat, instead of concave; the foramen magnum and occipital condyles are narrower from side to side, and the symphysis of the mandible smaller and shallower.

For an account of the animals most nearly allied to the Manatee, the Rhytina, or "Northern Manatee" as it is sometimes called, and the Dugong, as well as the various extinct kindred forms, see MAMMALIA, pp. 390, 391.

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MÁNBHÚM, a district in the lieutenant-governorship of Bengal, India, lying between 22° 37′ and 24° 3′ N. lat., and 85° 51′ and 87° 16′ E. long., is bounded on the N. by Hazáribágh and Bírbhúm, on the E. by Bardwán and Bánkura, on the S. by Singbhúm and Midnapur, and on the W. by Lohárdagá and Hazáribágh. It has an area of 4147 square miles. The headquarters station is at Purulia. Mánbhúm district forms the first step of a gradual descent from the table-land of Chutiá Nágpur to the delta of lower Bengal. In the northern and eastern portions the country is open, and consists of a series of rolling downs, dotted here and there with isolated conical hills. The soil is for the most part composed of hard, dry, ferruginous gravel, but many of the lower levels are filled with good alluvial soil, which yields a fine rice crop. In the western and southern tracts the country is more broken, and the scenery much more picturesque. The principal hills are Dalmá (3407 feet), the crowning peak of a range of the same name; Gangábarí or Gajboro (2220 feet), the highest peak of the Baghmúndí range, about 20 miles south-west of Purulia; and Pánchkot or Pánchet (1600 feet), on the summit of which stands the old palace of the rájás of Pánchet. The hills are all covered with dense jungle. The chief river is the Kasái, which flows through the district from north-west to south-east into Midnapur, and on which a considerable floating trade in *sál* timber is carried on. The useful timber found in Mánbhúm is very limited in quantity, and with the present rate of decrease the supply cannot last many years. Tigers, leopards, bears, wolves, and jackals are not uncommon; various kinds of deer abound; and bison are occasionally met in the south of the district. Elephants come every year from the south-east into the hilly country between Mánbhúm and Singbhúm.

The census of 1872 returned the population at 820,521. The aboriginal tribes numbered about 100,000, Hindus nearly 700,000, and Mohammedans about 30,000. In 1881 the population was 1,042,117. A large proportion of the aborigines are now semi-Hinduized. The most numerous aboriginal tribe are the Santáls; but the Bhúmíj Kols are the characteristic aboriginal race. In Mánbhúm they inhabit the country lying on both sides of the Subarnarekhá. They are pure Mundas, but their compatriots to the east have dropped the title of Munda and the use of their distinctive language, have adopted Hindu customs, and are fast becoming Hindus in religion. The Bhúmíj Kols of the Jungle Mahál's were once the terror of the surrounding districts; they are now a more peaceful tribe, but have lost to a great extent the simplicity and truthfulness of character for which their cognates are generally distinguished. Among high-caste Hindus about 50,000 are Bráhmans and 16,000 Rájputs. The Kevmús, who are agriculturists, form the most numerous caste in the district. The Christian population numbers about 600, most of whom are engaged in agriculture. Mánbhúm is a thoroughly rural district, and contains only two towns with upwards of 5000 inhabitants, namely Purulia and Raghunáthpur, and three others with over 2000, namely Jhálidá, Kásípur, and Mánbázár.

Three principal crops of rice are grown, one sown broadcast early in May on table-lands and the tops of ridges, an autumn crop, and a winter crop, the last forming the chief harvest of the district. Other crops are wheat, barley, Indian corn, pulses, oilseeds, linseeds, jute, hemp, sugar-cane, indigo, pan, and tobacco. Owing to the completeness of the natural drainage floods are unknown, but the country is liable to droughts caused by deficient rainfall. The principal articles of export are oilseeds, pulses, *ghi*, lac, indigo, tasar silk (manufactured near Raghunáthpur), timber, resin, coal, and (in good seasons) rice. The chief imports are salt, piece goods, brass utensils, and unwrought iron. Cotton hand-loom weaving is carried on all over the district. Coal is found at Iharia, a few miles from Parasnáth. The total revenue of Mánbhúm district in 1881 amounted to £25,760, of which £7562 was obtained from land, and £6424 from excise. The schools in 1877 numbered 392, with 9616 pupils. The climate of the district is fairly healthy. The average rainfall for the ten years ending 1880–81 was 55·95 inches.

MANCHA, La. This name, when employed in its widest sense, denotes that bare and monotonous elevated plateau of central Spain which stretches between the mountains of Toledo and the western spurs of the hills of Cuenca, being bounded on the S. by the Sierra Morena and on the N. by the Alcarria, which skirts the upper course of the Tagus. It thus comprises portions of the modern provinces of Toledo, Albacete, and Cuenca, and almost the whole of Ciudad Real. Down to the 16th century the eastern portion was known as La Mancha de Montearagon or de Aragon, and the western simply as La Mancha; afterwards the north-eastern and south-western sections respectively were distinguished by the epithets "Alta" and "Baja" (upper and lower). La Mancha was created a province in 1691; its officially recognized boundaries have since that time varied considerably, and in common parlance it is often now identified with the modern province of Ciudad Real. Ciudad Real, which is bounded on the N. by Toledo and Cuenca, on the E. by Albacete, on the S. by Jaen and Cordova, and on the W. by Badajoz, ranks next to Badajoz and Caceres in point of extent, containing an area of 7840 square miles. The population in 1877 was 260,641. From the scarcity of water and the absence of trees and fences, as also from the circumstance of the rural population being concentrated only at certain points, it as a whole presents to the traveller the arid and cheerless aspect of a desert. The principal river is the Guadiana, which rises in the so-called Ojos ("Eyes") del Guadiana in the north-east, and is joined by the Azuer and the Jabalon on the left, and by the united waters of the Zancara and Giguela on the right. No advantage, unfortunately, is taken of these or any of the other streams in the province for irrigation, the inhabitants depending entirely on the meagre and precarious rainfall. A peculiarity of the province is the facility with which water can be reached by digging; but neither has this resource been turned to much account. The mineral wealth of the province (lead, copper, iron, antimony, coal) is great, the cinnabar mines of Almaden, in particular, which were known to the ancients, being the chief European source for the supply of quicksilver. Saltpetre is obtained in several places, especially in the north (Herencia and Alcazar de San Juan), and there are quarries of fine stone at Santa Cruz and elsewhere. The crops, when not interfered with by drought and locusts, the two scourges of La Mancha, are very large; they include wheat, barley, rye, chick pease, wine (that of Valdepeñas being especially famous), vinegar, and brandy, some oil, saffron, esparto, flax, and silk. The mules reared in the province are considered the best in or out of Spain. There are manufactures of woollen fabrics, lace, earthenware, cutlery, saltpetre, gunpowder, and soap. The lace of Almagro is much appreciated throughout the peninsula. The province is traversed by the Madrid and Cordova Railway, which enters near Alcazar de San Juan and passes through Manzanares and Valdepeñas, entering Jaen at the Venta de Cardenas in the Sierra Morena. The Madrid and Badajoz line passes through Ciudad Real, the capital of the province, which is connected by rail with Manzanares. There are ten judicial partidos,—those of Alcázar de San Juan, Almaden, Almagro, Almodóvar del Campo, Ciudad Real, Daimiel, Infantes, Manzanares, Piedrabuena, and Valdepeñas. The only towns having a population above 10,000 in 1877 were Almodóvar del Campo, Ciudad Real, and Valdepeñas.

MANCHE, a department in the north-west of France, washed by the English Channel (Fr., *La Manche*), from which it derives its name, and made up of the Cotentin, the Avranchin, and part of the Bocage, three districts of the former province of Normandy, lies between 48° 28′ 40″ and 49° 47′ 30″ N. lat., and between 0° 43′ and 1° 54′ 30″ W. long., bounded W., N., and N.E. by the Channel, E. by the department of Calvados, S.E. by Orne, S. by Mayenne and Ille-et-Vilaine. The capital, St Lô, is 159 miles west of Paris. The extreme length from north-west to south-east is 81 miles, the mean breadth from east to west about 28 miles, and the area 2289 square miles.

The department is traversed from south to north by a range of hills, in many parts picturesque, and connected in the south with those of Maine and Brittany. In the country round Mortain, which has been called the Switzerland of Normandy, they rise to a height of 1200 feet, and at Cherbourg their altitude is still from 500 to 600 feet. As a whole the department has an English aspect, with its broken and tide-beaten shores often enveloped in mist, and its ever-verdant meadows. The coast-line, running northward along the bay of the Seine from the rocks of Grand Camp to Cape Barfleur, thence westward to Cape la Hague, and finally southward to the Bay of Mont St Michel, has a length of 200 miles. The Vire and the Taute (which receives the Ouve as a tributary on the left) fall into the sea at the Calvados border, and are united by a canal some miles above their mouths. From the mouth of the Taute a low beach runs to St Vaast la Hougue, where the coast becomes rocky, with sandbanks. Between Cape Barfleur and Cape la Hague lie the roads of Cherbourg, protected by the famous breakwater. The whole western coast is inhospitable; its petty havens, lying behind formidable barriers and reefs, are almost dry at low tide. Great cliffs like the points of Jobourg (420 feet high) and Flamanville alternate with long strands such as that which extends for 30 miles from Cape Carteret to Granville. Between this coast and the Channel Islands the tide, pent up between numerous sandbanks, flows with a terrific force that has given these passages such ill-omened names as *Passage de la Déroute* and the like. The only important harbours are Granville and the haven of refuge of Diélette between Granville and Cherbourg. The chief stream is the Sienne with its tributary the Soulle flowing by Coutances. South of Granville the sands of St Pair are the commencement of the great Bay of Mount St Michel, whose area of 60,000 acres was covered with forest till the terrible tide of the year 709. The equinoctial tides reach a vertical height of nearly 50 feet. Amidst the foam rise the picturesque walls of the abbey, from the summit of a rock 400 feet high. The Sée, which waters Avranches, and the Couesnon (separating Manche from Ille-et-Vilaine) disembogue in the bay.

The climate of Manche is mild and humid from its propinquity to the sea. At Cherbourg, in spite of the northerly exposure, the mean temperature is 3° Fahr. above the mean for that latitude over France. Frosts are never severe; myrtles and fuchsias flourish in the open air. Excessive heat is also unusual; the predominant winds are south-west. Rains are frequent, as the verdure of the country testifies, but they are not violent, the annual rainfall varying from 30 to 34 inches.

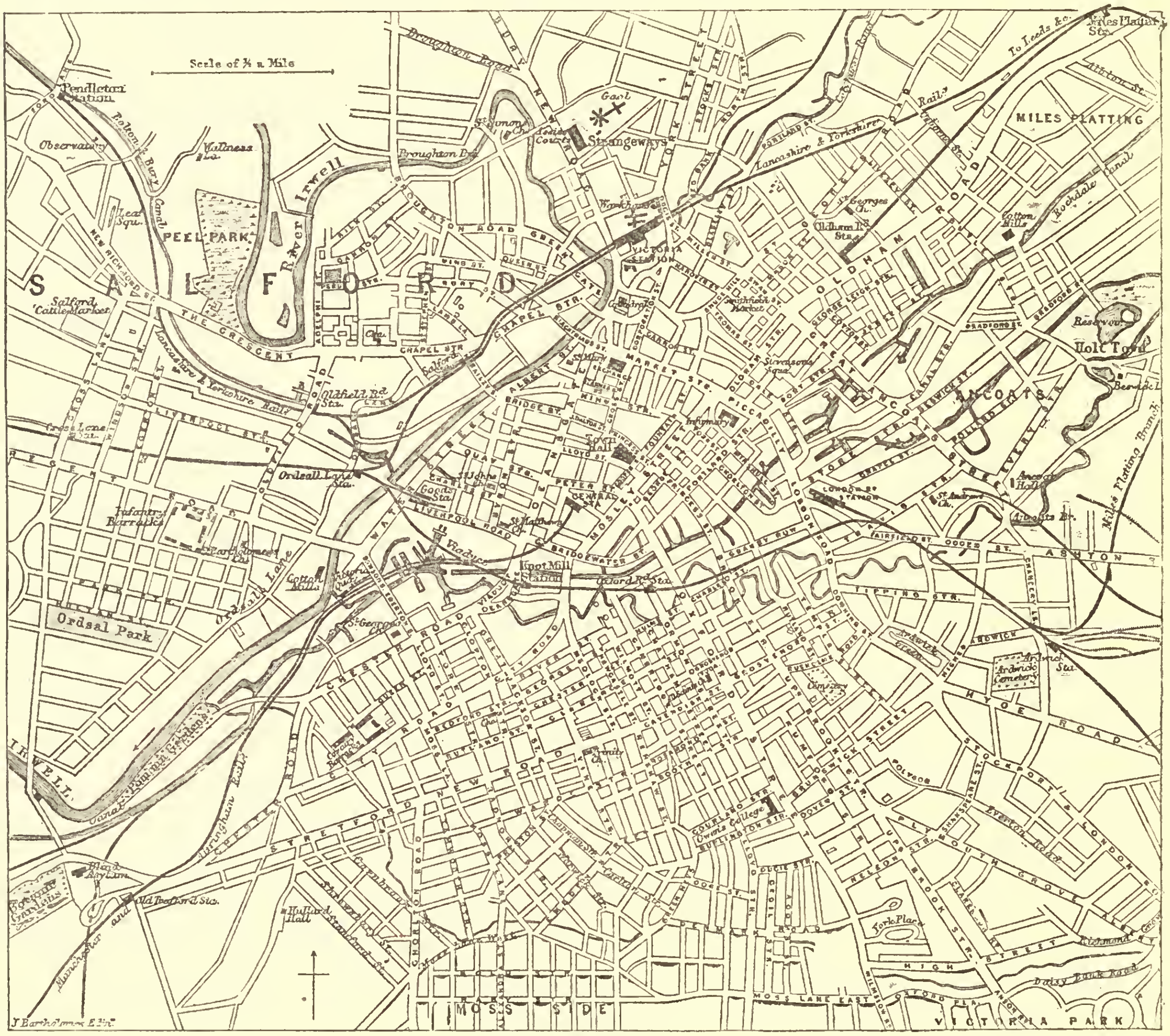
Of the entire area more than the half is arable, 198,000 acres are meadow land, 52,000 are under wood, and 82,000 are heath. The soil is not naturally fertile, but vegetation is promoted by the humidity of the climate and by artificial improvements. The characteristic industry of the department is the rearing of horses and other live stock; the horses number 92,839, besides several thousands of asses and mules, and there are 270,000 horned cattle, 277,000 sheep, upwards of 100,000 pigs, and 40,000 beehives. In 1876 the department yielded 1,458,476 hectolitres of wheat, 83,393 of meslin, 1,014,662 of barley, 427,360 of sarrasin, 484,365 of oats, 52,236 of rye, 683,834 of potatoes, 72,401 of dried legumes, 363,372 of beetroot, and 8758 quintals of hemp; and in the same year there were manufactured 86,088 kilogrammes of linseed oil and 39,380 kilogrammes of colza oil. The arable and meadow lands occupy the eastern portion of the department; legumes are grown in the west, where lands adapted for market gardening purposes are worth as much as 15,000 francs per hectare. Manche has a larger production of cider than any other department of France (upwards of 28,000,000 gallons). Besides apples, pears, plums, cherries, and figs are grown. The fields are lined with rows of oak, elm, and beech, which furnish good timber for building purposes. The aspen, poplar, walnut, and chestnut are also common. Some attempts at reclamation have been made along the sea-shore. The department contains valuable granite quarries in the Cherbourg arrondissement and the Chausay Islands; there are also deposits of carboniferous marble, kaolin, talc, and of calcareous sand ("tangue") used as manure. There are smiths' forges and iron foundries, important brass foundries, and establishments for the manufacture of tools, needles, and other kinds of hardware. The port and arsenal of Cherbourg is very complete in all its appointments. The department has 45 wool-spinning factories with 13,123 spindles, and 6 cotton-spinning mills with 50,000 spindles; and cloth-making, paper-making, tanning, and other industries are carried on. On the coast there are important beds for oyster culture, and the maritime population, when not engaged in the pursuit of the herring, mackerel, or lobster, collect ware and sea-grass. The shipping of Manche amounts to some 4600 vessels, with an aggregate tonnage of 29,000 tons; the exports consist of butter, eggs, poultry, live stock, legumes, meat, fish, horses, grain, stone, brasiery, and hardware. The population in 1876 was 539,910. There are six arrondissements (St Lô, Avranches, Cherbourg, Coutances, Mortain, Valognes), 48 cantons, and 643 communes; the capital is St Lô.

MANCHESTER, a city whose industries are famous throughout the civilized world, is situated in the south-eastern corner of Lancashire, and forms the centre of the towns and villages which constitute the great English cotton district.

The city of Manchester and the borough of Salford are about 180 miles north-west of London, and lie in 53° 29′ N. lat., 2° 14′ 23″ W. long. The sister towns stand for the most part on a level plain, the rising ground being chiefly on the north side. The rivers are the Irwell, the Medlock, the Irk, and the Tib, the last entirely overarched and covered by streets and warehouses. The Irwell, which separates Manchester from Salford, is crossed by a series of bridges; it has here an average width of 91 feet and an average depth of about 7 feet; and it discharges itself into the Mersey, which is about ten miles distant. The chief part of the district, before it was covered with the superficial drift of sand, gravel, and clay, consisted of upper New Red Sandstone with slight portions of lower New Red Sandstone, magnesian marls and upper red marls, hard sandstone and limestone rock, and cold clays and shales of contiguous coal-fields. The town, as its thousands of brick-built houses show, has been for the most part dug out of its own fields of clay. The parliamentary borough of Manchester has an area of 6349 acres; the municipal area is 4294 acres. The parliamentary and municipal boundaries of Salford are identical, and have an area of 5208 acres.

Parks and Statues.—Of the parks and open spaces the principal is the Peel Park in Salford, containing an area of about 40 acres. In its centre is the building containing the Salford library, and also a valuable museum of natural history and a collection of paintings known as the Langworthy gallery (built and endowed by the late Mr E. R. Langworthy, a wealthy Manchester merchant). Among the notable pictures may be named the Last Sleep of Argyll and the Execution of Montrose, by Mr E. M. Ward. Seedley Park, Ordsall Park, and Albert Park have been recently constructed, and are situated in Salford,—where also is the Kersal Moor, a bit of wild moorland, some 21 acres in extent, now under the care of the corporation of Salford. The moor has long been noted for the richness of its flora, about one-eighth of the English flowering plants having been gathered on its very limited area. It has also been the scene of an entomological incident of some interest—the capture of the *Œcophara Woodiella*, of which there is no other recorded habitat. The Queen's Park at Harpurhey is pleasantly situated, notwithstanding that it is now completely surrounded by cottages and manufactories. In the centre is a small museum, the chief interest of which depends upon a series of phrenological casts made by Gall and Spurzheim and completed by Bally. Philips Park is also attractive, notwithstanding its close proximity to some of the densest portions of the town. The principal parks so far named were constructed from money obtained by a public subscription in 1846, but the Alexandra Park at Moss Side has been entirely paid for out of the public rates. It has very good ornamental grounds, but owing to the difficulties of the situation the construction has been somewhat costly. In this connexion may be mentioned the Botanical Gardens, which are situated at Old Trafford, and, although intended chiefly for the subscribers, are open at certain times to the public on liberal terms.

Manchester is not remarkable for the number of its public memorials of the dead; but it possesses some which should not be passed unnoticed. In front of the infirmary are bronze statues of Wellington, Watt, Dalton, and Peel. A bronze statue of Cobden occupies a prominent position in St Ann's Square. The marble statue of the Prince Consort, covered by a Gothic canopy of stone, is placed in Albert Square, in proximity to the town-hall, the enormous proportions of which have the effect of dwarfing what would otherwise be a striking monument. The most picturesque is the bronze statue of Cromwell, on a huge block of rough granite as pedestal. In the Peel Park are statues of Queen Victoria, the Prince Consort, Sir Robert Peel, and Joseph Brotherton.



Plan of Manchester.

Public Buildings.—There are many fine public buildings in Manchester. Among them may briefly be noticed the royal infirmary, consisting of three sides of a quadrangle, one of which owes its existence to the benevolence of Jenny Lind, who gave two concerts in order to raise the necessary funds. The institution will accommodate about two hundred and sixty patients. The royal exchange is a fine specimen of Italian architecture, and was erected in 1869; the great meeting-hall is one of the largest rooms in England, the ceiling having a clear area, without supports, of 120 feet in width. The exchange is seen at its best on market days (Tuesday and Friday), when representatives from all parts of Lancashire, and indeed of the neighbouring counties, are earnestly engaged in buying and selling. The assize courts were built in 1864 from designs by Waterhouse. The style is a mixture of Early English and Decorative, and a large amount of decorative art has been expended on the building. The cost was about £100,000. The New Bailey prison, intended for the criminals of Salford hundred, was built (1787) in accordance with the suggestions of Howard, the prison philanthropist, but in 1868 the present structure, at the rear of the assize courts, was erected. The style of architecture is Norman, and the building, which covers 9 acres, cost £170,000. The city jail is situated in Hyde Road. The old town-hall was built in 1832, in imitation of the Erectheum of Athens, at a cost of £40,000; it is now occupied by the town library. The business of the city is conducted in the new town-hall, probably beyond dispute the most important municipal building in the kingdom, if not in Europe. It was completed in 1877, from designs by Waterhouse, who selected as the style of architecture a form of Gothic, but treated it very freely as purposes of utility required. The edifice covers 8000 square yards, and includes more than two hundred and fifty rooms. The triangular or flat-iron form of the site was a great difficulty, but the architect has skilfully surmounted it. The building consists of continuous lines of corridors surrounding a central courtyard and connected by bridges. The principal tower is 260 feet high, and affords a view which extends over a large part of South Lancashire and Cheshire, and is bounded only by the hills of Derbyshire. It contains a remarkable peal of bells by Taylor of Loughborough, forming an almost perfect chromatic scale of twenty-one bells; each bell has on it a line from section 105 of Tennyson's *In Memoriam*. The great hall is 100 feet long and 50 feet wide, and contains a magnificent organ built by Cavaillé-Coll of Paris. The panels of this room are being filled with mural paintings illustrating the various incidents connected with the history and progress of the city. The total cost of the building has been £1,053,264, inclusive of £201,925 for interest. The branch Bank of England is a Doric building designed by Cockerell. The Salford town-hall is also Doric; and there are besides separate town-halls for the townships of Ardwick, Chorlton, Hulme, Cheetham, Broughton, and Pendleton. The Free Trade hall is a fine structure in the Lombardo-Venetian style, and its great hall will accommodate five thousand people. It is used for public meetings, concerts, &c., and was built by Walters. The young men's Christian association hall was originally used as a natural history museum. The Royal Institution, built by Sir Charles Barry, is a proprietary institution intended for the encouragement chiefly of the fine arts. In the entrance hall are casts of the Elgin Marbles, given by George IV., and a statue of Dalton by Chantrey. There is a small permanent gallery, and periodical exhibitions of pictures are held and courses of lectures delivered. Arrangements have now (1882) been concluded by which the institution will become the property of the town and be managed by a joint committee of members of the town council and others interested in art and literature. The Athenæum, also designed by Barry, was founded by Richard Cobden and others associated with him, for "the advancement and diffusion of knowledge." The institution has, perhaps, not developed exactly on the lines contemplated by its promoters, but it has become one of the most useful in the town. All the advantages enjoyed by members of high-class social clubs, with the addition of facilities for educational classes and the use of an excellent news-room and a well-selected library of 18,000 volumes, are offered in return for a payment which does not amount to a penny a day. The mechanics' institution contains a library of 17,000 volumes, and has connected with it excellent day and evening schools, and classes for technical instruction. The Portico is a good specimen of the older proprietary libraries and news-rooms. It dates from 1806, and has a library of 20,000 volumes. The Memorial Hall was built to commemorate the memory of the Nonconformist ejected ministers of 1662. The Unitarian home missionary board has here its library and rooms for the education of students; and the building is used for a variety of meetings, scientific, educational, musical, and religious. The inconvenience arising from inadequate provision for postal service is, after many years of hesitation, to be remedied by the erection, now (1882) in progress, of a commodious post-office.

Means of Communication.—The opening of the Manchester and Liverpool Railway in 1830 marked an important epoch in the history of modern industry, and since that time Manchester has gradually been connected by rail with every part of the kingdom. The enormous traffic by this means has not, however, entirely superseded the use of the canals, which formerly played so important a part in the cotton industry. The construction of the Bridgewater Canal in 1761 was an event second in importance only to that of the introduction of the railway system. There are three large railway stations, Victoria, London Road, and the Central, and several minor ones. The excellence of the omnibus system of the city was perhaps one principal cause for the somewhat tardy adoption of tramways; but these have now rapidly developed, and ensure facilities for transit between the different parts of the city and also for communication with the neighbouring towns and villages. The establishment of a ship canal to connect Manchester with the sea has been frequently suggested at intervals for the last sixty years, and a scheme of tidal navigation elaborated by Mr Hamilton Fulton is now (1882) being actively discussed.

Water Supply.—This is under the control of the corporation, which supplies not only the citizens but the surrounding populations. The gathering-ground is a series of reservoirs in the valley of Longdendale, chiefly along the course of the river Etherow. Woodhead, the chief reservoir, 20 miles from Manchester, is 777 feet above sea-level, is 72 feet deep, covers an area of 155 acres, and has a capacity of 1,235,000,000 gallons. The present system of waterworks, including the portions now being constructed at Audenshaw and Denton, have an area of reservoirs of 854½ acres, and a capacity of holding 5,914,000,000 gallons. The average daily supply of water was in 1855 8,078,152 gallons; in 1881 it was 18,929,704 gallons. In 1877 the water committee announced that in view of the increased demand it would be necessary to obtain additional or fresh sources of supply. The proposal to utilize Thirlmere in Cumberland for this purpose was vehemently opposed, but the scheme was eventually sanctioned by parliament, and the works have been begun, but have not as yet made rapid progress. Thirlmere is 533 feet above the sea, and it is proposed to raise it by an embankment to 584 feet above the sea. From this height it is estimated that a maximum quantity of 50,000,000 gallons might be withdrawn daily.

Lighting.—The corporation not only manufactures gas for the lighting of the city, but sells it to out-districts. The area of distribution amounts to 42 square miles, and the street mains for the gas supply are 597 miles long. The entire assets of the gas-works were valued in September 1881 at £1,386,942. The average quantity of gas transmitted daily was 2,425,630,000 cubic feet. The revenue from the sale of bye-products is about £90,000. Salford, which is supplied with water by Manchester, has its own gas-works, the property of the ratepayers, and managed by a committee of the town council.

Administration of Justice.—The city has a stipendiary magistrate who, in conjunction with lay magistrates, tries cases of summary jurisdiction in the police courts; these are held in a building erected for the purpose, and having some architectural pretensions. There are also quarter sessions, presided over by a recorder. Separate sessions are held for the Salford hundred. Salford has also a police court with a stipendiary magistrate. Certain sittings of the Court of Chancery for the duchy of Lancaster are held in Manchester. In addition to the county court, there is an ancient civil court known as the Salford Hundred Court of Record. Assizes have been held since 1866.

Churches.—The chief ecclesiastical building in Manchester is the cathedral, which, however, hardly corresponds to the ideas usually associated with that word. It was indeed built simply as a parish church, and, although a fine specimen of Perpendicular Gothic, is by no means what might be expected as the cathedral of an important and wealthy diocese. Though there are remains of older work, the bulk of the building belongs to the early part of the 15th century. The first warden was John Huntington, rector of Ashton, who built the choir. The building, which was noticed for its hard stone by Leland when he visited the town, did not stand time and weather well, and by 1845 some portions of it were rapidly decaying. This led to its restoration by Holden, which was not finished until 1868, when the tower was almost completely renovated in a more durable stone than that formerly used. The total length is 220 feet and the breadth 112 feet; the only parish church exceeding it in this last dimension is said to be that of Coventry. There are several stained-glass windows. In the Ely chapel is the altar tomb of Bishop Stanley, the father of the gallant Sir John Stanley, who fought at Flodden Field. In the stalls there are some curious *miserere* carvings. The tower is 139 feet high, and contains a peal of ten bells, chiefly from the foundry of the Rudhalls. There are two organs, one by Father Smith, and a new one erected at a cost of more than £7000, and enclosed in an oak case designed by the late Sir G. Scott. The church endowments are considerable, and have been the subject of a special act of parliament, known as the Manchester Rectory Division Act of 1845, which provides £1500 per annum for the dean, and £600 to each of the four canons, and divides the residue among the incumbents of the new churches formed out of the old parish. There are about one hundred places of worship in Manchester belonging to the Church of England, but they are not especially remarkable. Of the Roman Catholic churches, the most important are the cathedral church of St John in Salford, of the earliest Decorative character, with a spire 240 feet in height, and the church of the Holy Name, which belongs to the Jesuits, and is remarkable for its costly decoration. Salford is the seat of a Roman Catholic bishopric, as Manchester is the seat of an Anglican one. Most of the Nonconformist bodies have churches in the city and its environs. The meeting-house of the Society of Friends is said to be the largest of the kind in the kingdom, and will seat twelve hundred persons.

Literature and Science.—Manchester possesses numerous associations for the cultivation of literature and science. The oldest of these, the Literary and Philosophical Society, founded in 1781, has a high reputation, and has numbered among its working members John Dalton, Eaton Hodgkinson, William Fairbairn, J. P. Joule, H. E. Roscoe, and many other famous men of science. It has published a lengthy series of memoirs and proceedings. The Manchester Literary Club was founded in 1862, and publishes an annual volume of papers. The Manchester Statistical Society was the first society of the kind established in the kingdom, and has issued *Transactions* containing many important papers. The Scientific Students' Association, the Field Naturalists' and Archæologists' Society, the Microscopical Society, the Botanists' Association, the Geological Society, and the Science Association may also be named. Several printing clubs, the Chetham, Record, Holbein, and English Dialect societies, have their headquarters here. Nine daily papers are published, and the journalism of Manchester takes high rank. The periodicals issued are between fifty and sixty in number.

University and Schools.—There are many educational facilities in Manchester and Salford. The oldest school is the Manchester grammar school, which was founded in 1519 by Hugh Oldham, bishop of Exeter, who was a native of Crumpsall, one of the outskirts of the town. The foundation was done "out of the good mind he bore to the county of Lancashire, perceiving that the children thereof, having pregnant wits, were for the most part brought up rudely and idly; that knowledge might be advanced, and that the children might be better taught to love, honour, and dread God and His laws." The master and usher appointed by the good bishop were to teach freely every child and scholar coming to the school, "without any money or reward taken." Some mills were devised for the maintenance of the school, which was further endowed at both the universities by Sarah, duchess of Somerset, in 1692. The school has been reconstituted on a new basis within recent years, and has now two hundred and fifty free scholars, whilst other pupils are received on payment of low fees. Mr E. R. Langworthy bequeathed to it £10,000 as an endowment for scholarships. Among those educated at the grammar school may be mentioned Thomas De Quincey and the late Mr Harrison Ainsworth.

The Owens College was founded in 1846 by John Owens, who left nearly £100,000 to trustees for an institution in which should be taught "such branches of learning and science as were then and might be hereafter usually taught in English universities." The college was opened in 1851, in a house which had formerly been the residence of Cobden, but in 1872 it was removed to its present home, a handsome Gothic building designed by Waterhouse. An appeal made to the public in 1867 in behalf of the college was heartily responded to, and its capital funds now amount to over £400,000. The building is carefully adapted to its purposes; and the chemical laboratory, a separate structure at the rear, is of the completest description. The first bishop of Manchester, Dr J. Prince Lee, who had an interesting library of some 6000 volumes, bequeathed it to the college, which has also received gifts of books and money from various other quarters, and thus has now the nucleus of an important collection. The Royal School of Medicine, which was founded in 1824, and had acquired the reputation of being one of the most successful of the provincial schools, has been amalgamated with the college. The Medical Society has, by an arrangement with the college authorities, deposited its valuable library of 22,000 volumes in the college rooms. The Manchester museum is now the property of the college, and contains the bulk of the specimens gathered by the Geological Society and by the now extinct Natural History Society. A suitable building for the accommodation of the museum has long been a decided want, and is now (1882) about to be undertaken. The growing importance of the Owens College led to the project for a university charter. The proposal was not received without some opposition, but as the result of lengthy discussions and adjustments a scheme was evolved for a university to consist of affiliated colleges, situated in different towns, but having its centre in Manchester; and the charter of the Victoria University was granted in 1880, with full powers to grant degrees except in medicine—an exception which is to be removed. Among the other educational institutions of the district are the Lancashire Independent college, the Primitive Methodist college, the Baptist institute, the St Bede's college (Roman Catholic), the college for women, the Salford college for working men, the school of art, and many minor institutions. The elementary education is controlled by an elected school board. Salford has also a school board. Very nearly the oldest educational institution in the town is the Chetham hospital, a bluecoat school educating one hundred boys; and almost the latest addition to these institutions is a similar institution founded by the late Alderman Nicholls. The schools for the deaf and dumb are situated at Old

Trafford, in a contiguous building of the same Gothic design as the blind asylum, to which Mr Thomas Henshaw left a bequest of £20,000. There is also an adult deaf and dumb institution, containing a news-room, lecture-hall, chapel, &c., for the use of deaf mutes.

Libraries and Museums.—Manchester is well provided with libraries. The Chetham library is sometimes spoken of as the oldest free library in Europe, and certainly its doors have been open without let or hindrance for more than two centuries, and the building which it occupies is almost the only relic now left of ancient Manchester. What had once been the barons' hall, and afterwards the residence of the clergy, was purchased by the trustees of Humphrey Chetham, and by them applied to the purposes of a blue-coat school and library, provision for the foundation and maintenance of which he had made by will. The library, with its quiet and almost monastic corridors, forms a striking contrast to the busy streets without. The contents now amount to about 40,000 volumes, and include many rare manuscripts and curious books, the gem of the collection undoubtedly being a copy of the historical compilation of Matthew Paris, with corrections in the author's handwriting. There is a large collection of matter relating to the history and archæology of Lancashire and Cheshire. A recent addition to its riches in this department is the extensive series of Lancashire manuscripts bequeathed by the late Canon Raines. The collection of broadsides formed by Mr J. O. Halliwell-Phillips, and the library of John Byrom, rich in mystics and shorthand writers, should also be named. In addition to the library, Chetham left provision for the education of a number of poor boys, and the increase in the value of the endowments has raised the number to one hundred, who receive a good English education and are afterwards put to some useful trade or calling. An additional school has recently been erected from designs by Waterhouse, who has been successful in making the new building harmonize with the quaint and sober architecture of the hospital and library. The Manchester Free Libraries were founded by Sir John Potter, who was instrumental in promoting a public subscription from which a building was bought and stocked with books, and then handed over to the town, by whose municipal authorities the libraries have since been not only maintained but materially increased. There is now a reference library containing about 70,000 volumes, including an extensive series of English historical works and a remarkable collection of books of political economy and trade. The chief object has been to make a good working collection for the student and man of letters. But, although the collection of objects dear to the bibliomaniac has not been considered of first importance, the library now includes some literary curiosities of the first rank, among them specimens of the press of Caxton and Wynkyn de Worde. Affiliated to the central consulting library there are six lending libraries, the Hulme library having 17,000 volumes, Ancoats 15,000, Rochdale Road 15,000, Chorlton and Ardwick 17,000, Cheetham 12,000, and Deansgate 18,000. Each lending library has attached to it a commodious reading-room. There are also libraries in connexion with the Athenæum, the mechanics' institution, the Portico, the Owens College, and other institutions. The sister borough of Salford has also adopted the free library system, and possesses at Peel Park a large reference and lending library, whilst additional lending libraries and news-rooms have been opened at Pendleton, Greengate, and Regent Road.

Recreation.—The city has always been noted for its love of theatrical amusements, and the German element in its population has in the last fifty years largely influenced the taste for music by which it is now distinguished. The theatre royal is a patent theatre, and was opened in 1845, its predecessor having been burned in the previous year. It ranks in size with the large metropolitan theatres, and has connected with it memories of nearly all the great actors of the present and past generation. The Prince's theatre was opened in 1864, and is an elegant and beautifully finished structure. The Queen's theatre is a substantial building with but small architectural pretensions. A theatre has recently been opened in Salford. The concert-hall will hold twelve hundred people. There are many musical societies; and amongst other places of amusement may be mentioned the Belle Vue Zoological Gardens, the Pomona Palace, and numerous music-halls, &c.

Population.—According to the census of 1881, the municipal borough of Manchester contains a population of 341,414 (163,475 males, 177,939 females), while the parliamentary borough has 393,585 (189,005 males, 204,580 females). Salford, on the same authority, has 176,235 (84,610 males, 91,625 females). These figures, however, hardly convey the actual facts of the case. Manchester and Salford are as closely joined as London and Southwark, and are surrounded by populous districts quite as much united as the component parts of what the registrar-general styles "Greater London." There has been a seeming decrease in the population of the city, which in 1871 was stated to contain 355,655 persons; but this appearance is fallacious, for, while the progress of city improvements has reduced the number of inhabited houses in the centre, there has been a large influx into Salford, which has increased by 51,432 persons during the last ten years. The two boroughs, with the urban sanitary districts immediately contiguous, have a population of about 800,000 persons. In the Middle Ages there were in Manchester and Salford probably not more than two or three hundred burgesses and their dependants. In 1588 the population was estimated at 10,000, but the parish is here meant. In 1757 the two towns contained 19,839 persons, who by 1773 had increased to 27,246, and by 1783 to over 39,000. At the first census in 1801 Manchester had 75,275, and Salford 14,477. The last four census statements are:—

	Manchester.	Salford.
1851	303,382	63,850
1861	338,722	102,449
1871	351,189	124,801
1881	341,414	176,235

The increase in rateable value has been equally remarkable. In 1815 Manchester was rated at £357,778; in 1882 the estimate was £2,761,469. The corresponding values for Salford were £54,130 and £801,192.

Sanitary Condition.—Manchester, like other towns, grew more rapidly than the provision for its wise government; but determined efforts have been made in the direction of sanitary improvement. The death-rate in 1840 was 34·3; in 1850, 29·6; in 1860, 28·0; in 1861, 30·4; in 1862, 30·3; in 1869, 28·9; in 1870, 26·52; in 1871, 29·8; in 1877, 25·4; in 1880, 24·7; and for nine months of 1881 it was 23·3. Whatever may be the causes of these fluctuations, it is clear that there is still ample room for further improvement. The air laden with the products of the combustion of coal, and the unspeakably filthy rivers, are urgently in need of energetic remedial action.

Manufactures and Commerce.—As has already been stated, Manchester is the centre of the English cotton industry; but in the town itself of late years the tendency has been more and more in the direction of commerce. Owing to the enhanced value of land, many mills and workshops have been removed to the outskirts and to neighbouring villages and towns, so that the centre of Manchester and an ever-widening circle around is now chiefly devoted not so much to production as to the various offices of distribution. Large and handsome warehouses and shops abound, and there is every evidence of quick and opulent life. It would be a mistake, however, to regard Manchester as solely dependent upon the industries connected with cotton. There are other important manufactures which in another community would be described as gigantic. Wool and silk are manufactured on a considerable scale, though the latter industry has for some years been on the decline. The miscellaneous and multifarious articles grouped under the designation of smallwares occupy many hands. Machinery and tools, using the term with its most comprehensive meaning so as to include alike philosophical instruments and steam-engines, are made in vast quantities. The chemical industries of the city are also on a large scale. In short, there are but few important manufactures that are wholly unrepresented. The proximity of Manchester to the rich coal-fields of Lancashire has had a marked influence upon its prosperity; but for this, indeed, the rapid expansion of its industries would have been impossible.

It would probably be difficult to find a community in any part of the world with which Manchester has no commercial relations. The enterprise of its merchants has kept pace with the energy of its manufacturers, and the products of its looms are to be found in every land, though doubtless the supremacy which its cotton goods have held in the markets of the world tends to become more and more abated by the gradually increasing foreign competition.

From figures laid before the Manchester Statistical Society, the money extent of trading operations at this centre has been calculated at about £207,000,000 in 1872 and £318,000,000 in 1881. These figures, though to be taken with certain reservations, indicate approximately the extent of the activity of the city.

The commercial institutions of Manchester are too numerous for detailed description. Its chamber of commerce has for more than sixty years held a position of much influence in regard to the trade of the district and of the nation. There are eleven joint-stock banks, seven of which have their head offices in the town; these banks, besides numerous branches in the surrounding district, have sixteen branches in the town; and there are several private bankers.

Municipality.—The affairs of the town are regulated by a council consisting of sixty-four representatives of the fifteen wards into which the city is divided. The body corporate of sixteen aldermen and forty-eight councillors, who are presided over by the mayor, has shown much enterprise and public spirit in the energy with which it has prosecuted public improvements, and in the business ability with which it has managed the vast undertakings connected with the lighting and water supply of the town. The town council of Salford consists also of sixteen aldermen and forty-eight councillors, and there are fourteen wards.

History.—Very little is known with certainty of the early history of Manchester. It has, indeed, been conjectured, and with some probability, that at Castlefield there was a British fortress, which was afterwards taken possession of by the soldiers of Agricola. It is at all events certain that a Roman station of some importance existed in this locality, and a fragment of the wall still exists. In the last century considerable evidences of Roman occupation were still visible; and from time to time, in the course of excavation (especially during the making of the Bridgewater Canal), Roman remains have been found. The coins were chiefly those of Vespasian, Antoninus Pius, Trajan, Hadrian, Nero, Domitian, Vitellius, and Constantine. The period succeeding the Roman occupation is for some time legendary. As late as the 17th century there was a floating tradition that Tarquin, an enemy of King Arthur, kept the castle of Manchester, and was killed by Launcelot of the Lake. The mention of the town in authentic annals is very scanty. It was probably one of the scenes of the missionary preaching of Paulinus; and it is said (though by a chronicler of comparatively late date) to have been the residence of Ina, king of Wessex, and his queen Ethelberga, after he had defeated Ivor, somewhere about the year 689. Nearly the only point of certainty in its history before the Conquest is that it suffered greatly from the devastations of the Danes, and that in 923 Edward, who was then at Thelwall, near Warrington, sent a number of his Mercian troops to repair and garrison it. In Domesday Book Manchester, Salford, Rochdale, and Radcliffe are the only places named in South-East Lancashire, a district now covered by populous towns. Large portions of it were then forest, wood, and waste lands. Twenty-one thanes held the manor of Salford among them. The church of St Mary and the church of St Michael in Manchester are both named in Domesday, and some difficulty has arisen as to their proper identification. Most antiquaries have considered that the passage refers to the town only, whilst others think it relates to the parish, and that, while St Mary's is the present cathedral, St Michael's would be the present parish church of Ashton-under-Lyne. Manchester and Salford are so closely allied that it is impossible to dis-associate their history. Salford received a charter from Ranulph de Blundeville, in the reign of Henry III., constituting it a free borough, and Manchester in 1301 received a similar warrant of municipal liberties and privileges, from its baron, Thomas Gresley, a descendant of one to whom the manor had been given by Roger of Poictou, who was created by William the Conqueror lord of all the land between the rivers Mersey and Ribble. The Gresleys were succeeded by the De la Warres, the last of whom was educated for the priesthood, and became rector of the town. To avoid the evil of a non-resident clergy, he made considerable additions to the lands of the church, in order that it might be endowed as a collegiate institution. A sacred guild was thus formed, whose members were bound to perform the necessary services at the parish church, and to whom the old baronial hall was granted as a place of residence. The manorial rights passed to Sir Reginald West, the son of Joan Greslet, and he was summoned to parliament as Baron de la Warre. The West family, in 1579, sold the manorial rights for £3000 to John Lacy, who, in 1596, resold them to Sir Nicholas Mosley, whose descendants enjoyed the emoluments and profits to be derived from them until the middle of the present century (1845), when they were purchased by the present town council of Manchester for a sum of £200,000. The lord of the manor had the right to tax and toll all articles brought for sale into the market of the town. But, though the inhabitants were thus to a large extent taxed for the benefit of one individual, they had a far greater amount of local self-government than might have been supposed, and the court leet, which was then the governing body of the town, had, though doubtless in a somewhat rudimentary form, nearly all the powers and functions now possessed by municipal corporations. This court had not only control over the watching and watering of the town, the regulation of the water supply, and the cleaning of the streets, but also had power, which at times was used freely, of interfering with what would now be considered the private liberty of their fellow-citizens. Some of the regulations adopted, and presumably enforced, sound grotesquely at the present day. Thus, no single woman was allowed to be a householder; no person might employ other than the town musicians; and the amount to be spent at wedding feasts and other festivities was carefully settled. Under the protection of the barons the town appears to have steadily increased in prosperity, and it early became an important seat of the textile manufactures. Fulling mills were at work in the district in the 13th century; and documentary evidence exists to show that woollen manufactures were carried on in Ancoats at that period. In 1641 we hear of the Manchester people purchasing linen yarn from the Irish, weaving it, and returning it for sale in a finished state. They also brought cotton wool from Smyrna to work into fustians and dimities. An Act passed in the reign of Edward VI. regulates the length of cottons called Manchester, Lancashire, and Cheshire cottons. These, notwithstanding their name, were probably all woollen textures. It is thought that some of the Flemish weavers who were introduced into England by Queen Philippa of Hainault were settled at Manchester; and Fuller has given an exceedingly quaint and picturesque description of the manner in which these artisans were welcomed by the inhabitants of the country they were about to enrich with a new industry, one which in after centuries has become perhaps the most important industry of the country. The Flemish weavers were in all probability reinforced by religious refugees from the Low Countries. Leland, writing in 1638, describes Manchester as the "fairest, best builded, quickest, and most populous town of Lancashire." The right of sanctuary had been granted to the town, but this was found so detrimental to its industrial pursuits that after very brief experience the privilege was taken away. The college of Manchester was dissolved in 1547, but was refounded in Mary's reign. Under her successor the town became the head-quarters of the commission for establishing the Reformed religion.

In the civil wars, the town was besieged by the Royalists under Lord Strange, but was successfully defended by the inhabitants under the command of a German soldier of fortune, Colonel Rosworm, who complained with some bitterness of their ingratitude to him. An earlier affray between the Puritans and some of Lord Strange's followers is said to have occasioned the shedding of the first blood in the disastrous struggle between the king and parliament. The year 1689 witnessed that strange episode, the trial of those concerned in the so-called Lancashire plot, which ended in the triumphant acquittal of the supposed Jacobites. That the district really contained many ardent sympathizers with the Stuarts was, however, shown in the rising of 1715, when the clergy ranged themselves to a large extent on the side of the Pretender, and was still more clearly shown in the rebellion of 1745, when the town was taken possession of by Prince Charles Edward Stuart, and a regiment, known afterwards as the Manchester regiment, was formed and placed under the command of Colonel Francis Townley. In the fatal retreat of the Stuart troops the Manchester contingent was left to garrison Carlisle, and surrendered to the duke of Cumberland. The officers were taken to London, where they were tried for high treason and beheaded on Kennington Common.

The variations of political action in Manchester had been exceedingly marked. In the 16th century, although it produced both Catholic and Protestant martyrs, it was earnestly in favour of the Reformed faith, and in the succeeding century it became indeed a stronghold of Puritanism. Yet the descendants of the Roundheads who defeated the army of Charles I. were Jacobite in their sympathies, and by the latter half of the 18th century had become imbued with the aggressive form of patriotic sentiment known as anti-Jacobinism, which showed itself chiefly in dislike of reform and reformers of every description. A change was, however, imminent. The distress caused by war and taxation, towards the end of the last and the beginning of the present century, led to bitter discontent, and the anomalies existing in the parliamentary system of representation afforded only too fair an object of attack. While single individuals in some portions of the country had the power to return members of parliament for their pocket boroughs, great towns like Manchester were entirely without representation. The injudicious conduct of the authorities, also, led to an increase in the bitterness with which the working classes regarded the condition of society in which they found themselves compelled to toil with very little profit to themselves. Their expressions of discontent, instead of being wisely regarded as symptoms of disease in the body politic, were looked upon as crimes, and the severest efforts were made to repress all expression of dissatisfaction. This foolish policy of the authorities reached its culmination in the affair of Peterloo, which may be regarded as the starting point of the modern reform agitation. This was in 1819, when an immense crowd assembled on St Peter's Fields (now covered by the Free Trade hall and warehouses) to petition parliament for a redress of their grievances. The authorities had the Riot Act read, but in such a manner as to be quite unheard by the mass of the people; and drunken yeomanry cavalry were then turned loose upon the unresisting mass of spectators. The yeomanry appear to have used their sabres somewhat freely; several people were killed and many more injured; and, although the magistrates received the thanks of the prince regent and the ministry, their conduct excited the deepest indignation throughout the entire country. Naturally enough, the Manchester politicians took an important part in the reform agitation, and when the Act of 1832 was passed, the town sent as its representatives the Right Hon. C. P. Thomson, vice-president of the Board of Trade, and Mr Mark Philips. With one notable exception, this was the first time that Manchester had been represented in parliament since its barons had seats in the House of Peers in the earlier centuries. In 1654 Mr Charles Worsley and Mr R. Radcliffe were nominated to represent it in Cromwell's parliament. Worsley was a man of great ability, and must ever have a conspicuous place in history as the man who carried out the injunction of the Protector to "remove that bauble," the mace of the House of Commons. The agitation for the repeal of the corn laws had its headquarters at Manchester, and the success which attended it, not less than the active interest taken by its inhabitants in public questions, has made the city the home of various projects of reform. The "United Kingdom Alliance for the suppression of the liquor traffic" was founded there in 1853, and during the continuance of the American War the adherents both of the North and of the South deemed it desirable to have organizations to influence public opinion in favour of their respective causes. A charter of incorporation was granted in 1838; a bishop was appointed in 1847; and the town became a city in 1853. The Lancashire cotton famine, caused by the civil war in America, produced much distress in the Manchester district, and led to a national movement to help the starving operatives. The relief operations then organized are amongst the most remarkable efforts of modern philanthropy.

Although several excellent books have been written on subjects connected with the town, there is no adequate modern history. The *History of Manchester*, by the Rev. John Whitaker, appeared in 1771; it is a mere fragment, and, though containing much important matter, requires to be very discreetly used. The following may be recommended:—Reilly, *History of Manchester*, 1861; Procter, *Manchester in Holiday Dress* (1866), *Memorials of Manchester Streets* (1874), *Memorials of Byegone Manchester*, 1880; Buxton, *Botanical Guide to Manchester*, &c., 2d ed., 1859; Axon, *Handbook of the Public Libraries of Manchester and Salford*, 1877; Grindon, *Manchester Flora*, 1859; Baines, *History of Lancashire*, 2d ed., 1868-70. (W. E. A. A.)

MANCHESTER, a town of the United States, in Hartford county, Connecticut, with a station on the New York and New England Railroad, 8 miles east of Hartford. Its spinning and weaving mills turn out annually 2,000,000 yards of gingham and 90,000 pairs of stockings; and its paper mills (upwards of a dozen in number) produce not only vast quantities of book paper but Government and bank-note paper for several nations. At South Manchester, 2½ miles distant, and reached by a branch line, are the silk factories of Messrs Cheney, which cover about 8 acres, and give employment to one thousand operatives. The factory village has been laid out by a landscape gardener; and connected with it are a public hall, a library and reading-room, and a free school. The population of the town has increased from 4223 in 1870 to 6462 in 1880.

MANCHESTER, a city of the United States, one of the shire towns of Hillsborough county, New Hampshire, is situated mainly on the left bank of the Merrimac, in a broad plain about 90 feet above the level of the river, in 42° 35′ N. lat. and 71° 31′ W. long., 16 miles from Concord and 46 north-west of Boston. It is a terminus of several railroads, as well as a principal station on the Boston, Lowell, and Concord line. The general plan is regular and spacious; there are several large and ornamental squares, and the main thoroughfare, Elm Street, is 100 feet wide, more than a mile long, and bordered by the trees from which it takes its name. Towards the river the frontage consists of great brick-built factories and substantial tenements for the accommodation of the operatives. A city-hall (rebuilt after the fire in 1842), the county court-house, the State reform school (for one hundred and fifty pupils), two opera-houses, and a Roman Catholic convent (St Ann's) and orphan asylum are among the buildings of note. The city library (24,000 volumes), founded by private enterprise in 1844 as the Manchester Athenæum, became public property in 1854. Water from Lake Massabesic (4 miles distant and 2300 acres in extent) was introduced into the town in 1874, at a cost of nearly $1,000,000, and is stored in a reservoir capable of containing 16,000,000 gallons. It is almost exclusively to the water-power furnished by the Blodgett Canal (built in 1816 round the Amoskeag Falls, which have a descent of 47 feet) that Manchester owes its prosperity as a manufacturing centre. The Amoskeag Company (dating from 1831), the Stark mills (1838), the Manchester mills (1839), the Langdon mills (1857), and the Amory mills (1880) are the leading establishments; they possess an aggregate capital of $7,650,000, work 12,000 looms and 409,000 spindles, and make 143 miles of web daily. Locomotive engines (produced at the rate of fourteen per month), steam fire-engines, edge tools, circular saws, files, sewing machines, carriages, leather, boots and shoes, paper, and ale all likewise form important items in the local industry. Manchester is governed by a mayor, a board of aldermen (one member for each of the eight wards), and a common council (three members for each ward). The assessed value of property in 1881 was $19,175,408; and the city debt $965,550. The population, which was 13,932 in 1850, stands in the succeeding decades at 20,107, 23,536, and 32,630, and is stated in 1882 at 36,500.

Originally settled in the close of the 17th century by Scotch Presbyterians and Massachusetts Puritans, Derryfield, as it was then called, though incorporated in 1751, continued for upwards of seventy years to be a place of less than one hundred inhabitants, with neither minister nor lawyer, and so dependent on the river fisheries that the eels were known as the "Derryfield beef." The name Manchester was legally recognized in 1810, and a city charter was granted in 1846. The city has recently been described as paying nearly one-ninth of the State tax and producing one-eighth of the manufactured goods made in the State, as embracing one-tenth of the population of the State, as the fourth city of the Union in the value of its cotton and woollen manufactures, and the third city in New England in increase during the last decade.

MANCHURIA is the name by which the territory in the east of Asia occupied by the Manchus is known in Europe. By the Chinese it is called the country of the Manchows, or, as it is pronounced by the natives, of the Manchus, an epithet meaning "Pure," chosen by the founder of the dynasty which now rules over Manchuria and China as an appropriate designation for his family. Manchuria as it has existed for upwards of two centuries, that is to say since it has had an historical existence, is a tract of country lying in a north-easterly and south-westerly direction between 38° 40′ and 49° N. lat. and 120° and 133° E. long., and is wedged in between China and Mongolia on the west and north-west, and Corea and the Russian territory on the Amur on the east and north. Speaking more definitely, it is bounded on the N. by the Amur, on the E. by the Usuri, on the S. by the Gulf of Leaou-tung, the Yellow Sea, and Corea, and on the W. by the river Nonni and a line of palisades which stretch from Kwan-chung-tsze to the Great Wall of China. The territory thus defined is about 800 miles in length and 500 miles in width, and contains about 390,000 square miles. It is divided into three provinces, viz., Tsitsihar or Northern Manchuria, Kirin or Central Manchuria, and Leaou-tung or Southern Manchuria. Physically the country is divided into two regions, the one a series of mountain ranges occupying the northern and eastern portions of the kingdom, and the other a plain which stretches southwards from Moukden, the capital, to the Gulf of Leaou-tung. Speaking generally, the mountains run in a direction parallel with the lie of the country, and are interspersed with numerous and fertile valleys, more especially on the southern and eastern slopes, where the summer sun brings to rich perfection the fruits of the soil fertilized by the showers of the south monsoon.

The principal range of mountains is the Shan-a lin, the Chinese *Chang pih Shan*, "the long white mountains," which runs in a north-easterly direction from the shores of the Gulf of Leaou-tung to the mouth of the Amur river. In its course through Northern Manchuria it forms the watershed of the Sungari, Hurka, and Usuri rivers, and in the south that of the Ya-lu, Ta-yang, and many smaller streams. It also forms the eastern boundary of the great plain of Leaou-tung. The mountains of this range reach their greatest height on the south-east of Kirin, where their snow-capped peaks rise to the elevation of from 10,000 to 12,000 feet. The scenery among them is justly celebrated for the grandeur of its beauty, more especially in the neighbourhood of Haiching, Siu-yen, and the Corean Gate. Another range forms a parallel line to the Shan-a-lin mountains on their west, and runs from the neighbourhood of the junction of the Hurka and Sungari rivers, passing Kirin, to the plain on the north side of Moukden.

The three principal rivers of Manchuria are the Sungari, Hurka, and Usuri already mentioned. Of these the Sungari, which is the largest, rises on the northern slopes of the Shan-a-lin range, and runs in a north-westerly direction to its junction with the Nonni, from which point it turns north-east until it empties itself into the Amur. It is navigable by native junks above Kirin, to which city also the Russians have succeeded in travelling on it by steamer. In its long course it varies greatly both in depth and width, in some parts being only a few feet deep and spreading out to a width of more than a mile, while in other and mountainous portions of its course its channel is narrowed to 300 or 400 feet, and its depth is increased in inverse ratio. The Usuri rises in about 44° N. lat. and 131° E. long., and, after running a north-easterly course for nearly 500 miles, it also loses itself in the Amur. The Hurka takes its rise, like the Sungari, on the northern slopes of the Shan-a-lin range, and not far form the sources of that river. It takes a north-easterly course as far as the city of Ninguta, at which point it turns northward, and so continues until it joins the Sungari at San-sing. It is navigable by junks between that city and Ninguta, though the torrents in its course make the voyage backwards and forwards one of considerable difficulty. Next in importance to these rivers are the Leaou and Ta-yang, the former of which rises in Mongolia, and after running in an easterly direction for about 400 miles enters Manchuria in about 43° N. lat., and turning southward empties itself into the Gulf of Leaou-tung. In bygone days large junks were able to sail up it as far as New-chwang, but owing to the silting up of the bed it is not now navigable for any but small boats beyond Ying-tsze, where the foreign settlement is situated. The Ta-yang rises on the southern slopes of the Shan-a-lin mountains, and flows southward into the Yellow Sea.

Moukden, or as it is called by the Chinese Shing-yang, the capital city of Manchuria, is situated in the province of Leaou-tung, in 41° 40′ N. lat. and 130° 30′ E. long. It occupies a fine position on the river Shin, an affluent of the Leaou, and is a city with considerable pretensions to grandeur. The city wall presents a handsome appearance, and is pierced by eight gates. Like Peking, the town possesses a drum tower and a huge bell. The streets are broad and well laid out, and the shops are well supplied with both native and foreign goods. The population is estimated at about 200,000, including that of the suburbs, the richest and most extensive of which are on the western and southern faces of the city. Leaou-yang, which was once the capital of the country, also stands in the province of Leaou-tung, but it is not now a place of much importance. Such trade as there is is carried on in the centre of the city, the remaining portions being open, having been turned into vegetable gardens. The other cities in the province are King-chow-foo on the west of the Gulf of Leaou-tung; Kin-chow, on the western extremity of the Leaou-tung peninsula; Kai-chow, on the north-western shore of the same peninsula; Hai-ching, on the road from Ying-tsze to Moukden; Ki-yuen, a populous and prosperous city in the north of the province; and Hing-king, on the northern slope of the Shan-a-lin mountains, which is famous rather from the fact that it was the original seat of the founders of the present dynasty than for any pretensions to present importance. The most important commercial place, however, is the treaty port of Ying-tsze, which is situated at the head of the Gulf of Leaou-tung. The main street, which is lined with shops and warehouses, is 2 miles in length, and the trade there carried on is very considerable. According to the custom-house returns the value of the foreign imports and exports in the year 1880 was £691,954 and £1,117,790 respectively, besides a large native trade carried on in junks. The population of the whole province of Leaou-tung is estimated to be about 12,000,000.

The province of Kirin, or Central Manchuria, is bounded on the N. and N.W. by the Sungari, on the S. by Leaou-tung and Corea, on the W. by the line of palisades already spoken of, and on the E. by the Usuri and the maritime Russian provinces. It contains an area of about 135,000 square miles, and is entirely mountainous with the exception of a stretch of plain country in its north-western corner. This plain produces large quantities of indigo and opium, and is physically remarkable for the number of isolated conical hills which dot its surface. These sometimes occur in a direct line at intervals of 15 or 20 miles, and elsewhere are scattered about "like dish-covers on a table." Kirin, the capital of the province, is situated in about 43° 40′ N. lat. and 126° 50′ E. long., and occupies a magnificent position, being surrounded on the north, west, and south by a semicircular range of mountains with the broad stream of the Sungari flowing across the front. The local trade is considerable, and is benefited by the presence of large junk-building yards, which, owing to the abundance and cheapness of wood, have been established there, and from which the place has derived its Chinese name of Chuen-chang or "shipyard." The town has a well-to-do appearance, and in summer time the houses and shops are gaily decorated with flowers brought from the sunny south. Ashehoh, on the Ashe, with its population of 40,000; Petuna, *Sinice* Sing-chung, on the Sungari, population 30,000; San-sing, near the junction of the Sungari and Hurka; La-lin, 120 miles to the north of Kirin, population 20,000; and Ninguta, are the other principal cities in the province.

Tsi-tsi-har, or Northern Manchuria, which contains about 195,000 square miles, is bounded on the N. and N.E. by the Amur, on the S. by the Sungari, and on the W. by the Nonni and Mongolia. This province is thinly populated, and is cultivated only along the lines of its rivers. The only towns of any importance are Tsitsihar and Mergen, both situated on the Nonni.

Four principal highways traverse Manchuria. The first runs from Peking to Kirin *via* Moukden, where it sends off a branch to Corea. At Kirin it bifurcates, one branch going to San-sing, the extreme north-eastern town of the province of Kirin, and the other to Poissiet on the coast *via* Ninguta. The second road runs from the treaty port of Ying-tsze through Moukden to Petuna in the north-western corner of the Kirin province and thence to Tsitsihar, Mergen, and the Amur. The third also starts from Ying-tsze, and strikes southward to Kin-chow at the extremity of the Leaou-tung peninsula. And the fourth connects Ying-tsze with the Gate of Corea.

The great plain in Leaou-tung is in many parts swampy, and in the neighbourhood of the sea, where the soil emits a saline exudation such as is also common in the north of China, it is perfectly sterile. In other parts fine crops of millet and various kinds of grain are grown, and on it trees flourish abundantly.

The climate over the greater part of the country varies between the two extremes of heat and cold, the thermometer ranging between 90° in the summer and 10° below zero in the winter. As in the north of China, the rivers are frozen up during the four winter months. After a short spring the heat of summer succeeds, which in its turn is separated by an autumn of six weeks' duration from snow and ice. The trees and plants are much the same as those common in England, and severe as the weather is in winter the less elevated mountains are covered to their summits with trees. The wild animals also are those known in Europe, with the addition of tigers and panthers. Bears, wild boars, hares, wolves, foxes, and wild cats are very common, and, in the north, sables are found in great numbers. One of the most noticeable of the birds is the Mongolian lark (*Melanocoryphya mongolica*), which is found in a wild state both in Manchuria and in the desert of Mongolia. This bird is exported in large numbers to northern China, where it is much prized on account of the extraordinary power it possesses of imitating the songs of other birds, the different tones of the barks of dogs, and the mews and hisses of cats, as well as all the noises peculiar to the neighbourhood in which it lives. The Manchurian crane is common, as also are eagles, cuckoos, laughing doves, &c. Insects, of which there are, according to the Russians, one thousand different species, abound, owing to the swampy nature of much of the country. The rivers are well stocked with fish, especially with salmon, which forms a common article of food among the people. In such immense shoals do these fish appear in some of the smaller streams that numbers are squeezed out on to the banks and there perish. This fact possibly gave rise to the legend of a certain Prince whose royal mother became pregnant by the influence of the rays of the sun, and who brought forth an egg from which the prince was sprung. His supernatural origin excited the alarm of the king's ministers, who advised that he should be put to death, but his mother, having warning of their intention, sent him away privately. This Manchurian Phaeton thereupon wandered forth, and in his travels came to a river having neither bridge nor ferry. In his difficulty he cried for help to his father the Sun, and instantly fishes rose to the surface of the water and formed themselves into such close array that the prince was able to walk to the opposite bank on their backs.

In minerals Manchuria is very rich: coal, gold, iron (as well as magnetic iron ore), and precious stones are found in quantities which suggest that if better appliances were employed than are now in use the returns might be very large.

Of the crops grown by the people indigo and opium are the most lucrative. The indigo plant is grown in large quantities in the plain country to the north of Moukden, and is transported thence to the coast in carts, each of which carries rather more than a ton weight of the dye. The poppy is cultivated wherever it will grow, the crop being far more profitable than that of any other product. Cotton, tobacco, pulse, millet, wheat, and barley are other crops grown by the Manchurian farmers.

History.—Manchow, or more correctly Manchu, is, as has been said, not the name of the country but of the people who inhabit it. The name is a modern one, having been adopted by a ruler who rose to power in the beginning of the 13th century. Before that time the Manchus were more or less a shifting population, with no fixed location, and, being broken up into a number of tribes, they went mainly under the distinctive name of those clans which at different periods exercised lordship over them. Thus under the Chow dynasty (1122–225 B.C.) we find them spoken of as Sewshin, and at subsequent periods they were known as Yih-low, Wuhkeih, Moh-hoh, Pohai, Nüchin, and according to the Chinese historians also as K'etan. Throughout their history they appear as a rude people, the tribute they brought to the Chinese court consisting of stone arrow-heads, hawks, gold, and latterly ginseng. Assuming that, as the Chinese say, the K'etans were Manchus, the first appearance of the Manchus, as a people, in China dates from the beginning of the 10th century, when K'etans having first conquered the kingdom of Pohai crossed the frontier into China and established the Leaou or Iron dynasty in the northern portion of the empire. These invaders were in their turn overthrown two centuries later by another invasion from Manchuria. These new conquerors were Nüchins, and, therefore, direct ancestors of the Manchus. On assuming the imperial yellow in China, their chief adopted the title of Kin or "Golden" for his dynasty. "Iron" (Leaou), he said, "rusts, but gold always keeps its purity and colour, therefore my dynasty shall be called Kin." In a little more than a century, however, the Kins were driven out of China by the Mongols under Jenghiz Khan. But before the close of their rule a miraculous event occurred on the Shan-a-lin mountains which is popularly believed to have laid the seeds of the greatness of the present rulers of the empire. Three heaven-born maidens, so runs the legend, were bathing one day in a lake under the Shan-a-lin mountains when a passing magpie dropped a ripe red fruit into the lap of one of them. The maiden ate the fruit, and in due course a child was born to her, whom she named Aisin Gioro, or the Golden. When quite a lad Aisin Gioro was elected chief over three contending clans, and established his capital at Otole near the Shan-a-lin mountains. His reign, however, was not of long duration, for his subjects rose against him and murdered him, together with all his sons except the youngest, Fancha, who, like the infant Haitu in Mongolian history, was miraculously saved from his pursuers. Nothing is recorded of the facts of Aisin Gioro's reign except that he named the people over whom he reigned Manchu, or "Pure." His descendants, through the rescued Fancha, fell into complete obscurity until about the middle of the 16th century, when one of them, Norhachi by name, a chieftain of a small tribe, rose to power. Taking advantage of the shifting scenes of Manchurian politics, Norhachi played with skill and daring the rôle which had been played by Jenghiz Khan more than three centuries before in Mongolia. With even greater success than his Mongolian counterpart, Norhachi drew tribe after tribe under his sway, and after numerous wars with Corea and Mongolia, he established his rule over the whole of Manchuria. Being thus the sovereign of an empire, he, again like Jenghiz Khan, adopted for himself the title of Ying-ming, "Brave and Illustrious," and took for his reign the title of T'een-ming. Thirteen years later, in 1617, after numerous border fights with the Chinese, Norhachi drew up a list of "seven hates," or indictments, against his southern neighbours, and, not getting the satisfaction he demanded, declared war against them. The progress of this war, the hastily patched up peace, the equally hasty alliance and its consequences, being matters of Chinese history, have been treated of under the article CHINA.

At the present day the Manchus are rapidly dying out before the quietly advancing Chinese settlers. By far the greater number of the present inhabitants of Manchuria are Chinamen. The Chinese system of education is adopted everywhere throughout the country; the Chinese language is taught in all the schools; and Manchuria promises to become before long as much a Chinese province as Chih-le or Shantung.

See *Journeys in North China, Manchuria, and Eastern Mongolia*, by the Rev. Alexander Williamson; *The Manchus*, by Rev. John Ross; *Man-chow yuen lew kaou.* (R. K. D.)

MANDÆANS, also known as Sabians, Nasoræans, or St John's Christians,[1] an Oriental sect of great antiquity, interesting to the theologian as almost the only surviving example of a religion compounded of Christian, heathen, and Jewish elements on a type which is essentially that of ancient Gnosticism.

The Mandæans, who can never have been numerous, and are now much decayed, are found in the marshy lands of South Babylonia (al-baṭáiḥ), the ancient refuge of so many strange sects, particularly in the neighbourhood of Basrah (or Bussorah), and in Khúzistán (Disful, Shuster).[2] They speak the languages of the localities in which they are settled (Arabic or Persian), but the language of their sacred books is an Aramaic dialect, which has its closest affinities with that of the Babylonian Talmud, written in a peculiar character suggestive of the old Palmyrene.[3] The existence of the Mandæans has been known since the middle of the 17th century, when the first Christian missionaries, Ignatius a Jesu[4]

[1] The first of these names (not Mendæans or Mandaites) is that given by themselves, and means γνωστικοί, followers of Gnosis (מאנדאייא, from מאנדא, Hebr. מַדָּע). The Gnosis of which they profess themselves adherents is a *personification*, the æon and mediator "knowledge of life" (see below). The title Nasoræans (Náṣóráyé), according to Petermann, they give only to those among themselves who are most distinguished for knowledge and character. Like the Arabic Naṣára, it is originally identical with the name of the half heathen half Jewish-Christian Ναζωραῖοι, and indicates an early connexion with that sect. The inappropriate designation of St John's Christians arises from the early and imperfect acquaintance of Christian missionaries, who had regard merely to the reverence in which the name of the Baptist is held among them, and their frequent baptisms. In their dealings with members of other communions the designation they take is Sabians, in Arabic Ṣubbá' (sing. Ṣábi'), from צבע=צְבָא, to baptize, thus claiming the toleration extended by the Koran (Sur. 5, 73; 22, 17; 2, 59) to those of that name.

[2] Recent accounts (1882) represent them as shrunk to 200 families, and seeking a new settlement on the Tigris, to escape the persecutions to which they are exposed.

[3] See Nöldeke's admirable *Mandäische Grammatik*, Halle, 1875.

[4] *Narratio originis, rituum, et errorum Christianorum S. Joannis*, Rome, 1652.

and Angelus a Sancto, began to labour among them at Basrah; further information was gathered at a somewhat later date by Pietro della Valle[1] and Thevenot,[2] and in the following century by Kaempfer, Chardin, and Niebuhr. In recent times they have been visited by Petermann[3] and Albert Socin, and last of all Liouffi[4] published in 1880 a full and accurate account of the manners and customs of the sect, taken from the lips of a converted Mandæan himself. For our knowledge of their doctrinal system, however, we must of course still depend chiefly upon the sacred books already mentioned, consisting of fragments of very various antiquity derived from an older literature.[5] Of these the largest and most important is the *Sidrá rabbá* or "Great Book," known also as *Ginzá* (treasure), consisting of two unequal parts, of which the larger is called "yaminá" (to the right hand) and the smaller "s'málá" (to the left hand), because of the manner in which they are bound together. In Petermann's edition the former occupies three hundred and ninety-five large quarto pages and the other only one hundred and thirty-eight. The former is intended for the living; the latter consists chiefly of prayers to be read at the burial of priests. As regards doctrine, the work is exhaustive; but it is characterized throughout by diffuseness, and often by extreme obscurity, besides being occasionally self-contradictory, as might be expected in a work which consists of a number of unconnected paragraphs of various authorship and date. The last section of the "right-hand" part (the "Book of Kings") is one of the older portions, and from its allusion to "the Persian and Arabian kings" may be concluded to date from somewhere between 700 and 900 A.D. Many of the doctrinal portions may in substance well be still older, and date from the time of the Sassanids. None of the MSS., however, are older than the 16th century.[6]

The following sketch represents, as far as can be gathered from these heterogeneous sources, the principal features of the Mandæan system. The ground and origin of all things is Pírá, or more correctly Pérá rabbá, "the great abyss" (either Persian Pír, "old," or from פער, "to split," comp. the Gnostic βυθός), associated with whom, and forming a triad with him, are the primal æons Ayar zívá rabbá, "the great shining æther," and Máná rabbá d'ĕkárá, "the great spirit of glory," usually called simply Máná rabbá. The last-named, the most prominent of the three, is the king of light properly so called, from whom the development of all things begins. From him emanates Yardĕná rabbá, "the great Jordan," which, as the higher world soul, permeates the whole æther, the domain of Ayar. Alongside of Máná rabbá frequent mention is made of D'múthá, his "image," as a female power; the name "image of the father" arises out of the same conception as that which gives rise to the names of σιγή and ἔννοια among the Greek Gnostics. Máná rabbá called into being the highest of the æons properly so-called, Hayyé Ḳadmáyé, "Primal Life," and then withdrew into deepest secrecy, visible indeed to the highest but not to the lowest æons (comp. Σοφία and Προπάτωρ), yet manifesting himself also to the souls of the more pious of the Mandæans after their separation from the body. Primal Life, who is properly speaking the Mandæan god, has the same predicates as the primal spirit, and every prayer, as well as every section of the sacred books, begins by invoking him.[7] The extremely fantastic delineation of the world of light by which Hayyé Ḳadmáyé is surrounded (see for example the beginning of *Sidrá rabbá*) corresponds very closely with the Manichæan description of the abode of the "king of the paradise of light." The king of light "sits in the far north in might and glory." The Primal Light unfolds himself by five great branches, viz., "the highest purest light, the gentle wind, the harmony of sounds, the voice of all the æons, and the beauty of their forms," all these being treated as abstractions and personified. Out of the further development and combination of these primary manifestations arise numerous æons ('Uthré, "splendours," from עתר, "is rich"), of which the number is often stated to be three hundred and sixty. They are divided into a number of classes (kings, hypostases, forms, &c.); the proper names by which they are invoked are many, and for the most part obscure, borrowed doubtless, to some extent, from the Parsee angelology. From the First Life proceeds as a principal emanation the "Second Life," Hayyé Tinyáné, generally called Yúshamín. This last name is evidently meant to be Hebrew, "Jehovah of the heavens," the God of the Jews being of a secondary rank in the usual Gnostic style. The next emanation after Yúshamín is "the messenger of life" (Mandá d'hayyé, literally γνῶσις τῆς ζωῆς), the most important figure in the entire system, the mediator and redeemer, the λόγος and the Christ of the Mandæans, from whom, as already stated, they take their name. He is occasionally also called the primal man, Gabrá Ḳadmáyá, as in the Kabbala and by Mani. Yúshamín desired to raise himself above the Primal Light, but failed in the attempt, and was punished by removal out of the pure ætherial world into that of inferior light. The one world is separated from the other by water channels (H'fíké Mayyé). Mandá on the other hand continues with the First Life and Máná rabbá, and is called his "beloved son," the "first born, "high priest," and "word of life." Mandá makes his appearance in the visible world in a series of incarnations beginning with the three brothers Hibil, Shithil, and Anúsh (late Judæo-Babylonian transformations of the well-known names of the book of Genesis), and ending with John the Baptist. Of the first three the most highly honoured is Hibil, almost invariably referred to as "the brilliant Hibil"; he is the alter ego of Mandá, his image in this present world, having the same predicates and the same activities, and is the Jesus Christ of the Mandæans. The Second Life, Yúshamín, has as the last of three sons Hayyé t'lítáyé, the "Third Life," the most distinguished of

[1] *Reisebeschreibung*, part iv., Geneva, 1674.
[2] *Voyage au Levant*, Paris, 1689.
[3] *Reisen im Orient*, ii. 447 *sq.*
[4] Liouffi, *Études sur la Religion . . . des Soubbas*, Paris, 1880.
[5] Mandæan MSS. occur in the British Museum, the Bodleian Library, the Bibliothèque Nationale of France, and also in Rome, Weimar, and Berlin.
[6] The first printed edition and translation of the *Sidrá rabbá*, by Matth. Norberg (*Codex Nazaræus, liber Adami appellatus*, 3 vols., Copenhagen, 1815–16, followed by a lexicon in 1816, and an onomasticon in 1817), is so defective as to be quite useless; even the name Book of Adam is unknown to the Mandæans. Petermann's *Thesaurus s. Liber magnus, vulgo "Liber Adami" appellatus, opus Mandæorum summi ponderis* (2 vols., Leipsic, 1867), is an excellent metallographic reproduction of the Paris MS. A critical edition still remains a desideratum. Next in importance to the *Sidrá rabbá* is the *Sidrá d'Yahyá*, or "Book of John," otherwise known as the *D'ráshé d'Malké*, or "Discourses of the Kings," which has not as yet been printed as a whole, although portions have been published by Lorsbach and Tychsen (see *Museum f. bibl. u. orient. Lit.*, 1807, and Stäudlin's *Beitr. z. Phil. u. Gesch. d. Relig u. Sittenlehre*, 1796 *sq.*). The *Kolástá* (Ar., *Kholáṣa*, "Quintessence"), or, according to its fuller title *'Enyáné uleráshé d'maṣbáthá umassekthá* ("Songs and Discourses of Baptism and the Ascent," viz., of the soul after death) has been admirably lithographed by Euting (Stuttgart, 1867). It is also known as *Sidrá d'neshmátha*, "Book of Souls," and besides hymns and doctrinal discourses contains prayers to be offered by the priests at sacrifice and at meals, as well as other liturgical matter. The Mandæan marriage service occurs both in Paris and in Oxford as an independent MS. The *Díwán*, hitherto unpublished, contains the ritual for atonement. The *Asfar malwáshé*, or "Book of the Zodiac," is astrological. Of smaller pieces many are magical and used as amulets.
[7] The use of the word "life" in a personal sense is usual in Gnosticism; compare the Ζωή of Valentin, and el-ḥayát el-muallama, "the dark life," of Mani in the *Fihrist*.

the ʿUthré, hence usually called their father (Abá d' ʿUthré, Abáthúr). His usual epithet is "the Ancient" (ʿAṭíḳá); and he is also called "the deeply hidden and guarded." He stands on the borderland between the here and the hereafter, like the mysterious πρεσβύτης τρίτος or *senex tertius* of Mani, whose becoming visible will betoken the end of the world. Abáthúr sits on the furthest verge of the world of light that lies towards the lower regions, and weighs in his balance the deeds of the departed spirits who ascend to him. Beneath him was originally nothing but a huge void with muddy black water at the bottom, in which his image was reflected, becoming ultimately solidified into P'táhíl, his son, who now partakes of the nature of matter. The demiurge of the Mandæans, and corresponding to the Ialdabaoth of the Ophites, he at the instance of his father frames the earth and men,—according to some passages in conjunction with the seven bad planetary spirits. He created Adam and Eve, but was unable to make them stand upright, whereupon Hibil, Shithil, and Anúsh were sent by the First Life to infuse into their forms spirit from Máná rabbá himself. Hibil, at the instance of the supreme God, also taught men about the world of light and the æons, and especially gave them to know that not P'tahíl but another was their creator and supreme God, who as "the great king of light, without number, without limit," stands far above him. At the same time he enjoined the protoplasts to marry and people the world. P'tahíl had now lost his power over men, and was driven by his father out of the world of light into a place beneath it, whence he shall at the day of judgment be raised, and after receiving baptism be made king of the ʿUthré with divine honours.

The underworld is made up of four vestibules and three hells properly so-called. The vestibules have each two rulers, Zartay and Zartanay, Hag and Mag, Gaf and Gafan, Anatan and Kin. In the highest hell rules alone the grisly king Sh'dúm, "the warrior"; in the story immediately beneath is Giv, "the great"; and in the lowest is Krún or Karkúm, the oldest and most powerful of all, commonly called "the great mountain of flesh" (Túrá rabbá d'besrá), but also "the first-born of darkness." In the vestibules dirty water is still to be met with, but the hells are full of scorching consuming fire, except Krún's domain, where is nought but dust, ashes, and vacancy. Into these regions descended Hibil the brilliant, in the power of Máná rabbá, just as in the Manichæan mythology the "primal man," armed with the elements of the king of light, descends to a contest with the primal devil. Hibil lingers, gradually unfolding his power, in each of the vestibules, and finally passing from hell to hell reaches Karkúm. Hibil allows himself to be half swallowed by the monster, but is unhurt, and compels his antagonist to recognize the superiority of Máná rabbá, the God of light, and to divulge his profoundest secret, the hidden name of darkness. Armed with this he returns through the successive hells, compelling the disclosure of every secret, depriving the rulers of their power, and barring the doors of the several regions. From the fourth vestibule he brought the female devil Rúhá, daughter of Kin, and set her over the whole four. This Rúhá, the mother of falsehood and lies, of poisoning and fornication, is an anti-Christian parody of the Rúhá d'Ḳudshá (Holy Spirit) of the Syriac Church. She is the mother of Ur, the personified fire of hell, who in anger and pride made a violent onset on the world of light (compare the similar occurrence in the Manichæan mythology), but was mastered by Hibil and thrown in chains down to the "black water," and imprisoned within seven iron and seven golden walls. By Ur, Rúhá, while P'táhíl was engaged in his work of creation, became mother of three sets of seven, twelve, and five sons respectively; all were translated by P'táhíl to the heavenly firmament (like the Archons of Mani), the first group forming the planets and the next the signs of the zodiac, while the third is as yet undetermined. Of the names of the planets Estera (Istar, Venus, also called Rúhá d'Ḳudshá, "holy spirit"), Enba (Nebo, Mercury), Sín (moon), Kéwán (Saturn), Bíl (Jupiter), and Niríg (Nirgal, Mars) reveal their Babylonian origin; Il or Il Il, the sun, is also known as Ḳádúsh and Adúnay (the Adonai of the Old Testament); as lord of the planetary spirits his place is in the midst of them; they are the source of all temptation and evil amongst men. The houses of the planets, as well as the earth and a second world immediately to the north of it, rest upon anvils laid by Hibil on the belly of Ur.

In the Mandæan representation the sky is an ocean of water, pure and clear, but of more than adamantine solidity, upon which the stars and planets sail. Its transparency allows us to see even to the pole star, who is the central sun around whom all the heavenly bodies move. Wearing a jewelled crown, he stands before Abáthúr's door at the gate of the world of light; the Mandæans accordingly invariably pray with their faces turned northward. The earth is conceived of as a round disk, slightly sloping towards the south, surrounded on three sides by the sea but on the north by a high mountain of turquoises; behind this is the abode of the blest, a sort of inferior paradise, inhabited by the Egyptians drowned along with Pharaoh in the Red Sea, whom the Mandæans look upon as their ancestors, Pharaoh himself having been their first high priest and king. The total duration of the earth they fix at four hundred and eighty thousand years, divided into seven epochs, in each of which one of the planets rules. The *Sidrá Rabbá* knows of three total destructions of the human race by fire and water, pestilence and sword, a single pair alone surviving in each case. In the Mandæan view the Old Testament saints are false prophets; such are Abraham, who arose six thousand years after Nú (Noah) during the reign of the Sun, Míshá (Moses), in whose time the true religion was professed by the Egyptians, and Shlímún (Solomon) bar Davith, the lord of the demons. Another false prophet and magician was Yishu M'shíhá, who was in fact a manifestation of the planet Mercury. Forty-two years before his day, under King Pontius Pilate, there had appeared the true prophet Yahyá or John son of Zechariah, an incarnation of Hibil, of whose birth and childhood fantastic stories are told. Yahyá by a mistake gave baptism to the false Messiah, who had feigned humility; on the completion of his mission, after undergoing a seeming execution, he returned clothed with light into the kingdom of light. As a contemporary of Yahyá and the false Messiah Hibil's younger brother Anúsh ʿUthrá came down from heaven, caused himself to be baptized by Yahyá, wrought miracles of healing and of raising the dead, and brought about the crucifixion of the false Messiah. He preached the true religion, destroyed Jerusalem ("Urashlam," *i.e.*, "the devil finished it"), which had been built by Adúnay, dispersed over the world the Jews who had put Yahyá to death, and previous to his return into the worlds of light sent forth three hundred and sixty prophets for the diffusion of the true religion. All this speaks of intense hatred alike of Jews and Christians; the fasts, celibacy, and monastic and anchoret life of the latter are peculiarly objectionable to the Mandæans. Two hundred and forty years after the appearing of the false Messiah there came to the world sixty thousand saints out of Pharaoh's world to take the place of the Mandæans, who had been completely extirpated; their high priest had his residence in Damascus. The last false prophet was M'hammad or Ahmat bar Bisbat (Mohammed), but Anúsh, who remained close beside him and his immediate successors, prevented hostilities against the true believers, who claim to have had in Babylonia, under the Abbasides, four hundred places of worship. Subsequent persecutions compelled their withdrawal to 'Ammárah in the neighbourhood of Wásit, and ultimately to Khúzistán. At the end of the world the devil Ur will swallow up the earth and the other intermediate higher worlds, and thereupon will burst and fall into the abyss of darkness, where, along with all the worlds and powers of darkness, he will ultimately cease to be, so that thenceforward the universe will consist of but one everlasting world of light.

The chief depositaries of these Mandæan mysteries are the priests, who enjoy a high degree of power and social regard. The priesthood has three grades. (1) the Sh'kandá or deacon is generally chosen from episcopal or priestly families, and must be without bodily blemish. The candidate for orders must be at least nineteen years old and have undergone twelve years' preparation; he is then qualified to assist the priesthood in the ceremonies of religion. (2) The Tarmídá (*i.e.*, "Talmídá," initiated") or priest is ordained by a bishop and two priests or by four priests after a long and extremely painful period of preparation. (3) The Ganzivrá ("treasurer") or bishop, the highest dignitary, is chosen from the whole body of the Tarmídás after a variety of tests, and possesses unlimited authority over the clergy. A supreme priestly rank, that of Rísh 'ammá, or "head of the people," is recognized, but only in theory; since the time of Pharaoh this sovereign pontificate has only once been filled. The priestly dress, which is all white, consists of drawers, an upper garment, and a girdle with the so-called tágá or "crown"; in all ceremonies the celebrants must be barefoot. By far the most frequent and important of the religious ceremonies is that of baptism (maṣbúthá), which is called for in a great variety of cases, not only for children but for adults, where consecration or purification is required, as for example on all Sundays and feast days, after contact with a dead body, after return from abroad, after neglect of any formality on the part of a priest in the discharge of his functions. In all these cases baptism is performed by total immersion in running water, but during the five days' baptismal festival the rite is observed wholesale by mere sprinkling of large masses of the faithful at once. The Mandæans observe also with the elements of bread (pehtá) and wine (mambúgá, lit. "fountain") a sort of eucharist, which has a special sanctifying efficacy, and is usually dispensed at festivals, but only to baptized persons of good repute who have never willingly denied the Mandæan faith. In receiving it the communicant must not touch the host with his finger; otherwise it loses its virtue. The hosts are made by the priests from unleavened fine flour. A peculiar act of piety is for a layman under the guidance of the bishop to receive the masseḳtha ("elevation"), and thereby become a sort of ascetic, a shalmáná tábá ("really perfect"). The Mandæan places of worship, being designed only for the priests and their assistants, are excessively small, and very simply furnished; two windows, a door that opens towards the south so that those who enter have their faces turned towards the pole star, a few boards in the corner, and a gabled roof complete the whole structure; there is neither altar nor decoration of any kind. The neighbourhood of running water (for baptisms) is essential. At the consecration of a church the sacrifice of a dove (the bird of Venus) has place among the ceremonies. Besides Sundays there are six great feasts: (1) that of the New Year (Naurúz rabbá), on the first day of the first month of winter; (2) Dehwá h'níná, the anniversary of the happy return of Hibil Zívá from the kingdom of darkness into that of light, lasting five days, beginning with the 18th of the first month of spring; (3) the Marwáná, in commemoration of the drowned Egyptians, on the first day of the second month of spring; (4) the great five days' baptismal festival (pantshá), the chief feast, kept on the five intercalary days at the end of the second month of summer,—during its continuance every Mandæan, male and female, must dress in white and bathe thrice daily; (5) Dehwá d'daimáná, in honour of one of the three hundred and sixty 'Uthras, on the first day of the second month of autumn; (6) Kanshe Zahlá, the preparation feast, held on the last day of the year. There are also fast days called m'battal (Arab.), on which it is forbidden to kill any living thing or eat flesh. The year is solar, and has twelve months of thirty days each, with five intercalary days between the eighth and the ninth month. Of the seven days of the week, next to Sunday (habshabá) Thursday has a special sacredness as the day of Hibil Zívá. As regards secular occupation, the present Mandæans are goldsmiths, ironworkers, and house and ship carpenters. They practise polygamy, the *Sidrá Rabbá* laying great stress upon the duty of procreation, but few of them are rich enough to maintain more than two wives. In the 17th century, according to the old travellers, they numbered about 20,000 families, but at the present day they hardly number more than 1200 souls. In external appearance the Mandæan is distinguished from the Moslem only by a brown coat and a parti-coloured headcloth with a cord twisted round it. They have some peculiar death-bed rites: a deacon with some attendants waits upon the dying, and as death approaches administers a bath first of warm and afterwards of cold water; a holy dress, consisting of seven pieces (rastá), is then put on; the feet are directed towards the north and the head turned to the south, so that the body faces the pole star. After the burial a funeral feast is held in the house of mourning.

The Mandæans are strictly reticent about their theological dogmas in the presence of strangers; and the knowledge they actually possess of these is extremely small. The foundation of the system is obviously to be sought in Gnosticism, and more particularly in the older type of that doctrine (known from the serpent symbol as Ophite or Naassene) which obtained in Mesopotamia and Further Asia generally. But it is equally plain that the Ophite nucleus has from time to time received very numerous and often curiously perverted accretions from Babylonian Judaism, Oriental Christianity, and Parsism, exhibiting a striking example of religious syncretism. In the Gnostic basis itself it is not difficult to recognize the general features of the religion of ancient Babylonia, and thus we are brought nearer a solution of the problem as to the origin of Gnosticism in general. It is certain that Babylonia, the seat of the present Mandæans, must be regarded also as the cradle in which their system was reared; it is impossible to think of them as coming from Palestine, or to attribute to their doctrines a Jewish or Christian origin. They do not spring historically from the disciples of John the Baptist (Acts xviii. 25; xix. 3 *sq.*; *Recog. Clem.*, i. 54); the tradition in which he and the Jordan figure so largely is not original, and is therefore worthless; at the same time it is true that their baptismal praxis and its interpretation place them in the same religious group with the Hemerobaptists of Eusebius (*H. E.*, iv. 22) and Epiphanius (*Hær.*, xvii.), or with the sect of disciples of John who remained apart from Christianity. Their reverence for John is of a piece with their whole syncretizing attitude towards the New Testament. Indeed, as has been seen, they appropriate the entire personale of the Bible from Adam, Seth, Abel, Enos, and Pharaoh to Jesus and John, a phenomenon which bears witness to the close relations of the Mandæan doctrine, at the time of its formation, both with Judaism and Christianity,—not the less close because they were relations of hostility. The history of religion presents other examples of the degradation of holy to demonic figures on occasion of religious schism. The use of the word "Jordan," even in the plural, for "sacred water," is precisely similar to that by the Naassenes described in the *Philosophumena* (v. 7); there ὁ μέγας Ἰορδάνης denotes the spiritualizing, sanctifying fluid which pervades the world of light. The notions of the Egyptians and the Red Sea, according to the same work (v. 16), are used by the Peratæ much as by the Mandæans. And the position assigned by the Sethians (Σηθιανοί) to Seth is precisely similar to that given by the Mandæans to Abel. Both alike are merely old Babylonian divinities in a new Biblical garb. The genesis of Mandæism and the older gnosis from the old and elaborate Babylonio-Chaldæan religion is clearly seen also in the fact that the names of the old pantheon (as for example those of the planetary divinities) are retained, but their holders degraded to the position of demons,—a conclusion confirmed by the fact that the Mandæans, like the allied Ophites, Peratæ, and Manichæans, certainly have their original seat in Mesopotamia and Babylonia. Great caution is necessary, in the present state of our knowledge, in the use made of the results of cuneiform decipherment in relation to Babylonian mythology; but so much seems clear, that the trinity of Anu, Bil, and Ea in the old Babylonian religion has its counterpart in the Mandæan Píra, Ayar, and Máná rabbá. The D'múthá of Máná is the Damkina, the wife of Ea, mentioned by Damascius as Δαύκη, wife of Ἀός. Mandá d'hayyé and his image Hibil Zívá with his incarnations clearly correspond with the old Babylonian Marduk, Merodach, the "first-born" son of Ea, with his incarnations, the chief divinity of the city of Babylon, the mediator and redeemer in the old religion. Hibil's contest with darkness has its prototype in Marduk's battle with chaos, the dragon Tiamat, which (another striking parallel) partially swallows Marduk, just as is related of Hibil and the Manichæan primal man. Other features are borrowed by the Mandæan mythology under this head from the well-known epos of Istar's *descensus ad inferos*. The sanctity with which water is invested by the Mandæans is to be explained by this fact that Ea has his seat "in the depths of the world sea."

Compare K. Kessler's article "Mandäer" in Herzog-Plitt's *Real-encyklopädie*, and the same author's paper, "Ueber Gnosis u. altbabylonische Religion," in the *Abhandh. d. fünften internationalen Orientalisten-congresses zu Berlin* (Berlin, 1882). (K. K.)

MANDALAY, the capital of Independent Burmah, is situated about 2 miles from the left bank of the Irawadi river, in 21° 59′ N. lat. and 96° 8′ E. long. It was founded by the king of Burmah, who transferred to it the seat of government from Amarapura in 1860. The city proper is laid out in a square, each side of which is a little over a mile in length. It is enclosed by a crenellated brick wall 26 feet high and 3 feet thick; the twelve gates (three on each side) are surmounted with wooden watch-towers. A deep wet moat, 100 feet broad, with its escarp 60 feet from the walls, extends along all four sides; it is crossed by five bridges. The palace of the king occupies the central space of the city; the walls of its enclosure are laid symmetrically with those of the city, and each face is about 370 yards in length. The outer fence consists of a stockade of teak-wood posts 20 feet high, and within it are three successive enclosures, bounded by brick walls. The palace is built within the inner enclosure; and its front, which faces the east, contains the great hall of audience, 260 feet long, composed of teak timber, elaborately carved and gilded, erected on a terrace of brickwork 10 feet high. It is in the form of a colonnade, the central part running back, forming a nave with two side aisles. At the extremity of this nave is a space like a chancel (said to be the exact centre of the city) where stands the throne, over which rises a graceful gilded spire, visible from all parts of the city and surrounding country. Another feature of the complex palace buildings is the lofty campanile. Around the palace walls a wide space has been laid out as an esplanade, on the further margin of which are situated most of the houses of the princes, ministers of state, and court officials. The city may be said to consist of two parts, intramural and extramural; the streets in the former run parallel with the walls, dividing the building sites into rectangular blocks. The majority of the houses are constructed of bamboos and bamboo matting, slightly raised from the ground on posts, with here and there a few brick and wooden buildings. The streets inside the city are very wide, the principal ones being lined with tamarind trees. In the suburbs the roads are laid out with something of the same regularity as in the city, but are of less width, with the exception of the principal road, the Kuladan or foreign quarter, inhabited chiefly by Armenians, Mughals, and the few European residents. The number of houses in the city and suburbs is said to be, in round numbers, 12,000; and the population is roughly estimated at 65,000. Monasteries and pagodas are dotted about in open spaces, both within and without the walls. Silk-weaving is the principal manufacture.

See Fytche, *Burma Past and Present*, 1878.

MANDAMUS, Writ of, in English law, is usually described as a high prerogative writ, containing a command in the name of the king, and issuing from the King's Bench, directed to persons, corporations, and inferior courts, ordering them to do a specific act within the duty of their office. Direct orders from the sovereign to subjects commanding the performance of particular acts were common in early times, and to this class of orders mandamus originally belonged. It became customary for the Court of King's Bench, in cases where a legal duty was established but no sufficient means existed for enforcing it, to order performance by this writ. At all times, accordingly, mandamus has been regarded as of the nature of an equitable interference supplementing the deficiencies of the common law. When the object sought could be equally well obtained by other means, as by an action, or by any other form of proceedings, then mandamus would not lie. A further condition of mandamus at common law was that it lay only for the performance of acts of a public or official character. The enforcement of merely private obligations, such as those arising from contracts, was not within its scope. Further, the interference of the court could only be obtained when there was no doubt of the existence of the duty, or when performance had been demanded and refused. Nor would the writ be issued when performance had become impossible. By the Common Law Procedure Act, 1854, the plaintiff in any action other than replevin and ejectment was entitled to claim a writ of mandamus to compel the defendant to discharge any duty in which the plaintiff might show that he was personally interested, or from the non-performance of which he might sustain damage. The duties so enforceable must, however, be of a public character. By the Judicature Act, 1873, a mandamus may be granted by an interlocutory order of the court in all cases in which it shall appear to the court to be just and convenient, and subject to such terms and conditions, if any, as the court shall think just. Under this section it has been held that the court (which now includes what was formerly the Court of Chancery) has power to issue a writ of mandamus in any cause or matter pending before it, but when the cause is at an end the power is gone. And it has also been held that, when the circumstances are such as would form ground for an application for the old prerogative writ of mandamus, the application must be made to the Queen's Bench division, which has taken the place of the Court of Queen's Bench on the old system. The jurisdiction of the Court of Chancery to compel specific performance of contracts has some resemblance to mandamus in the domain of semi-public law. For a collection of the cases in which the prerogative writ of mandamus will or will not lie, reference may be made to Tapping *On Mandamus*, and to Selwyn's *Nisi Prius*, art. "Mandamus."

The writ has passed into the law of the United States. "There is in the federal judiciary an employment of the writ substantially as the old prerogative writ in the King's Bench practice, also as a mode of exercising appellate jurisdiction, also as a proceeding ancillary to a judgment previously rendered, in exercise of original jurisdiction, as when a circuit court having rendered a judgment against a county issues a mandamus requiring its officers to levy a tax to provide for the payment of the judgment." And in the various States mandamus is used under varying regulations, mandate being in some cases substituted as the name of the proceeding. See Abbott's *Law Dictionary*.

MANDATE (Mandatum). The contract of *mandatum* in Roman law was constituted by one person (the *mandatarius*) promising to do something gratuitously at the request of another (the *mandator*), who undertakes to indemnify him against loss. The jurist distinguished the different cases of mandatum according as the object of the contract was the benefit of the mandator or a third person singly, or the mandator and a third person, the mandator and the mandatarius, or the mandatarius and a third person together. When the benefit was that of the mandatarius alone, the obligations of the contract were held not to arise, although the form of the contract might exist, the commission being held to be merely advice tendered to the mandatarius, and acted on by him at his own risk. Mandatum was classified as one of the contracts established by consent of the parties alone; but, as there was really no obligation of any kind until the mandatarius had acted on the mandate, it has with more propriety been referred to the contracts created by the supply of some fact (*re*). The obligations of the mandatarius under the contract were, briefly, to do what he had promised according to his instructions, observing ordinary diligence in taking care of any property entrusted to him, and handing over to his principal the results of his action, including the right to sue in his name. On the other hand, the principal was bound to recoup him his expenses and indemnify him against loss through obligations he might have incurred.

The essentials and the terminology of the contract are preserved in most modern systems of law. But in English law mandate, under that name, can hardly be said to exist as a separate form of contract. To some extent the law of mandatum corresponds partly to our law of principal and agent, partly to that of principal and surety. Story, disputing the assertion that "in the laws of England the contract of mandatum is of no use," points out that "the common law does not indeed comprehend under that appellation all the contracts of mandate according to the civil law,—such, for example, as mere naked acts of agency, where there is no bailment of anything to the agent. But for the most part the principles applicable to all the various classes of mandate have a place in our law, although they may be differently named." The difference, however, is more than one of name. English law in this as in other cases reaches its end by a different method through different principles from those of the civil law, though the end may be the same.

Mandate is retained by Story and others to signify the contract more generally known as gratuitous bailment. It is restricted, as he points out, to personal property, and it implies the delivery of something to the bailee, both of which conditions are unknown in the mandatum of the civil law. Mandate in this later sense is further distinguished from deposit in that the custody of the thing is the principal object of the latter contract, while in the former it is something to be done with respect to the thing, though Story holds that custody and performance concur in both contracts,—this by way of correction of Sir W. Jones's distinction that mandate consists in feasance and deposit in custody.

MANDEVILLE, Bernard de (1670–1733), is generally known as an ethical writer of debasing and degrading tendency, but he was at least as much of a humorist as a philosopher, and set up as an analyst of "what is," repeatedly disavowing all pretensions as a lawgiver of "what ought to be." He was a foreigner by birth, a native of Rotterdam, where his father practised as a physician for thirty years. A remarkably eloquent schoolboy exercise, *De Medicina Oratio Scholastica*, was printed for him at Rotterdam in 1685. He studied for six years at Leyden, and took his degree in medicine in 1691, his inaugural thesis being *De Chylosi Vitiata*. Immediately afterwards he came over to England "to learn the language," which he did to some purpose, writing it with such mastery as to throw doubts upon his foreign extraction. He settled in London as a physician. The *Fable of the Bees* is the general title of the miscellaneous work by which he is known to fame. This work includes the fable proper, *The Grumbling Hive, or Knaves Turned Honest* (some two hundred doggerel couplets, published as a sixpenny pamphlet and pirated as a halfpenny sheet in 1705); *Remarks* on the fable and *An Inquiry into the Origin of Moral Virtue*, added to the edition of 1714; *An Essay on Charity Schools*, and *A Search into the Origin of Society*, added to the edition of 1723. Owing to a curious misprint in an edition published after Mandeville's death, a wrong date is commonly assigned to the *Grumbling Hive*, and the contemporary point of it consequently missed. It appeared during the heat of the bitterly contested elections of 1705, when the question before the country was whether Marlborough's war with France should be continued. The cry of the high Tory advocates of peace was that the war was carried on purely in the interests of the general and the men in office; charges of bribery, peculation, hypocrisy, every form of fraud and dishonesty, were freely cast about among the electors. It was amidst this excitement that Mandeville sought and found an audience for his grimly humorous paradox that "private vices are public benefits,"—that individual self-seeking, ambition, greed, vanity, luxury, are indispensable to the prosperity and greatness of a nation. "Fools only strive to make a great an honest hive." The bees of his fable grumbled as many Englishmen were disposed to do,—"cursed politicians, armies, fleets," whenever there came a reverse, and cried, "Had we but honesty!" Jove at last in a passion swore that he would "rid the bawling hive of fraud," and filled the hearts of the bees with honesty and all the virtues, strict justice, frugal living, contentment with little, acquiescence in the insults of enemies. Straightway the flourishing hive declined, till in time only a small remnant was left; this took refuge in a hollow tree, "blest with content and honesty," but destitute of arts and manufactures. The *Grumbling Hive* was in fact a political *jeu d'esprit*, full of the impartial mockery that might be expected from a humorous foreigner, and with as much ethical theory underlying it as might be expected from a highly educated man in an age of active ethical speculation. The underlying theory was made explicit in the *Remarks* and the *Inquiry into the Origin of Moral Virtue*, published in 1714. But his purpose in dwelling on the text that private vices are public benefits was still rather the invention of humorous paradoxes than the elaboration of serious theory. Dr Johnson, who owned that Mandeville "opened his views into real life very much," considered that the fallacy of his argument lay in his defining neither vices nor benefits. But such a criticism as this overlooks the hinge on which all Mandeville's paradoxes turn. He does define virtue and vice very precisely, in accordance with the current orthodoxy of the time. He "gives the name of virtue to every performance by which man, contrary to the impulse of nature, should endeavour the benefit of others, or the conquest of his own passions, out of a rational ambition of being good"; while "everything which, without regard to the public, man should commit to gratify any of his appetites" is vice. His paradoxical humour has ample scope in tracing how much vice and how little virtue there is in the world, when the terms are thus strictly defined. He finds self-love (a vice by the definition) masquerading in many virtuous disguises, lying at the root of asceticism, heroism, public spirit, decorous conduct,—at the root, in short, of all the actions that pass current as virtuous. These actions are not virtuous by the definition, because not performed solely "out of a rational ambition of being good." "This is the way," Dr Johnson says, "to try what is vicious, by ascertaining whether more evil than good is produced by it on the whole." Mandeville would at once have admitted this, but his definition compelled him, in determining virtue and vice, to consider also the motive. And having regard to the motive, "the nearer we search into human nature, the more we shall be convinced that the moral virtues are the political offspring which flattery begot upon pride." Man, "an extraordinary selfish and headstrong as well as a cunning animal," has been induced to subordinate his own appetites to the good of others, by the dexterous management of politicians and moralists, who have worked upon his pride to persuade him that self-indulgence is worthy only of the brutes, and altogether "unbecoming the dignity of such a sublime creature as himself." When Mandeville, in the 1723 edition of the fable, applied his analysis of self-regarding motives to the institution of charity schools, at that time a highly fashionable form of munificence, a great outcry was made against his doctrines; his book was presented to the justices by the grand jury of Middlesex as being of an immoral and pernicious tendency, and a copy was condemned to be burnt by the common hangman. Mandeville's defence of himself was that his remarks were "designed for the entertainment of people of knowledge and education," and that his inquiry could hardly be intelligible except to those accustomed to matters of speculation; and he claimed that he had "diverted persons of great probity and virtue and unquestionable good sense." The truth is that, to be rightly understood, the prose part of Mandeville's fable must be read in connexion with Lord Shaftesbury's ethical writings; the intention to ridicule the amiable but somewhat feebly reasoned theories of that moralist is most apparent in the *Search into the Origin of Society*, but many lurking references may be detected elsewhere. If Mandeville were taken seriously, he would certainly be open to the charge of conveying the impression that those who restrain their appetites and sacrifice personal interests for the public good make fools of themselves, and are the dupes of a designing society. But his main purpose seems to have been to entertain himself and others at the expense of more serious but less quick-witted theorizers.

Besides his political and philosophical parerga, Mandeville wrote, in 1711, a medical treatise, *Of the Hypochondriack and Hysterick Passions*—their symptoms, causes, and cures. The treatise is in the form of a dialogue, and is "interspersed with instructive discourses on the real art of physic itself, and entertaining remarks on the modern practice of physicians and apothecaries." In this, with the same entertaining style and clear and subtle judgment, he protests against and ridicules speculative therapeutics, and pleads for patient diagnosis and careful observation and record of facts. His own theories about the animal spirits and their connexion with "the stomachic ferment" are fanciful enough, but he shows an intimate acquaintance with the scientific methods of Locke, and a warm admiration for Sydenham. *The Virgin Unmasked*; *Free Thoughts on Religion, the Church, and National Happiness*; *An Inquiry into the Causes of the frequent Executions at Tyburn*; *An Inquiry into the Origin of Honour, and Usefulness of Christianity in War*—are titles of other works of Mandeville; but all that is characteristic of him as a thinker and humorist may be found in the *Fable of the Bees*. (W. M.)

MANDEVILLE, JEHAN DE, the name claimed by the compiler of a singular book of travels, written in French, and published between 1357 and 1371. By aid of translations into many other languages it acquired extraordinary popularity, while a few interpolated words in a particular edition of the English version have gained for Mandeville in modern times the spurious credit of being "the father of English prose."

In his preface the compiler calls himself a knight, and states that he was born and bred in England, of the town of St Albans; had crossed the sea on Michaelmas Day 1322; had travelled by way of Turkey (Asia Minor), Armenia the little (Cilicia) and the great, Tartary, Persia, Syria, Arabia, Egypt upper and lower, Libya, great part of Ethiopia, Chaldæa, Amazonia, India the less, the greater, and the middle, and many countries about India; had often been to Jerusalem; and had written in Romance as more generally understood than Latin. In the body of the work we hear that he had been at Paris and Constantinople; had served the sultan of Egypt a long time in his wars against the Bedouins, had been freely addressed by him on the corruption of contemporary Christendom, had been vainly offered by him a princely marriage and a great estate on condition of renouncing Christianity, and had left Egypt under Sultan Melech Madabron, *i.e.*, Muẓaffar or Mudhaffar[1] (who reigned in 1346–47); had been at Mount Sinai, and had visited the Holy Land with letters under the great seal of the sultan, which gave him extraordinary facilities; had been in Russia, Livonia, Cracow, Lithuania, "en roialme daresten" (? de Daresten or Silistria), and many other parts near Tartary, but not in Tartary itself; had drunk of the well of youth at Polombe (Quilon on the Malabar coast), and still seemed to feel the better; had taken astronomical observations on the way to Lamary (Sumatra), as well as in Brabant, Germany, Bohemia, and still farther north; had been at an isle called Pathen in the Indian Ocean; had been at Cansay (Hangchow-fu) in China, and had served the emperor of China fifteen months against the king of Manzi; had been among rocks of adamant in the Indian Ocean; had been through an haunted valley, which he places near Millestorach (= Millescorath, *i.e.*, Malasgird in Armenia); had been at many great feats of arms, but had been incapable of performing any himself; had been driven home against his will in 1357 by arthritic gout (despite the well of youth!); and had written his book as a consolation for his "wretched rest." The paragraph which states that he had had his book confirmed at Rome by the pope is, however, an interpolation of the English version.

This recital is of itself enough to provoke some little questioning, and on investigating the sources of the book it will presently be obvious that part at least of the personal history of Mandeville is mere invention. Under these circumstances the truth of any part of that history, and even the genuineness of the compiler's name, become matter for serious doubt. No contemporary corroboration of the existence of such a Jehan de Mandeville seems to be known. Some French MSS., not contemporary, give a Latin letter of presentation from him to Edward III., but this is so hopelessly vague that it might have been penned by any writer on any subject. At Liége, in the abbey of the Guilelmites, now pulled down, there certainly was in the 16th century a tomb of a man in armour said to be Mandeville; but the old French inscription showed no name, and the arms were quite unlike those of the Mandevilles, earls of Essex; while the Latin inscription, stating that the tomb was Mandeville's, and that he died at Liége on November 17, 1372, is not only apparently much later in style, but confounds him with a physician called "ad Barbam," who is said in a printed Latin edition of Mandeville to have met him first at Cairo and again at Liége, and to have persuaded and helped him to write his travels.[2]

Leaving this question, there remains the more complex one whether the book contains, in any measure, facts and knowledge acquired by actual travels and residence in the East. We believe that it may, but only as a small portion of the whole, and that confined entirely to the section of the work which treats of the Holy Land, and of the different ways of getting thither, as well as of Egypt, and in general of what we understand by the Levant.

The prologue indeed points almost exclusively to the Holy Land as the subject of the work. The mention of more distant regions comes in only towards the end of this prologue, and (in a manner) as an afterthought. As regards the writer's claim to have travelled in those more distant regions, it is somewhat astonishing to find that any modern editor could have regarded this as possibly founded in truth. And the apology sometimes made for the book, as only a compilation of what was regarded as truth in the writer's age, is not tenable in the face of the frequent assertion (explicit or implicit) that he had himself been in the remotest regions spoken of, and had witnessed some of the most marvellous circumstances that he details. To this we shall recur later, for the bearing of these statements can only be appreciated when the true derivation of the matter about the further East shall have been exhibited.

By far the greater part of these more distant travels, extending in fact from Trebizond to Ormus, India, the Indian Archipelago, and China, and back again to western Asia, has been appropriated from the narrative of Friar Odoric (written in 1330). These passages, as served up by Mandeville, are almost always, indeed, swollen with interpolated particulars, usually of an extravagant kind, whilst in no few cases the writer has failed to understand the passages which he adopts from Odoric and professes to give as his own experiences. Thus (p. 193)[3] in appropriating a passage of Odoric about tortoises

[1] The *on* in Madabron apparently represents the Arabic nunation, though its use in such a case is very odd.

[2] This physician is called in a French MS. "Jehan de Bourgoigne dit a la Barbe." M. Michelant once saw the title of a medical or botanical treatise bearing the name of Jehan de Bourgoigne. Can he also have written these travels under a feigned name?

[3] Page indications like this refer to passages in the 1866 re-issue of Halliwell's edition, as being the most ready of access. But all these passages have also been verified as substantially occurring in the French MS. from Lord Ashburnham's library mentioned below (of 1371 A.D.), cited A, and in that numbered xxxix. of the Grenville collection (B. M.), which dates probably from the early part of the 15th century, cited G.

of great size, seen in Champa, these are described as "snails" (*lymecons*, A., *limassons*, G.) whose shells were as big as cottages.

In another place (p. 209), where Odoric has given a most curious and veracious account of the Chinese custom of employing tame cormorants to catch fish, the cormorants are converted by Mandeville into "little beasts called *loyres* (*layre*, A.), which are taught to go into the water" (the word *loyre* being apparently used here for "otter," *lutra*, for which the Provençal is *luria* or *loiria*). Where Odoric, describing the court of the Great Khan, mentions the genuine Tartar custom which forbade any man in entering to set down his foot on the threshold of the door (an etiquette which P. della Valle found still in force at Ispahan in the 17th century), Mandeville quite fails to understand the point (see p. 220).

At a very early date the coincidence of Mandeville's stories with those of Odoric was recognized, insomuch that a MS. of Odoric, which is or was in the chapter library at Mainz, begins with the words: *Incipit Itinerarius fidelis fratris Odorici socii Militis Mendavil per Indiam; licet hic* [read *ille*] *prius et alter posterius peregrinationem suam descripsit.* At a later day Sir T. Herbert calls Odoric "travelling companion of our Sir John"; and Purchas, with most perverse injustice, whilst calling Mandeville, next to Polo, "if next, . . . the greatest Asian traveller that ever the world had," insinuates that Odoric's story was stolen from Mandeville's. Mandeville himself is crafty enough, at least in one passage, to anticipate criticism by suggesting the probability of his having travelled with Odoric (see p. 282, and below).

Much again of Mandeville's matter, particularly in Asiatic geography and history, is taken bodily from the book of Hayton, an Armenian of princely family, who became a monk of the Præmonstrant order, and in 1307 dictated this work on the East in the French tongue at Poictiers, out of his own extraordinary acquaintance with Asia and its history in his own time.

It is curious that no passage in Mandeville can be plausibly traced to Marco Polo, with one exception. This is (p. 163) where he states that at Ormus the people, during the great heat, lie in water,—a circumstance mentioned by Polo, though not by Odoric. We should suppose it most likely that this fact had been interpolated in the copy of Odoric used by Mandeville; for, if he had borrowed it direct from Polo, he would have borrowed more.

A good deal about the manners and customs of the Tartars is demonstrably derived from the famous work of the Franciscan John of Plano Carpini (see CARPINI, vol. v. p. 132), though possibly the immediate source for Mandeville may have been some popular compilation. For though the passages in question are all to be found in Carpini, more or less exactly, the expression is condensed and the order changed. For examples compare Mandeville, p. 250, on the tasks done by Tartar women, with Plano Carpini, p. 643;[1] Mandeville, p. 250, on Tartar habits of eating, with Plano Carpini pp. 639-40; Mandeville, p. 231, on the titles borne on the seals of the Great Khan, with Plano Carpini, p. 715, &c.

The account of Prester John, and all the wonders of his court and realm, is taken from the famous *Epistle* of that imaginary potentate, which was so widely diffused in the 13th century, and created that renown which made it incumbent on every traveller in Asia to assume his existence, and to find some new tale to tell of him. Many fabulous stories again of monsters, such as cyclopes, sciapodes, hippopodes, monoscelides, anthropophagi, and men whose heads did grow beneath their shoulders, of the phœnix and the weeping crocodile, such as Pliny has collected, are introduced here and there, derived no doubt from the popular versions of Solinus. And interspersed, especially in the chapters about the Levant, are the stories and legends that were retailed to every pilgrim, such as the legend of Seth and the grains of paradise from which grew the wood of the cross, that of the shooting of old Cain by Lamech, that of the castle of the sparrow-hawk (which appears in the tale of Melusina), those of the origin of the balsam plants at Matariya, of the dragon of Cos, of the river Sabbation, &c.

Even in that part of the book which may be admitted with probability to represent some genuine experience, there are distinct traces that another work has been made use of, more or less, as an aid in the compilation, we might almost say as a framework to fill up. This is the itinerary of the German knight William of Boldensele, written in 1336 at the desire of Cardinal Talleyrand de Perigord.[2] A cursory comparison of this with Mandeville leaves no doubt of the fact that the latter has followed its thread, using its suggestions, and on many subjects its expressions, though digressing and expanding on every side, and too often eliminating the singular good sense of the German traveller. After such a comparison we may indicate as examples Boldensele's account of Cyprus (Mandeville, p. 28, and p. 10), of Tyre and the coast of Palestine (Mandeville, 29, 30, 33, 34), of the journey from Gaza to Egypt (34), passages about Babylon of Egypt (40), about Mecca (42), the general account of Egypt (45), the pyramids (52), some of the particular wonders of Cairo, such as the slave-market, the chicken-hatching stoves, and the apples of paradise, *i.e.*, plantains (49), the Red Sea (57), the convent on Sinai (58, 60), the account of the church of the Holy Sepulchre (74-76), &c. The following may be quoted as a specimen, showing how Mandeville has at once followed Boldensele and deviated from his good sense:—

Boldensele (ed. Basnage, p. 342).	*Mandeville* (p. 52).
"Sunt plura antiquorum monumenta, figuræ pyramidalis, inter quæ sunt duo miræ magnitudinis et altitudinis, de maximis lapidibus et politis, in quibus inveni scripturas diversorum idiomatum. . . . Dicunt simplices hæc maxima monumenta fuisse granaria Pharaonis, et sic ea appellant, quod verum nullo modo est; quia nec ad imponendam nec ad servandam annonam . . . locus in ipsis pyramidibus aptus deprehenditur . . . verum quod monumenta sunt," &c.	"Now also I shall speak of another thing . . . that is to say of the Garners of Joseph that he caused to be made. . . . And they be made of stone, full well made of mason's craft; of which two be marvellously great and high, and the other is not so great. . . . And above the Garners, without, be many scriptures of divers languages. And some say that they are sepulchres of great Lords . . . but that is not true; for all the common rumour and speech is . . . that they be the Garners of Joseph."

It will be seen from these indications, and more particularly from the specific analysis given below, that there is only a small residuum of the book to which genuine character, as containing the experiences of the author, can possibly be attributed. Yet, as has been intimated, the borrowed stories are frequently claimed as such experiences. We have already alluded to Mandeville's claim (p. 4) to have visited distant parts of Asia; to have drunk of the Fountain of Youth, a favourite mediæval fable which he interpolates in Odoric's account of Malabar (169); to his assertion that he had visited Lamary (Sumatra), and indeed that he had gone beyond it to 33° 16′ of S. lat. (181-82); and that he had been at a certain other island in the Indian Archipelago (190). He alleges also that he had witnessed the curious exhibition of the garden of transmigrated souls (described by Odoric) at Cansay, *i.e.*, Hangchow-fu (211). He and his fellows with their valets had remained fifteen months in service with the emperor of Cathay in his wars against the king of Manzi,—Manzi, or Southern China, having ceased to have any existence as a separate kingdom some seventy years before the time referred to. Similar false statements are found at pp. 219, 235, 248, 271. But the most notable of these passages occurs in his adoption from Odoric of the story of the Valley Perilous (282). This is, in its original form, apparently founded on real experiences of Odoric viewed through a haze of excitement and superstition. Mandeville, whilst swelling the wonders of the tale with a variety of extravagant touches, appears to safeguard himself from the reader's possible discovery that the tale was stolen by the interpolation: "And some of our fellows accorded to enter, and some not. So there were with us two worthy men, Friars Minor, that were of Lombardy, who said that if any man would enter they would go in with us. And when they had said so, upon the gracious trust of God and of them, we caused mass to be sung, and made every man to be shriven and houselled; and then we entered, fourteen persons: but at our going out we were but nine," &c.

In referring to this passage it is only fair to recognize that the description (though the suggestion of the greatest part exists in Odoric) displays a good deal of imaginative power; and there is much in the account of Christian's passage through the Valley of the Shadow of Death, in Bunyan's famous allegory, which indicates a possibility that John Bunyan may have read and remembered this episode either in Mandeville or in Hakluyt's Odoric.

Such a passage, however, as that which we recently quoted, and which appears to exist in all the MSS. and versions that have been examined, leaves no room for the rehabilitation of Mandeville's character as regards conscious mendacity. But it does not necessarily follow that the whole work is borrowed or fictitious. There are other examples in mediæval works of travel in which fiction has been linked to true experiences. Even the great Moorish traveller Ibn Batuta, accurate and veracious in the main, seems, in one part at least of his narrative, to invent experiences; and in such works as those of John of Hese and Arnold von Harff, we have examples of pilgrims to the Holy Land whose narratives begin apparently in sober truth, and gradually pass into flourishes of fiction and extravagance. So in Mandeville also we find various particulars which we are unable to trace to other writers, and which may therefore be, provisionally at least, assigned to the writer's own experience, or to knowledge acquired by colloquial intercourse in the East.

It is difficult to decide on the character of his statements as to recent Egyptian history. In his account of that country (pp. 37, 38) though the series of the Comanian (*i.e.*, of the Bahri Mameluke) sultans is borrowed from Hayton down to the accession of *Melechnasser*, *i.e.*, El-Malik el-Nâṣir Mohammed ibn Kalâûn, who came first to the throne in 1299, Mandeville appears to speak from his own knowledge when he adds that this "*Melechnasser* reigned long and governed wisely." In fact, though twice displaced in the early part of his life, Malik Nâṣir reigned till 1341, a duration un-

[1] Viz., in D'Avezac's ed. in tom. iv. of *Rec. de Voyages et de Mémoires*, pub. by the Soc. de Géog., 1839.

[2] It is found in the *Thesaurus* of Canisius, 1604, v. pt. ii. p. 95, and in ed. of same by Basnage, 1725, iv. 337.

paralleled in Mohammedan Egypt, whilst we are told that during the last thirty years of his reign Egypt rose to a high pitch of wealth and prosperity. Mandeville, however, then goes on to say that his eldest son *Melechemader* was chosen to succeed, but this prince was caused privily to be slain by his brother, who took the kingdom under the name of *Melechmadabron*. "And he was Soldan when I departed from those countries." Now Malik Násir Mohammed was followed in succession by no less than eight of his sons in thirteen years, the first three of whom reigned in aggregate only a few months. The names mentioned by Mandeville appear to represent those of the fourth and sixth of the eight, viz., El-Malik el-Ṣálih '*Imádu-d-dín*, and El-Malik el-*Muzaffar* Zainu-d-dín Hájj; and these the statements of Mandeville do not fit.

Among particulars which seem to suggest personal knowledge may be instanced the very good description of the Bedouins (p. 64), starting from that of Boldensele, but largely and accurately expanded; the use of carrier pigeons in Syria (p. 118); the intimation that the Red Sea was frequented by Venetian merchants trading with India (p. 140). There are some other particulars which the author can hardly have witnessed, but which may possibly have been heard in communication with other travellers (if not borrowed from some untraced source). Such are the practice of polyandry in a certain island (p. 287), and the rite of fraternal adoption between two persons by drinking each other's blood (195). The mention of Ani in Armenia with its thousand churches (148) is probably derived from some book; the city and its thousand churches are mentioned by William of Rubrouck.

On several occasions the writer indicates some acquaintance with Arabic, though the words are not always recognizable, owing perhaps to the carelessness of copyists in such matters. Thus (p. 142) he gives the Mohammedan confession of faith as *La ellet ella Machometh rores alla* (*Rosel-alla*, A.) (Lá iláha illá 'lláh Muhammadun rasúlu 'lláh); (p. 50) the Arabic names of the wood, fruit, and sap of the balsam plant; (p. 99) the name of bitumen, "alkatran" (*al-Katrân*); (p. 131) three titles of the Koran, viz., "*Alkoran*," "*Meshaf*" (*i.e.*, *mishaf*, "written sheets or pages," "a copy of the Koran"), and *Harme* (*i.e.*, *haram*, in the sense of "sacred, inviolable"); (p. 168) the names of the three different kinds of pepper (long pepper, black pepper, and white pepper) as *sorbotin*, *fulful*, and *bano* or *bauo* (*fulful* is the common Arabic word for pepper, the others we cannot explain with any confidence); (p. 192) the name of the elephant (but in A. this runs: *Et apelle on là les oliphans vaches*).

Mandeville again, in some passages (and especially in one which is familiar from its being cited by Dr Johnson in the preface to his dictionary) shows a correct idea of the form of the earth, and of position in latitude ascertained by observation of the pole star; he knows that there are antipodes, and that if ships were sent on voyages of discovery they might sail round the world. And he tells a curious story, which he had heard in his youth, how a worthy man did travel ever eastward until he came to his own country again (p. 183). But on the other hand he repeatedly asserts the old belief that Jerusalem was in the centre of the world (79, 183), whilst he maintains in proof of this that at the equinox a spear planted erect in Jerusalem casts no shadow at noon,—which if true would only show that the city was on the equator.

Brief Analysis.—Prologue. Chaps. i.-iii. The way to Constantinople; the wonders and holy places there; the Greek islands, Greek Church, &c. Chaps. iv.-v. Constantinople and Palestine; Rhodes, Cyprus, coast of Palestine; Egypt and Babylon of Egypt; the Sinai desert and convent (these two chapters on the lines of Boldensele; succession of Ayubite and Mameluke sultans from Hayton). Chaps. v.-x. Palestine and the holy places (the most original part of the work, but based occasionally on Boldensele). Chap. xi. Syria, various routes from Western Europe; description of Tartary (the steppe country about the Volga,—very good, though expressly not from personal experience). Chap. xii. On the Saracens and their religion, Mohammed, &c. (partly based on Boldensele). Chap. xiii. Countries of Asia and Africa; journey to the East from Trebizond (this and on to chap. xx. inclusive is all based on Odoric, with interpolations *ad libitum*). Chap. xxi. The Great Khan; the history of Jenghiz and his successors (from Hayton, with something from Plano Carpini). Chap. xxii. The court and splendour of the khan, his paper-money, &c. (from Odoric). Chap. xxiii. Customs of the Tartars, &c. (chiefly from Plano Carpini). Chap. xxiv. Countries of Asia shortly described (from Hayton). Chap. xxvi. The lamb-plant (from Odoric), with much added about Alexander and the shut-up nations, griffins, and other monsters. Chap. xxvii. The royal estate of Prester John (chiefly from the "Letter" of Prester John, with something from Hayton); the Old Man of the Mountain (from Odoric). Chap. xxviii. The Valley Perilous (from Odoric, with inventions), followed by a quantity of fabulous geography of mixed and uncertain origin. Chaps. xxix., xxx. Similar hotchpotch continued (from the romance of Alexander, the letter of Prester John, Plinian fables, &c.). Chap. xxxi. The return journey from Cathay, &c. (from Odoric). The epilogue.

The oldest known MS. of the original is the earl of Ashburnham's MS. Libri xxiv., dated 1371, but nevertheless very inaccurate in proper names. The English version was made, at least as early as the beginning of the 15th century, from a French MS. defective between p. 36 l. 7 ("And there") of Halliwell's edition and p. 62 l. 25 ("And that Valey"), and is represented in this state by nearly every known English MS. It was completed and revised by two independent editors, neither of them later than the first quarter of the 15th century. One of these revisions is represented by the British Museum MS. Egerton 1982, and the very badly abbreviated Bodleian MS. e Mus. 116. The other is represented by the British Museum MS. Cotton Titus C. xvi. The first printed edition of the English version is apparently the undated edition of Pynson, which gives the version in its original defective shape. So do Wynkyn de Worde's edition of 1499 and eleven editions before 1725, except that they insert a paragraph seemingly abbreviated from the revision represented by Cotton Titus C. xvi. This latter revision was, however, followed in full by the editions of 1725 and 1727, and is, in Halliwell's editions, the text now current. The other revision seems never to have been printed.

That none of the forms of the English version can conceivably be from the same hand which wrote the original work is made patent to any critical reader by their glaring errors of translation, but the form now current asserts in the preface that it was made by Mandeville himself, and this assertion has been taken on trust by almost all modern historians of English literature. The words of the original "je eusse cest livret mis en latin . . . . mais . . . je l'ay mis en rōmant" were mistranslated as if "je eusse" meant "I had" instead of "I should have," and then (whether of fraudulent intent or by the error of a copyist thinking to supply an accidental omission) the words were added "and translated it aȝen out of Frensche into Englyssche." Schönborn and Mätzner respectively seem to have been the first to show that the current Latin and English texts cannot possibly have been made by Mandeville himself. Dr J. Vogels states the same of unprinted Latin versions which he has discovered in the British Museum, and he has proved it as regards the Italian version.

The terseness, the simplicity, and the quaintness of the English version, together with the curiosity of the subject-matter, will always make it delightful reading; but the title "father of English prose," which in its stricter sense already belonged to King Alfred, must in its looser sense be now transferred to Wickliffe.

See Schönborn's *Bibliographische Untersuchungen über die Reise-Beschreibung des Sir John Mandeville*, Breslau, 1840; Mätzner's *Altenglische Sprachproben*, I. ii. pp. 154-55; letters by E. B. Nicholson in *The Academy* of November 11, 1876, and February 12, 1881; Vogels, "Das Verhältniss der italienischen Version der Reisebeschreibung Mandeville's zur französischen" in a *Festschrift, dem Gymnasium zu Moers zur Feier seines 300jährigen Bestehens gewidmet vom Lehrer-Collegium des Crefelder Gymnasiums*, Bonn, 1882, and his forthcoming "Handschriftliche Untersuchungen über Mandeville's Reisebeschreibung," in Vollmöller's *Romanische Forschungen*; also for the bibliography of editions and translations, up to 1867, Tobler's *Bibliographia geographica Palæstinæ*. See also Yule's *Cathay and the Way Thither* (Hakluyt Society), i, 27, 28, on the sources of the book. At least two critical editions are understood to be in preparation—by Vogels (French and English), and by Michelant (French, for the Société de l'Orient Latin). On a French *Lapidaire* and other works attributed to Mandeville see Pannier's *Lapidaires français du moyen âge*, Paris, 1882, pp. 189-204. (E. B. N.—H. Y.)

MANDI, a native state in the Punjab, India, lying between 31° 23′ 45″ and 32° 4′ N. lat., and between 76° 40′ and 77° 22′ 30″ E. long., and bounded on the N. and E. by Kullu, on the S. by Suket, and on the W. by Kángrá. The country is very mountainous, being intersected by two great parallel ranges, reaching to an average height of from 5000 to 7000 feet above sea. The valleys between the hill ranges are very fertile, and produce all the ordinary grains, besides more valuable crops of rice, maize, sugarcane, poppy, and tobacco. Salt-mines contribute about one-third of the state revenue. Iron is found in places, and also gold in small quantities. The area of the state is estimated at about 1200 square miles, and a census in 1881 gives the population as 147,017. The chief, a Rájput by caste, enjoys an approximate income of £36,500, and the state pays a tribute to the British Government of £10,000 a year. Mandi town, the capital, is situated on the Biás, in 31° 43′ N. lat. and 76° 58′ E. long.

MANDINGOES, otherwise known as WANGARAWA, MALINKES, or WAKORE (the last probably their primitive designation), are one of the most widely distributed and important peoples of Western Africa to the north of the equator, and perhaps form the best representatives of the Negro stock. The country of Manding, from which their ordinary name is derived, is a comparatively small district on both banks of the Niger, about the intersection of 12° N. lat. with 9° E. long. A Mandingo empire, usually called after Mali, the chief town, which stood on the bank of the Niger to the north of Buré, was founded by a certain prince Baramindana or Baramangole in the 12th century; and its power was gradually extended till, in the reign of Mansa Musa (1311–31), Songhai, Timbuctoo, and, in fact, the whole of the Sudan with the exception of Genné on the Niger, were more or less thoroughly subjugated. Timbuctoo finally fell into the hands of the Berbers about 1433; but Mali remained a leading state and its capital a great commercial centre till the beginning of the 16th century, when Omar Askia, prince of Songhai, captured the city. The Mali dynasty was a Mohammedan one; and, though some sections of the Mandingo race are still pagans, the greater number are ardent supporters of Islam. Of the present grouping and relations of the states in which they are the dominant element detailed information does not exist; but such accounts as those of Benjamin Anderson (*Journey to Musardu, the capital of the Western Mandingoes*, New York, 1870) show that some of them are possessed of a considerable share of barbaric civilization. According to Dr Quintin, the leading areas of Mandingo occupation are the country watered by the great head-streams of the Senegal (the Faleme, the Bafing, &c.), the district to the south of the lower course of the Gambia, and the coast region of Susu to the north of Sierra Leone. The Mandingoes are generally tall and strongly built; black in complexion, and harsh and ugly in features, but with a spirited and intellectual expression. They are great traders, work in iron and gold, weave cotton cloth, tan excellent leather, and regularly cultivate a considerable variety of crops—rice, cotton, tobacco, kola, potatoes. Their clay-built walled towns often contain 8000 to 10,000 inhabitants, and villages and hamlets are thickly scattered over the country.

Besides Park's *Travels* (in which the Mandingoes play a prominent part) see Barth, *Travels in Central Africa*, and Dr L. Quintin, "Etude ethnogr. sur les pays entre le Sénégal et le Niger," in *Bull. de la Soc. de Géogr.*, Paris, 1881.

MANDLA, a district in the chief commissionership of the Central Provinces, India, lying between 22° 14′ and 23° 22′ N. lat., and between 80° and 81° 48′ E. long., is bounded on the N.E. by Rewah state, on the S.E. by Bilâspur, on the S.W. by Balaghat, and on the W. by Seoni and Jabalpur. It has an area of 4719 square miles, and the headquarters are at Mandla town. The district consists of a wild highland region, broken up by the valleys of numerous rivers and streams. In the lower valleys there is abundance of rich black cotton soil, while in the less favoured valleys a light friable soil is found. The Nerbudda river flows through the centre of the district, receiving several tributaries which take their rise in the Maikal Hills, a range densely clothed with *sál* forest, and forming part of the great watershed between eastern and western India. The loftiest mountain is Chaurádadar, about 3400 feet high. Tigers and wild beasts abound, and the proportion of deaths caused by wild animals is greater in Mandla than in any other district of the Central Provinces.

The census of 1872 disclosed a population of 213,018 (males, 110,473; females, 102,545). The aboriginal or hill tribes number more strongly in Mandla than in any other district of the Central Provinces, the Gonas being alone returned at 113,306. Mandla town, with a population of 4936, is the only place in the district with upwards of 2000 inhabitants. Of the total area of 4719 square miles, 556 were returned in 1881 as cultivated, and 2530 as cultivable. In the same year 54,431 acres were devoted to the production of rice, and 75,196 to wheat, while other food grains occupied 199,062 acres. Fibres and sugar-cane are produced in considerable quantities. The magnificent *sál* forests which formerly clothed the highlands of the district have suffered greatly from the nomadic system of cultivation practised by the hill tribes, who cut down and burn the wood on the hill-sides, and sow their crops in the ashes. Of late years, however, measures have been taken to prevent further damage to the forests. The only local manufacture consists in the weaving of coarse cotton cloth. The total gross revenue of the district in 1881 was returned at £21,398, of which £8999 was derived from the land. There are 46 Government and aided schools. The cost of officials and police was £6396. The district has a bad reputation for fever.

MANDOLINE. See LUTE.

MANDRAKE, *Mandragora officinarum*, L., of the potato family, order *Solanaceæ*, is a native of Spain, Sicily, Crete, Cilicia, Syria, &c., and North Africa (Benth. et Hook., *Gen. Pl.*, ii. p. 900; and DC., *Prod.*, xiii. p. 466). It has a short stem bearing a tuft of ovate leaves, with a thick fleshy and often forked root. The flowers are solitary, with a purple bell-shaped corolla. The fruit is a fleshy orange-coloured berry. The mandrake has been long known for its poisonous properties and supposed virtues. It acts as an emetic, purgative, and narcotic, and was much esteemed in old times; but, except in Africa and the East, where it is used as a narcotic and antispasmodic, it has fallen into disrepute (Pickering's *Chron. Hist. of Plants*, p. 247). In ancient times, according to Isidorus and Serapion, it was used as a narcotic to diminish sensibility under surgical operations, and the same use is mentioned by Kazwíní, i. 297, *s.v.* "Luffáh." Shakespeare more than once alludes to this plant, as when Banquo in *Macbeth* says—"Or have we eaten of the insane root that takes the reason prisoner?" and again in *Antony and Cleopatra*—"Give me to drink mandragora." The notion that the plant shrieked when touched, so that those who desired to pluck it up had to stop their ears with pitch, is alluded to in *Romeo and Juliet*—"And shrieks like mandrakes torn out of the earth, that living mortals, hearing them, run mad." The mandrake, often growing like the lower limbs of a man, was supposed to have other virtues, and was much used for love philtres (Diosc., iv. 76), while the fruit was supposed, and in the East is still supposed, to facilitate pregnancy (Aug., *C. Faust.*, xxii. 56; compare Gen. xxx. 14, where the Hebrew דּוּדָאִים is undoubtedly the mandrake). Like the mallow, the mandrake was potent in all kinds of enchantment (see Maimonides in Chwolson, *Ssabier*, ii. 459, and the notes). Dioscorides identifies it with the κιρκαία, the root named after the enchantress Circe. To it appears to apply the fable of the magical herb Baaras, which cured demoniacs, and was procured at great risk or by the death of a dog employed to drag it up, in Josephus (*B. J.*, vii. 6, § 3). The German name of the plant (Alraune; O. H. G. Alrûna) indicates the prophetic power supposed to be in little images (homunculi, Goldmännchen, Galgenmännchen) made of this root which were cherished as oracles. The possession of such roots was thought to ensure prosperity. (See Ducange, *s.v.* "Mandragora," and Littré.)

Gerard in 1597 (*Herball*, p. 280) described the male and female mandrakes. Dioscorides also recognizes two such plants apparently corresponding to the spring and autumn species (*M. vernalis*, Bert., and *M. officinarum*, L., respectively), differing as he says in the colour of the foliage and shape of fruit. He alludes to the "ridiculous tales" and "doltish dreames" about it merely to scout them. He notes that the root is often single, or with two to many branches. Even in his day, as now, the root of the wild bryony was trimmed to represent the human form, miscalled mandrake, and then sold as such to the ignorant.

MANDRILL, the name of one of the most remarkable, at all events in outward appearance, of the Baboons, *Cynocephalus maimon* or *mormon*. The general characters of the genus to which it belongs are given in the article APE, vol. ii. p. 152. The word appears to have been first introduced into our literature in a work published in 1744 called *A New Voyage to Guinea*, by William Smith, who in an account of the animals of Sierra Leone describes one "called by the white men in this country Mandrill," but adds, "why it is so called I know not."[1] Smith gives sufficiently accurate details to show that his animal is not

[1] "'Mandrill' seems to signify a 'man-like ape,' the word 'Drill' or 'Dril' having been anciently employed in England to denote an Ape or Baboon. Thus in the fifth edition of Blount's '*Glossographia*, or a dictionary interpreting the hard words of whatsoever language now used in our refined English tongue . . . very useful for all such as desire to understand what they read,' published in 1681, I find 'Dril, a stonecutter's tool wherewith he bores little holes in marble,

that now called Mandrill, but the Chimpanzee. Buffon, however, while quoting Smith's description, transferred the name to the very different species now under consideration, and to that it has been attached ever since.

The Baboons generally are distinguished from other Monkeys by the comparative equality of the length of their limbs, which with the structure of the vertebral column adapts them rather for quadrupedal progression on the ground than for climbing among the branches of trees. They are also remarkable for the great size of their face and jaws as compared with the part of the skull which encloses the brain. The Mandrill, in addition to these characters, is distinguished by the heaviness of its body, stoutness and strength of its limbs, and exceeding shortness of its tail, which is a mere stump, not 2 inches long, and usually carried erect. It is, moreover, remarkable for the prominence of its brow ridges, beneath which the small and closely approximated eyes are deeply sunk; the immense size of the canine teeth; the great development of a pair of oval bony prominences on the maxillary bones in front of the orbits, rising on each side of the median line of the face, and covered by a longitudinally-ribbed naked skin; and more especially for the extraordinarily vivid colouring of some parts of the skin.

The body generally is covered with a full soft coating of hair of a light olive-brown above and silvery-grey beneath, and the chin is furnished underneath with a small pointed yellow beard. The hair of the forehead and temples is directed upwards so as to meet in a point on the crown, which gives the head a triangular appearance. The ears are naked and of a bluish-black colour. The hands and feet are naked and black. A large space around the greatly developed ischial callosities, as well as the upper part of the insides of the thighs, is naked and of a crimson colour, shading off on the sides to lilac or blue, which, depending not upon pigment but upon injection of the superficial blood-vessels, varies in intensity according to the condition of the animal—increasing under excitement, fading during sickness, and disappearing after death. But it is in the face that the most remarkable disposition of vivid hues occur, more resembling those of a brilliantly coloured flower than what might be expected in the cutaneous covering of a mammal. The cheek prominences are of an intense blue, the effect of which is heightened by deeply sunk longitudinal furrows of a darker tint, while the central line and termination of the nose are a bright scarlet. Notwithstanding the beauty of these colours in themselves, the whole combination, with the form and expression of features, quite justifies Cuvier's assertion that "il serait difficile de se figurer un être plus hideux que le Mandrill."

It is only to fully adult males that this description applies. The female is of much smaller size, and of more slender make; and, though the general tone of the hairy parts of the body is the same, the prominences, furrows, and colouring of the face are very much less marked. The young males have black faces. At the age of three the blue of the cheeks begins to appear, and it is not until they are about five, when they cut their great canine teeth, that they acquire the characteristic red of the end of the nose.

The Mandrills, especially the old males, are remarkable for the ferocity of their disposition, as well as for other disagreeable qualities, which are fully described in Cuvier's account of the animal in *La Ménagerie du Muséum d'Histoire Naturelle* (1801), but when young they can easily be tamed. Like the rest of the Baboons, they appear to be rather indiscriminate eaters, feeding upon fruit, roots, reptiles, insects, scorpions, &c., and inhabit open rocky ground rather than forests. Not much is known of the Mandrill's habits in the wild state, nor of the exact limits of its geographical distribution. The specimens brought to Europe all come from the west coast of tropical Africa, from Guinea to the Gaboon.

An allied species, the Drill (*Cynocephalus leucophæus*), which resembles the Mandrill in size, general proportions, and shortness of tail, but wants the bright colouring of the face which makes that animal so remarkable, inhabits the same district. (W. H. F.)

&c. Also a large overgrown Ape and Baboon, so called.' 'Drill' is used in the same sense in Charlton's *Onomasticon Zoicon*, 1668. The singular etymology of the word given by Buffon seems hardly a probable one."—Huxley's *Man's Place in Nature*, p. 10, 1863.

MANDURIA, a city of Italy in the province of Lecce, 22 miles east of Taranto on the road to Lecce, in the midst of a wide open country. It had 7948 inhabitants at the census of 1871, is the seat of two pretty important fairs, and contains a spacious palace of the Francavilla family, and a fine old church with campanile and rose window; but the main interest of the place attaches to the ruins of the ancient city in the neighbourhood. The whole circuit of the double line of ancient walls, built of large rectangular stones without mortar, can still be traced, the outer wall and ditch measuring 23 feet in breadth, and the inner passage with the inner wall about 50 feet. At Scegno, just outside the walls, the visitor may still see the fountain of Manduria, the level of which, according to Pliny, it was impossible to alter by any drawing out or pouring in of water.

Manduria is first mentioned in connexion with the death of Archidamus, king of Sparta, who perished in a battle fought under its walls in 338 B.C.; and the only other fact of importance in its ancient annals is the capture by Fabius Maximus in 209. Though omitted from Pliny's list of towns in this region, it appears in the Tabula Peutingeriana. After the destruction of the old town by the Saracens the inhabitants removed to the present site, and the name Casalnuovo, which they at first applied to the new settlement, was exchanged by Ferdinand I. for the original Manduria.

MANES. This term, which is clearly euphemistic, meaning "goodies" or "good fellows," was applied by the Romans to the spirits of the departed. As in all nations of antiquity, and in many existing savage tribes, these spirits were held by them in great awe and veneration, as being powerful for good or for harm. The doctrine, whether imported from the Egyptian theology or of Turanian origin through the Etruscan tomb-builders, is closely allied to that of the Greek belief in the existence of the souls of heroes, ancestors, and generally of the "mighty dead," whom they called δαίμονες, but, of course, in a sense widely different from our notion of *demons*. Thus in Æschylus the spirits of Agamemnon and of Darius are invoked as δαίμονες, and in the *Suppliant Women* (24) they are appealed to as βαρύτιμοι χθόνιοι, where the notion of "heavily-punishing" seems conveyed by the compound epithet. Generally, the *dæmones* were regarded as hostile, or at least dangerous, and blood-offerings (ἐναγισμοί) were made to them to propitiate their wrath, and to induce them to send aid or material blessings from the realms below. The idea appears to have been that the spirits ranged the earth, hungry and forlorn, and seeking whom they might devour. Hence pestilences and sudden deaths were attributed to them, and in this sense they came to be regarded as the enemies of the living. Victims were given to them, that they might not themselves make victims of whomsoever they pleased. Offerings of all kinds were placed in the tomb or burnt on the pyre, and the rites of burial were, with the lamentations of surviving friends, thought necessary for the repose of the ghost. Hesiod, however, in a remarkable passage (*Op. et D.*, 122), speaks of the δαίμονες in terms more allied to our ideas of "guardian angels." He says they were the souls or spirits of the men who lived in the golden age, and that their office now is to walk the earth unseen, and to watch the actions and conduct of man. The meaning of the word *demon* is very obscure. Some connect it with διϝ, the root of *Dis*, *Dyaus*, Ζεύς, *Juppiter*, &c., others with δαίειν, "to allot," "to distribute," (Curtius, *Gr. Etym.*, i. 230), while others, with Plato (*Cratylus*, p. 398, B), have supposed that δαήμων, "knowing," is the original sense. In a general way, δαίμων meant a man's luck or fortune in life, and hence δυσδαίμων and εὐδαίμων are common phrases for "unfortunate" and "prosperous."

The word *manes* seems referable to an old adjective, of which there were two forms, *manis* and *manus*, "good." From the former comes *immanis*, applied to things or persons of formidable size, power, dimensions, &c., and so "huge," "savage," or in any sense "uncanny." The morning is *mane*, "the good or lucky time," because there was an old proverb (Hesiod, *Op. et D.*, 578) that morning was the best time for work. It is generally used as an ablative, *mane novo*, &c., yet Virgil has *dum mane novum*, (*Georg.* iii. 325). *Manus* is found in the old Italian divinity *Genita Mana*, the "good mother," also called Mania and Larunda, the reputed mother of the Lares or household gods. To this goddess Pliny tells us (*N. H.* xxix. 58) the Romans offered in sacrifice a puppy-dog, *catulus*. In xxi. 11 he says that chaplets used to be offered to the manes, and in xxxiii. 2 he speaks of men digging mines to get wealth *in sede manium*, in the depths where the spirits reside.

There can be no doubt that food offerings were, according to a widely spread superstition, offered to the manes, as to the Lar, to Hecate, to Trivia, and to other infernal powers. Thus Virgil (who is fond of the use of the word) says in *Æn.* iii. 63, "aggeritur tumulo tellus; stant Manibus aræ." On these altars, he adds, goblets of milk and the blood of victims were offered, though he evidently has in view the Greek rite of appeasing the dæmons. Perhaps there were not such solemn propitiatory sacrifices made to the manes as to the Greek δαίμονες. But all nations have reverenced the spirits of their ancestors, and especially those nations which retain strongly patriarchal traditions and the distinctions of caste.

The *genius* was a kind of attendant on the living, the sharer of his fortunes, and perhaps to some extent regulating them, from birth to death. To indulge one's genius originally meant to please him with good cheer, an idea that lay at the root of all primitive notions of sacrifice. Of this notion there is no Greek equivalent. It seems more nearly allied to the superstition of a "double" or "wraith," a kind of *alter ego* who at once was, and was not, identical with the individual person. (See Hor., *Epist.* ii. 2, 187.)

Between the *manes* and the received idea of *souls* there was a pretty close analogy. When Virgil says (*Æn.* vi. 743), "quisque suos patimur manes," he appears to mean that the souls of all receive the reward of deeds done in life. There was, of course, a corresponding idea that the *manes* could be conjured up, and could appear as ghosts. Thus Propertius (*El.*, v. 7), commencing with the verse "Sunt aliquid manes, letum non omnia finit," describes how the ghost of his Cynthia appeared to him and upbraided him for his faithlessness. See also Virg., *Æn.* iv. 490 and v. 99. Like the δαίμονες, they were also supposed to have the power of sending dreams (*ibid.* vi. 897).

In sepulchral inscriptions, even on early Christian tombs, the dedication *dis manibus* is common, showing the strong tendency to deify which prevailed with the Romans under the empire.

MANETHO. Manetho Sebennyta (Μανέθων, Μανεθῶ, Μανεθώς, Μανεθῶθ, &c., *i.e.*, *Mai en Thoth*, "beloved by Thoth"), Egyptian priest and annalist, was a native of Sebennytus (Semmenúd) in the Delta. His name is connected by Plutarch with the reign of Ptolemy I., and he is usually stated to have written under Ptolemy II. Philadelphus, though the only authority for this is an epistle to that king of the Pseudo-Manetho, author of the forged *Book of Sothis* preserved by Syncellus. He was instructed in Greek—so Josephus tells us—and the three books of his Αἰγυπτιακά composed in that language opened to foreigners the history of Egypt from the mythical period downwards, as it was preserved in the records of the priests. Unhappily the book is now known only by some lists and fragments preserved by Josephus in his treatise *Against Apion*, by Eusebius in his *Chronica*, and by Syncellus. Syncellus used the work of Eusebius (also known to us through Jerome and the Armenian version[1]) and the lost *Pentabiblon* of Africanus. Thus the little that we know of Manetho's history has reached us through a process of transcription and retranscription very unfavourable to the correct transmission of the lists of kings and dynasties, to which Josephus alone adds any considerable narrative excerpts. It seems indeed that our authorities themselves used varying and partly corrupt recensions of the original text, and that deliberate corruptions of the Manethonic tradition were not wanting appears from the existence of the *Book of Sothis* cited by Syncellus, which was undoubtedly a spurious work. That Manetho himself made honest use of his Egyptian sources is generally recognized, since the Egyptian monuments have afforded confirmation of many, though by no means all, of his statements; but how the corrupt and varying data we now have should be used, or whether the Egyptian tradition can be made the basis of a rational chronology of the oldest historical period, is doubtful (see vol. vii. p. 729 *sq.*).

The titles of several other books ascribed to Manetho, with a mass of useful material and discussion, will be found along with the best edition of the fragments in Müller's *Fragmenta Historicorum Græcorum*, ii. 511–616. An extant astrological poem called Ἀποτελεσματικά bears the name of Manetho, but is of much later date (last edition by Koechly, Leipsic, 1858). See Boeckh, *Manetho u. die Hundssternperiode*, 1845; Gutschmid, in *Philologus* (1856), and *Rhein. Mus.*, 1859; Lauth, *Manetho und der Turiner Königs-Papyrus*, 1865; Lieblein, *Aeg. Chron.* (1863) and *Recherches sur la Chron. Ég.*, 1873; and in general the books on Egyptian history and chronology. A fuller list of relative literature is given by Engelmann, *Bibl. Scriptor. Class.* (8th ed.), i. 507.

MANFRED (*c.* 1231–1266), regent and king of the Two Sicilies, a natural son of the emperor Frederick II. by Bianca Lanzia, the daughter of a Lombard earl, was born in Sicily about 1231, and received from his father the title of prince of Tarentum in 1248. Frederick II. at his death appointed him regent of the Two Sicilies during the absence of his brother Conrad IV., and notwithstanding the hostility of Innocent IV., and the revolt of many nobles and towns in Apulia at the instigation of that pontiff, he was able in 1252 to hand over to Conrad an undivided sovereignty. On the death of the latter in 1254, Manfred was once more called to the regency in the interests of his infant nephew Conradin, and by his victory over the forces of Innocent IV. at Foggia on December 2d of that year was able to establish his authority over the entire kingdom. When in 1258 rumours had reached Sicily of the death of Conradin, Manfred, yielding to the solicitations of his prelates, barons, and people, allowed himself to be crowned at Palermo on August 11. Shortly afterwards envoys arrived from the mother of Conradin to say that he was still alive, and to demand the crown for him; but this the king, strong in the popularity which he had acquired by his brave defence of his country, by his pleasing person, and by his many accomplishments, declined to give, promising only to preserve the crown for his nephew,

[1] *Eusebi Chronicorum libri duo*, ed. A. Schoene, Berlin, 1866–75.

and faithfully to bequeath it to him on his own death. Excommunicated in 1259 by Alexander IV., Manfred again resorted to arms, and overrunning the papal states, was made master of Tuscany by the battle of Monte Aperto (September 4, 1260). Now at the height of his power, he was anew excommunicated by Urban IV. in 1261, and in 1263 his forfeited crown was offered to Charles, count of Anjou, and brother of Louis IX. of France. Towards the end of summer in 1265, giving effect to a crusade proclaimed by Urban, Charles with his army entered Piedmont, but the encounter with the Sicilians did not take place until February 1266 at Benevento, where Manfred, filled with despair by the cowardly flight of his Apulians, spurred into the thickest of the battle and fell covered with wounds. His mangled body was hastily buried under a heap of stones near the bridge, but afterwards, at the instance of Pope Clement IV., was dragged out and laid in unconsecrated ground on the frontier of the kingdom.

MANFREDONIA, a seaport and city of Italy, in the province of Foggia, the see of an archbishop, and the centre of a maritime district, lies 22 miles north-east of Foggia, with which it is connected by railway. The situation, on the shores of the Gulf of Manfredonia and at the foot of Monte Gargano, is finely sheltered, and the vegetation of the district is similar to that of Sicily. A castle dating from the 13th century protects the port, and the city is surrounded by walls and towers. The principal building is the cathedral. Though the anchorage is available only for small vessels, a fair trade is carried on in the export of grain. While in 1863 there entered in all 418 vessels with a total burden of 20,346 tons, in 1880 the burden of the 463 vessels was only 10,832 tons. The population of the commune in 1881 was 9401.

Manfredonia is the historical representative of Sipontum, a Roman municipium and colony of some mark, which lay about 1½ miles to the south. The ancient city having greatly declined, partly owing to the unhealthiness of its situation and partly to the disasters of war, Manfred transferred its inhabitants to the present site in 1261. For a time Manfredonia flourished greatly, but the ravages of the Turks in 1620 proved fatal to its development. The site of Sipontum is marked by the ancient church of Santa Maria di Siponto.

MANGALIA, a town on the coast of the Black Sea, in the south of the Dobrudja, at the head of a district in the new Roumanian province of Kustendji. In the time of Genoese supremacy in the Black Sea it was a place of 30,000 inhabitants; and its population has again risen from a few hundreds to upwards of two thousand. According to the *Corpus Inscriptionum Latinarum*, it is to be identified with the ancient Thracian city of Callatis (or Acervetis, as it was formerly called)—a colony of Miletus which continued to be a flourishing place to the close of the Roman period.

MANGALORE, the administrative headquarters of south Kánara district, Madras, is situated on the Malabar coast, in 12° 51′ 40″ N. lat., 74° 52′ 36″ E. long., with a population in 1871 of 29,667. The town is picturesque, clean, and prosperous. The native houses are laid out in good streets, and the European quarter is particularly pleasant. Mangalore clears and exports all the coffee of Coorg, and trades directly with Arabia and the Persian Gulf. In 1875 3600 ships of 264,000 tons entered. The exports in that year were valued at £505,800, and the imports at £272,704. There is a large native Roman Catholic population, with two European bishops, several churches, and a convent. The Basel Lutheran mission has its headquarters here, and has done much good in teaching trades, &c. Good cloth is woven at their establishment; the making of roof tiles, printing, and bookbinding are also taught.

MANGANESE, a metallic chemical element (symbol Mn; atomic weight 55) widely diffused throughout the mineral kingdom, being an almost constant companion of ferrous oxide, lime, and magnesia in their native carbonates and silicates. Of manganese minerals proper—which are comparatively scarce—the most important is *pyrolusite*, the native binoxide, MnO_2. This is a black crystalline or crystallized solid with semi-metallic lustre, sufficiently soft to give a (black) streak on paper; hardness, 2 to 2·5; specific gravity, 4·8 to 4·9. It is known in commerce as "black oxide of manganese" or "manganese," and is extensively used for the industrial extraction of chlorine from muriatic acid. Its most extensive beds are found at Ilmenau and Elgersburg, Thuringia; near Giessen, North Hesse; near Mährisch-Trübau, Moravia; and in Spain. Almost all pyrolusite is contaminated with more or less of the following "manganites"—general formula $MnO_2.R''O$—which besides occur (in the same localities) as independent minerals:—*braunite*, Mn_2O_3 or MnO_2MnO; *manganite*, or grey manganese ore, $Mn_2O_3.H_2O$; *hausmannite*, Mn_3O_4 or $MnO_2.2MnO$; and *psilomelan*, a complex mineral, the composition of which generally approximates to $4MnO_2.RO + xH_2O$,—the R being chiefly Ba or K_2, but including in general more or less of Ca, Mg, and Mn. These ores are not unlike pyrolusite in their general appearance, but can usually be easily distinguished from it by their greater hardness and other physical properties. Closely allied to psilomelan are those earthy, massive, or reniform mineral mixtures known as "bog-manganese," "cupreous manganese," "earthy cobalt." In the two last-named the RO is chiefly CuO and CoO respectively. We must here mention those curious formations known as "manganese nodules" which were so frequently dredged up by the "Challenger" expedition, and with which, it seems, large areas of the ocean's bed are thickly covered. The writer found in one of these, which seemed exceptionally rich in manganese, 20·12 per cent. of binoxide of manganese (fully oxidized), 0·4 of oxide of nickel, 0·25 of cobalt, and 0·27 of copper,—a total of 21·04 per cent. of the psilomelanic part, not reckoning the CaO, MgO, &c., belonging to it. All the manganese ores named are available for the manufacture of chlorine, and indeed are so used, as components of what goes in the arts as "manganese."

The industrial value of a "manganese" depends, of course, on its actual or virtual percentage of binoxide. A convenient method for its determination was worked out by Fresenius and Will, on the basis of a reaction long before discovered by Turner. When MnO_2 is brought in contact with aqueous sulphuric and oxalic acids, it is reduced to MnO (-salt) with formation of carbonic acid; thus: $MnO_2 + C_2O_4H_2 + H_2SO_4 = 2H_2O + MnOSO_3 + 2CO_2$. It is easy so to arrange matters that all the CO_2 leaves the apparatus and nothing else, so that the weight of CO_2 formed identifies itself with the loss of weight suffered by the co-reagents; and obviously every one gramme of CO_2 formed indicates $\frac{MnO_2}{2CO_2} = \frac{87}{88} = 0{\cdot}9986$ gramme of real MnO_2. A determination of the free water (loss of weight suffered by the powdered ore at 120° C.) must accompany the assay to enable one to compare two analyses made at different times.

For the making of manganese preparations, high class pyrolusite is the most convenient raw material.

Metallic manganese may be prepared by intimately mixing it with lamp-black and heating the mixture to whiteness in a blast furnace. But the regulus thus obtained contains a large percentage of combined carbon. A purer metal was obtained by Deville, who started with perfectly pure "red oxide," Mn_3O_4, and heated it along with a proportion of sugar-charcoal insufficient for complete reduction in a double crucible made of quicklime. The unreduced oxide (MnO) and part of the lime fuse together into a violet slag, from which the regulus is easily separated. Brunner's manganese (obtained by the reduction of the fluoride with sodium in a clay crucible) is not manganese at all, but a silicide of the metal.

Hugo Tamm, who endeavoured to work out a process for the manufacture of the metal, gives the following process:—11 parts of good pyrolusite is mixed with 1 part of lamp-black and 6 parts of a flux consisting of 20 parts of lead-free bottle-glass, 7 parts of quicklime, and 7 of fluor-spar; and the mixture is strongly heated, in a graphite crucible coated over with a mixture of 3 parts of graphite and 1 part of clay, by means of a blast-furnace. There is formed a regulus covered by a green silicious slag containing much protoxide of manganese. The "raw" manganese thus produced is contaminated with about 1 per cent. each of iron, silicon, and carbon, and traces of sulphur, phosphorus, calcium, and aluminium. The green slag in subsequent operations is substituted for part of the white flux. The raw metal, when re-fused with about one-third of its weight of manganous carbonate, yielded a regulus which contained 99·9 per cent. of the metal,—the remaining $\frac{1}{10}$ per cent. consisting of carbon, silicon, and iron.

Manganese metal is grey, like cast iron (Deville's had a reddish hue like bismuth); its specific gravity is about 8; it is hard and brittle, and about as difficult to fuse as wrought iron. It readily tarnishes in ordinary air; even pure water, and much more dilute acid, attack it with evolution of hydrogen and formation of manganous (MnO) hydrate or salt. It is worth stating that neither MnO nor $MnCl_2$ is reducible at a red heat by hydrogen gas; yet Bunsen succeeded in obtaining metallic manganese by the electrolysis of a concentrated solution of the chloride, using a strong current and a negative electrode of very small area.

Oxides.—Pure peroxide can be obtained artificially by keeping the pure nitrate at 200° C. But really pure nitrate is hard to procure. Perhaps the only method for obtaining a really pure preparation is Volhard's: 10 grammes of "pure" (iron- and cobalt-free) manganous sulphate is dissolved in half a litre of water and 100 cm. of nitric acid of 1·2 specific gravity; the solution is heated to boiling, and strong solution of permanganate of potash added until the MnO is nearly but not quite down, and the mixture kept for a while on a water-bath. The precipitate of binoxide formed (according to equation $Mn_2O_7 + 3MnO = 5MnO_2$) is washed, first with dilute nitric acid, then with water, and dried (when it retains some combined water).

When binoxide of manganese is heated to redness—in vacuum, air, oxygen, nitrogen—it loses oxygen with formation of lower oxides. This phenomenon was investigated by W. Dittmar, who found that, when the binoxide is heated in a constantly renewed atmosphere, the result, for a given temperature, depends only on the partial tension of the oxygen in that atmosphere. Pure (brown-red) Mn_3O_4 remains when this tension is less, while (black) Mn_2O_3 remains when the tension is greater than a certain limit value p. In Dittmar's experiments (which were all made at a temperature somewhat above the melting point of sterling silver), the value p was found to lie close to 26 cm. of mercury. An exact determination of this critical point was not possible, because the temperature was not perfectly constant, and an increase in temperature is equivalent to a diminution in the partial tension of the oxygen. Hence, supposing the oxide Mn_2O_3 to be heated, say in vacuum and within a close apparatus, it will give off oxygen at any temperature greater than a certain minimum t_0, and at any temperature $t_0 + \Delta t$ the gas-evolution will come to a stop as soon as the tension of the gas has come up to the critical value p corresponding to this $t_0 + \Delta t$,—p increasing with Δt.

The protoxide, MnO, is most readily obtained by heating any higher oxide to redness in a current of hydrogen gas, as a dull green powder which gets readily discoloured by oxidation in ordinary air. It is not acted on by water, but readily dissolves in aqueous acids, with formation of manganous salts.

The *sulphate*, $MnSO_4$, is prepared by making pyrolusite into a paste with concentrated sulphuric acid and then heating in a crucible to dull redness until vapours of the acid cease to come off. The ferric and aluminic sulphates (originally present) are now, at least mostly, decomposed and reduced to insoluble basic salts, so that the residue when treated with water and filtered may yield a solution free of these impurities, and, of course, of baryta.

Should any iron or alumina be left it is easily eliminated by digestion with a little carbonate of manganese (prepared from a small portion of the solution by precipitation with carbonate of soda) and filtration. Cobalt and nickel, if present, can be removed by fractional precipitation with sulphide of sodium (or H_2S in the presence of $MnCO_3$?); the black sulphide of Co or Ni comes down first, the (flesh-coloured) MnS afterwards. But lime, magnesia, and alkalies (which are frequently present) are very difficult to get rid of. Compare the section on binoxide. The salt, according to the temperature at which it crystallizes, takes up 7 or 5 or 4 or even 3 or 1 H_2O. Crystallized sulphate of manganese generally exhibits a rose-red tint; but this is owing to the presence of a trace of manganic salt (if not to cobalt salt). The pure salt is colourless.

The chloride, $MnCl_2$.—The crude chloride contained in the preparation of chlorine from the binoxide and muriatic acid is purified by methods analogous to those explained for the sulphate. This (very soluble) salt crystallizes at 15°–20° C., with $4H_2O$. To obtain real $MnCl_2$, the salt must be dehydrated in a current of dry hydrochloric acid gas.

The *carbonate*, $MnCO_3$, is obtained by precipitating the solution of the sulphate or chloride by excess of carbonate of soda on boiling. It is a white precipitate, soluble in 8000 parts of water, which, when dried in the air, gets slightly oxidized with discoloration.

Far more oxidizable is the *hydrate*, $Mn(OH)_2$, as obtained by precipitation of manganous solution by caustic alkalies. In the presence of an excess of alkali or other strong soluble base (such as lime, for instance) the oxidation progresses very rapidly, with formation, ultimately, of a black manganite $MnO_2.RO$ (*e.g.*, MnO_2CaO). This is the rationale of the famous "Weldon Process" for the recovery of the "manganese" from chlorine liquors (see BLEACHING POWDER). A mixed solution of chloride of manganese and sal-ammoniac, when mixed with ammonia, gives no precipitate; but the alkaline liquor readily absorbs oxygen from the atmosphere with formation of a brown precipitate of a higher oxide. If, immediately after addition of the ammonia, the excess of volatile alkali is chased away by boiling, the resulting (neutral or slightly acid) liquor remains clear, even in air. Hereupon is founded a method for the separation of ferric iron and alumina from manganese.

Manganic salts, *i.e.*, salts of Mn_2O_3, are produced only under very special conditions. Solutions containing the sulphate and a phosphate respectively are obtained by heating finely divided pyrolusite with strong sulphuric or phosphoric acid. Both products dissolve in water with formation of intensely purple solutions, which, however, are very unstable, showing a great tendency to pass into the manganous condition. Any manganic salt when boiled with hydrochloric acid gives manganous salt with evolution of chlorine. This tendency separates them sharply from the corresponding compounds of iron.

Manganates and permanganates (compounds with bases of the hypothetical oxides MnO_3 and Mn_2O_7).—The most important of these is the *manganate of potash*, K_2MnO_4. Four parts of very finely divided binoxide of manganese and $3\frac{1}{2}$ parts of chlorate of potash are evaporated to dryness with the solution of 5 parts of caustic potash, and the residue ignited (not fused) in platinum crucibles until all the chlorate is decomposed. The intensely green mass, containing large excess of caustic alkali, dissolves in water into an intensely green solution from which crystals of the salt K_2MnO_4 can be obtained; but when the alkali is neutralized by an acid, the liquor turns intensely purple with formation of permanganate and a precipitate of alkaliferous binoxide: $2K_2MnO_4 + 2H_2O = 2KMnO_4 + 2KHO + 2H$ and $2H + K_2MnO_4 = H_2O + K_2MnO_3$. The purple solution when alkalinized with potash contaminated with organic matter reassumes its original green colour (whence its old name of "chamæleon minerale"). For the preparation of permanganate of potash it is best to pass chlorine into the green solution, when the whole of the manganese assumes the permanganate form: $K_2MnO_4 + Cl = KCl + KMnO_4$.

From the purple liquid crystals of permanganate are easily obtained by evaporation. The crystals (long prisms) are isomorphous with perchlorate of potash, $KClO_4$. They are soluble in 16 parts of cold and far less of hot water. They are almost black, and endowed with a peculiar greenish or bluish metallic lustre. Their powder is red. Their aqueous solution is most intensely purple, one milligramme of the salt giving a perceptible colour to a whole litre and more of water. On addition of acid the solution, through liberation of Mn_2O_7, becomes pink.

Of all wet-way reagents, manganates and permanganates are the most powerful oxidizing agents, especially when they are employed in conjunction with free alkali, or (the permanganates) along with free mineral acid. By one or the other of the two combinations most oxidizable inorganic and almost all organic substances are promptly oxidized. Hence both manganates and permanganates are extensively employed as disinfectants, and, in chemical laboratories, as oxidizing agents. For the former purpose impure forms of the soda salts are generally used, while pure permanganate of potash, nowadays, is exclusively employed for scientific or analytical laboratory work.

The ultimate fate of the reagent depends on whether alkali or acid was used as an auxiliary agent. In the former case the salt passes successively into (green) manganate and (insoluble brown) hydrated binoxide of manganese,—three-sevenths of the oxygen in the Mn_2O_7 being utilized. In the presence of free acid (sulphuric works best) the Mn_2O_7 loses five-sevenths of its oxygen with formation of a *colourless* solution of manganous (MnO) salt. Hence, supposing such a change to take place promptly, and the reagent to be added gradually, the exact point of completed oxidation is reached when the liquid, by the addition of another drop of the permanganate, assumes a permanent pink colour. This is the principle of a number of processes for the determination of certain reducing agents by means of a standard solution of permanganate.

Analysis.—A manganiferous substance when fused up with carbonate of soda on platinum in the presence of air yields a green mass (manganate), the colour being more distinct after cooling. Manganese oxides, when fused up with a borax bead in the oxidizing flame, impart to it an intense amethyst colour, which disappears in the reducing flame. To detect manganese in a solution of mineral salts, we first eliminate what can be precipitated by sulphuretted hydrogen in the presence of mineral acid. In the filtrate the iron (if present) is oxidized by boiling with a granule of chlorate of potash, and the ferric oxide precipitated along with the alumina by addition of sal-ammoniac and excess of ammonia, and boiling off the free volatile alkali. From the filtrate the manganese is precipitated by sulphide of ammonium, as a sulphide which, when pure, exhibits a delicate flesh-red colour but is readily discoloured, by oxidation, when in contact with air. Cobalt, nickel, and zinc, if present, go down with the manganese, but can be eliminated by treatment of the washed sulphides with acetic acid, which dissolves the manganese only. (W. D.)

MANGEL WURZEL. See AGRICULTURE, vol. i. p. 368.

MANGO. The mango-tree (*Mangifera indica*, L., natural order *Anacardiaceæ* or *Terebinthaceæ*) is a native of tropical Asia, but during the last hundred years has been extensively cultivated in the tropical and subtropical regions of the New as well as the Old World. It grows rapidly to a height of 30 to 40 feet, and its dense, spreading, and glossy foliage would secure its cultivation for the sake of its shade and beauty alone. Its fruit, a drupe, though in the wild variety (not to be confused with that of *Spondias mangifera*, Pers., belonging to the same order, also called wild mango in India) stringy and sour from its containing much gallic acid, and with a disagreeable flavour of turpentine, has become sweet and luscious through culture and selection, to which we owe many varieties, differing not only in flavour but also in size, from that of a plum to that of an apple. When unripe, they are used to make pickles, tarts, and preserves; ripe, they form a wholesome and very agreeable dessert. In times of scarcity, the kernels also are eaten. Not only the flesh and kernel of the fruit, but also the bark and resin are of some medicinal value; and the timber, although soft and liable to decay, serves for common purposes, and, mixed with sandal wood, is employed in cremation by the Hindus. It is usually propagated by grafts, or by layering or inarching, rather than by seed. See Drury's *Useful Plants of India.*

MANGOSTEEN, *Garcinia Mangostana*, L., is a tree belonging to the gamboge order (*Clusiaceæ* or *Guttiferæ*). It is a native of the Molucca Islands, but has been introduced into the other islands of the eastern archipelago, Ceylon, and southern Asia, and even the Antilles, though not without difficulty. It grows about 20 feet high, and is somewhat fir-like in general form, but the leaves are large, oval, entire, coriaceous, and glistening. Its fruit, the much-valued mangosteen, is about the size and shape of an orange, and is somewhat similarly partitioned, but is of a reddish-brown to chestnut colour. Its thick rind yields a very astringent juice, rich in tannin, and containing a gamboge-like resin. The soft and juicy pulp is snow-white or rose-coloured, and of exceedingly delicious and subtle flavour and perfume. Being perfectly wholesome, it may be eaten freely, and administered in fever. *G. purpurea* is known in India as mate mangosteen, and *Embryopteris glutinifera*, an ebenaceous tree, as wild mangosteen. See Drury's *Useful Plants of India.*

MANGROVE. The remarkable "mangrove forests" which fringe tidal estuaries, overrun salt marshes, and line muddy coasts in the tropics of both Old and New Worlds, are composed of trees and shrubs belonging to the *Rhizophoraceæ*, a small order of calycifloral exogens, mixed, however, with the "white mangrove," *Avicennia*, a verbenaceous plant. Their trunks and branches constantly emit adventitious roots, which, descending in arched fashion, strike at some distance from the parent stem, and send up new trunks, the forest thus spreading like a banyan grove. The roots and stems afford lodgment and shelter to innumerable bivalves, crabs, and other marine animals, while the branches are inhabited by aquatic birds. A further advantage in dispersal, very characteristic of the order, is afforded by the seeds, which have a striking peculiarity of germination. While the fruit is still attached to the parent branch, the long radicle emerges from the seed and descends rapidly towards the mud, where it may even establish itself before falling off. Owing to its clubbed shape, this is always in the right position, the plumule then making its appearance. The wood of some species is hard and durable, and the astringent bark is employed in tanning. The fruit of the common mangrove, *Rhizophora Mangle*, L., is sweet and wholesome, and yields a light wine. See *Treasury of Botany*, and Lindley's *Vegetable Kingdom.*

MANICHÆISM. At the close of the 3d century three great religious systems stood opposed to one another in western Asia and the south of Europe; these were Neo-Platonism, Catholicism, and Manichæism. All three may be described as the final results reached, after a history of more than a thousand years, by the religious development of the civilized nations stretching from Persia to Italy. Each had put off the national and particular character of the ancient religions, and had become a world-religion, with universalizing tendencies, and with demands which in their effect transformed the whole of human life, both public and private. The place of national worship was taken by a system which not only aimed at being a philosophy of God, the world, and history, but at the same time embraced a definite code of ethics and a religious ritual. In point of form, then, the three religions were like each other, as they also were in this, that each had appropriated elements of older and widely different religions. Their mutual resemblance becomes still further apparent when we observe that in all three the ideas of revelation, redemption, ascetic virtue, and immortality come into the foreground. Neo-Platonism, however, was the spiritualized religion of nature, Greek polytheism transfigured and developed into Pantheism through Oriental influences and philosophical speculations; Catholicism was the monotheistic universal religion, based upon the Old Testament and the Gospel, but built up with the resources of Hellenic speculation and ethics; Manichæism was the dualistic and universal religion, founded on Chaldaism, but charged with Christian, Parsic, and perhaps Buddhistic ideas. In Manichæism the Hellenic element was wanting, in Catholicism the Chaldæo-Persian. These three universal religions were developed in the course of two centuries (*c.* 50–250 A.D.), Catholicism being the earliest and Manichæism the latest creation. To both of these, however, Neo-Platonism was from the outset inferior, because it did not possess a founder, and consequently did not develop elemental force, but retained the character of an artificial creation. Attempts were made to invent a founder for it, but these, of course, entirely failed. Catholicism, again, appears as superior to Manichæism, even if we do not look at the contents of the two religions, because it honoured its founder, not only as a bearer of revelation, but as Redeemer in His own person, and as the Son of God. The struggle of Catholicism with Neo-Platonism had been already decided by about the middle of the 4th century, though the latter maintained itself in the Greek empire for nearly two centuries longer. In its contest with Manichæism, the Catholic Church was from the outset certain of victory, being at the time the privileged church of the empire. But this rival could not be annihilated; it maintained itself both in the East and in the West, though in various forms and modifications, until far on in the Middle Ages.

Mani's life. Mani (Μάνης, Manes, Μανιχαῖος, Manichæus[1]) is said, in the *Acta Archelai*, to have originally been called "Cubricus" (according to Kessler, a corruption of "Shuraik"). Nothing reliable about his life was ever known in the Græco-Roman empire; for the account in the *Acta Archelai* is quite incredible, and shaped by the objects of its author. If criticism may succeed in showing the sources from which this account has flowed, in ascertaining the tendencies which have been at work in it, and thus in extracting some solid matter, it can only do so by starting from the Oriental, the Mohammedan, tradition, which is comparatively worthy of credence. It is therefore to the latter alone that we must apply for information. According to it, Mani was a high-born Persian of Ecbatana. The year of his birth is uncertain, but Kessler accepts as reliable the statement made by Bírúní, that Mani was born in the year 527 of the astronomers of Babylon (215–216 A.D.). He received a careful education at Ctesiphon from his father Fúták (Πατέκιος). As the father connected himself at a later period with the confession of the *Moghtasilah*, or "Baptists," in southern Babylonia, the son also was brought up in the religious doctrines and exercises of this sect. These Baptists (see the *Fihrist*) were apparently connected with the Elkesaites and the Hemerobaptists, and certainly with the Mandæans. It is not improbable that this Babylonian sect had absorbed Christian elements. Thus the boy early became acquainted with very different forms of religion. If even a small part of the stories about his father is founded on fact,—and there is no doubt that most of them are mere Manichæan legends,—it was he who first introduced Mani to that medley of religions out of which his system arose. Manichæan tradition relates that Mani received revelations while yet a boy, and assumed a critical attitude towards the religious instruction that was being imparted to him. This is the more incredible since the same tradition informs us that the boy was as yet prohibited from making public use of his new religious views. It was only when Mani had reached the age of twenty-five or thirty years that he began to proclaim his new religion. This he did at the court of the Persian king, Sapor I., and according to the story, on the coronation-day of that monarch (241–42). A Persian tradition says that he had previously been a Christian presbyter; but this is certainly incorrect. Mani did not remain long in Persia, but undertook long journeys for the purpose of spreading his religion, and also sent forth disciples. According to the *Acta Archelai*, his missionary activity extended westwards into the territory of the Christian church; but from Oriental sources it is certain that Mani rather went into Transoxania, western China, and southwards as far as India. His labours there as well as in Persia were not without result. Like Mohammed after him and the founder of the Elkesaites before him, he gave himself out for the last and highest prophet, who was to surpass all previous divine revelation, which only possessed a relative value, and to set up the perfect religion. In the closing years of the reign of Sapor I. (*c.* 270) Mani returned to the Persian capital, and gained adherents even at court. But the dominant priestly caste of the Magians, on whose support the king was dependent, were naturally hostile to him, and after some successes Mani was made a prisoner, and had then to flee. The successor of Sapor, Hormuz (272–273), appears to have been favourably disposed towards him, but Bahrám I. abandoned him to the fanaticism of the Magians, and caused him to be crucified in the capital in the year 276–7. The corpse was flayed, and Mani's adherents were cruelly persecuted by the king.

Mani's writings. Mani himself composed a large number of works and epistles, which were in great part still known to the Mohammedan historians, but are now lost. The later heads of the Manichæan churches also wrote religious treatises, so that the ancient Manichæan literature must have been very extensive. According to the *Fihrist*, Mani made use of the Persian and Syriac languages; but, like the Oriental Marcionites before him, he invented an alphabet of his own, which the *Fihrist* has handed down to us. In this alphabet the sacred books of the Manichæans were written even at a later period. The *Fihrist* reckons seven principal works of Mani, six being in the Syriac and one in the Persian language; regarding some of these we also have information in Epiphanius, Augustine, Titus of Bostra, and Photius, as well as in the formula of abjuration (Cotelerius, *PP. Apost. Opp.*, i. 543) and in the *Acta Archelai*. They are (1) *The Book of Secrets* (see *Acta Archel.*), containing discussions bearing on the Christian sects spread throughout the East, especially the Marcionites and Bardesanites, and dealing also with their conception of the Old and New Testaments; (2) *The Book of the Giants* (Demons?); (3) *The Book of Precepts for Hearers* (probably identical with the *Epistola Fundamenti* of Augustine, and with the *Book of Chapters* of Epiphanius and the *Acta Archelai*; this was the most widely spread and most popular Manichæan work, having been translated into Greek and Latin; it contained a short summary of all the doctrines of fundamental authority); (4) *The Book Sháhpúrakán* (Flügel was unable to explain this name; according to Kessler it signifies "epistle to King Sapor"; the treatise was of an eschatological character); (5) *The Book of Quickening* (Kessler identifies this work with the "Thesaurus [vitæ]" of the *Acta Archelai*, Epiphanius, Photius, and Augustine, and if this be correct, it also must have been in use among the Latin Manichæans); (6) *The Book* πραγματεία (of unknown contents); (7) a book in the Persian language, the title of which is not given in our present text of the *Fihrist*, but

[1] The name has not as yet been explained, nor is it even known whether it be of Persian or Semitic origin.

which is in all probability identical with the "holy gospel" of the Manichæans (mentioned in the *Acta Archel.* and many other authorities). It was this work which the Manichæans set up in opposition to the Gospels. Besides these principal works, Mani also wrote a large number of smaller treatises and epistles. The practice of writing epistles was continued by his successors. These Manichæan dissertations also became known in the Græco-Roman empire, and existed in collections.[1] There also existed a Manichæan book of memorabilia, and of prayers, in Greek, as well as many others,[2] all of which were destroyed by the Christian bishops acting in conjunction with the authorities. A Manichæan epistle, addressed to one Marcellus, has, however, been preserved for us in the *Acta Archelai.*[3]

ni- æan stem.

Though the leading features of Manichæan doctrine can be exhibited clearly even at the present day, and though it is undoubted that Mani himself drew up a complete system, many details are nevertheless uncertain, since they are differently described in different sources, and it often remains doubtful which of the accounts that have been transmitted to us represents the original teaching of the founder.

The Manichæan system is one of consistent, uncompromising dualism, in the form of a fantastic philosophy of nature. The physical and the ethical are not distinguished, and in this respect the character of the system is thoroughly materialistic; for when Mani coordinates good with light, and evil with darkness, this is no mere figure of speech, but light is actually the only good, and darkness the only evil. From this it follows that religious knowledge can be nothing else than the knowledge of nature and her elements, and that redemption can only consist in a physical process of freeing the element of light from the darkness. Under such circumstances ethics becomes a doctrine of abstinence in regard to all elements which have their source within the sphere of darkness.

The self-contradictory character of the present world forms the point of departure for Mani's speculations. This contradiction presents itself to his mind primarily as elemental, and only in the second instance as ethical, inasmuch as he considers the sensual nature of man to be the outflow of the evil elements in nature. From the contradictory character of the world he concludes the existence of two beings, originally quite separate from each other—light and darkness. Each is to be thought of according to the analogy of a kingdom. Light presents itself to us as the good primal spirit (God, radiant with the ten [twelve] virtues of love, faith, fidelity, high-mindedness, wisdom, meekness, knowledge, understanding, mystery, and insight), and then further as the heavens of light and the earth of light, with their guardians the glorious æons. Darkness is likewise a spiritual kingdom (more correctly, it also is conceived of as a spiritual and feminine personification), but it has no "God" at its head. It embraces an "earth of darkness." As the earth of light has five tokens (the mild zephyr, cooling wind, bright light, quickening fire, and clear water), so has the earth of darkness also five (mist, heat, the sirocco, darkness, and vapour). Satan with his demons was born from the kingdom of darkness. These two kingdoms stood opposed to each other from all eternity, touching each other on one side, but remaining unmingled. Then Satan began to rage, and made an incursion into the kingdom of light, into the earth of light. The God of light, with his syzygy, "the spirit of his right hand," now begot the primal man, and sent him, equipped with the five pure elements, to fight against Satan. But the latter proved himself the stronger, and the primal man was for a moment vanquished. And, although the God of light himself now took to the field, and with the help of new æons (the spirit of life, &c.), inflicted total defeat upon Satan, and set the primal man free, the latter had already been robbed of part of his light by the darkness, and the five dark elements had already mingled themselves with the generations of light. It only remained now for the primal man to descend into the abyss, and prevent the further increase of the generations of darkness by cutting off their roots; but he could not immediately separate again the elements that had once mingled. These mixed elements are the elements of the present visible world, which was formed from them at the command of the God of light. The forming of the world is in itself the beginning of the deliverance of the imprisoned elements of light. The world is represented as an orderly structure of various heavens and various earths, which is borne and supported by the æons, the angels of light. It possesses in the sun and moon, which are in their nature almost quite pure, large reservoirs, in which the portions of light that have been rescued are stored up. In the sun dwells the primal man himself, as well as the glorious spirits which carry on the work of redemption; in the moon the mother of life is enthroned. The twelve constellations of the zodiac form an ingenious machine, a great wheel with buckets, which pour into the sun and moon, those shining ships that sail continually through space, the portions of light set free from the world. Here they are purified anew, and attain finally to the kingdom of pure light and to God Himself. The later Western Manichæans termed those portions of light which are scattered throughout the world—in its elements and organisms—awaiting their deliverance, the *Jesus patibilis.*

It is a significant mark of the materialistic and inhuman character of the system that, while the formation of the world is considered as a work of the good spirits, the creation of man is referred to the princes of darkness. The first man Adam was engendered by Satan in conjunction with "sin," "cupidity," "desire." But the spirit of darkness drove into him all the portions of light he had stolen, in order to be able to dominate them the more securely. Hence Adam is a discordant being, created in the image of Satan, but carrying within him the stronger spark of light. Eve is given him by Satan as his companion. She is seductive sensuousness, though also having in her a small spark of light. But if the first human beings thus stood entirely under the dominion of the devil, the glorious spirits took them under their care from the very outset, sending æons down to them (including Jesus), who instructed them regarding their nature, and in particular warned Adam against sensuality. But this first man fell under the temptation of sexual desire. Cain and Abel indeed are not sons of Adam, but of Satan and Eve; Seth, however, who is full of light, is the offspring of Adam by Eve. Thus did mankind come into existence, its various members possessing very different shares of light, but the men having uniformly a larger measure of it than the women. In the course of history the demons sought to bind men to themselves by means of sensuality, error, and false religions (among which is to be reckoned above all

[1] A βιβλίον ἐπιστολῶν is spoken of in the formula of abjuration, and an *Epistola ad virginem Menoch* by Augustine. Fabricius has collected the "Greek fragments of Manichæan Epistles" in his *Bibliotheca Græca* (vii. p. 311 *sq.*).

[2] The *Canticum amatorium* is cited by Augustine.

[3] Zittwitz assumes that this epistle was in its original form of much larger extent, and that the author of the *Acts* took out of it the matter for the speeches which he makes Mani deliver during his disputation with Bishop Archelaus. The same scholar traces back the account by Turbo in the *Acts*, and the historical data given in the fourth section, to the writings of Turbo, a Mesopotamian, who is assumed to have been a Manichæan renegade and a Christian. But as to this difference of opinion is at least allowable.

the religion of Moses and the prophets), while the spirits of light carried on their process of distillation with the view of gaining the pure light which exists in the world. But these good spirits can only save men by imparting to them the true *gnosis* concerning nature and her forces, and by calling them away from the service of darkness and sensuality. To this end prophets, preachers of true knowledge, have been sent into the world. Mani, following the example of the gnostic Jewish Christians, appears to have held Adam, Noah, Abraham (perhaps Zoroaster and Buddha) to be such prophets. Probably Jesus was also accounted a prophet who had descended from the world of light,—not, however, the historical Jesus, the devilish Messiah of the Jews, but a contemporaneous phantom Jesus, who neither suffered nor died (*Jesus impatibilis*). According to the teaching of some Manichæans, it was the primal man who disseminated the true gnosis in the character of Christ. But at all events Mani himself, on his own claim, is to be reckoned the last and greatest prophet, who took up the work of Jesus impatibilis and of Paul (for he too finds recognition), and first brought full knowledge. He is the "leader," the "ambassador of the light," the "Paraclete." It is only through his agency and that of his imitators "the elect," that the separation of the light from the darkness can be completed. The system contains very fantastic descriptions of the processes by which the portions of light when once set free finally ascend even to the God of light. He who during his lifetime did not become one of the elect, who did not completely redeem himself, has to go through a severe process of purification on the other side of the grave, till he too is gathered to the blessedness of the light. It is erroneous, however, to ascribe, as has been done, a doctrine of transmigration to the Manichæans. Of course men's bodies as well as the souls of the unsaved, who according to the oldest conception have in them no light whatever, fall under the sway of the powers of darkness. A later view, adapted to the Christian one, represents the portions of light in the unsaved as actually becoming lost. When the elements of light have at last been completely, or as far as possible, delivered from the world, the end of all things comes. All glorious spirits assemble, the God of light himself appears, accompanied by the æons and the perfected just ones. The angels supporting the world withdraw themselves from their burden, and everything falls in ruins. A tremendous conflagration consumes the world; the perfect separation of the two powers takes place once more; high above is the kingdom of light, again brought into a condition of completeness, and deep below is the (? now powerless) darkness.

Ethics, social polity, and worship of the Manichæans.

On the basis of such a cosmical philosophy, ethics can only have a dualistic ascetic character. Manichæan ethics is not merely negative, however, since it is necessary to cherish, strengthen, and purify the elements of light, as well as free oneself from the elements of darkness. The aim is not self-destruction, but self-preservation; and yet the ethics of Manichæism appears in point of fact as thoroughly ascetic. The Manichæan had above all to refrain from sensual enjoyment, shutting himself up against it by three seals, the *signaculum oris*, *manus*, and *sinus*. The *signaculum oris* forbids all eating of unclean food (which included all bodies of animals, wine, &c.,—vegetable diet being allowed because plants contained more light, though the killing of plants, or even plucking their fruit and breaking their twigs, was not permitted), as well as all impure speech. The *signaculum manus* prohibits all traffic with things generally, in so far as they carry in them elements of darkness. Finally by the *signaculum sinus* every gratification of sexual desire, and hence also marriage, is forbidden. Besides all this, life was further regulated by an exceedingly rigorous system of fasts. Certain astronomical conjunctions determined the selection of the fast-days, which in their total number amounted to nearly a quarter of the year. Sunday was regularly solemnized as one, and the practice was also generally observed on Monday. Hours of prayer were determined with equal exactness. The Manichæan had to pray four times a day, each prayer being preceded by ablutions. The worshipper turned towards the sun, or the moon, or the north, as the seat of light; but it is erroneous to conclude from this, as has been done, that in Manichæism the sun and moon were themselves objects of worship. Forms of prayer used by the Manichæans have been preserved to us in the *Fihrist*. The prayers are addressed to the God of light, to the whole kingdom of light, to the glorious angels, and to Mani himself, who is apostrophized in them as "the great tree, which is all salvation." According to Kessler, these prayers are closely related to the Mandæan and the ancient Babylonian hymns. An asceticism so strict and painful as that demanded by Manichæism could only be practised by few; hence the religion must have abandoned all attempts at an extensive propaganda, had it not conceded the principle of a twofold morality. A distinction was made in the community between the *Electi* (*Perfecti*), the perfect Manichæans, and the *Catechumeni* (*Auditores*), the secular Manichæans. Only the former submitted themselves to all the demands made by their religion; for the latter the stringency of the precepts was relaxed. They had to avoid idolatry, sorcery, avarice, falsehood, fornication, &c.; above all, they were not allowed to kill any living being (the ten commandments of Mani). They had also to free themselves as much as possible from the world; but in truth they lived very much as their non-Manichæan fellow-citizens. We have here essentially the same condition of things as in the Catholic Church, where a twofold morality was also in force, that of the religious orders and that of secular Christians,—only that the position of the electi in Manichæism was a more distinguished one than that of the monks in Catholicism. For, after all, the Christian monks never quite forgot that salvation is given by God through Christ, whereas the Manichæan electi were actually themselves redeemers. Hence it was the duty of the auditores to pay the greatest respect and most assiduous attention to the electi. These "perfect ones," wasting away under their asceticism, were objects of admiration, and of the most elaborate solicitude.[1] Food was presented to them in abundance, and by their eating it the electi set free the portions of light from the vegetables. They prayed for the auditores, they blessed them and interceded for them, thereby shortening the process of purification the latter had to pass through after death. It was only the electi, too, who possessed full knowledge of religious truths, a point of distinction from Catholicism.

The distinction between electi and auditores, however, does not exhaust the conception of the Manichæan Church; on the contrary, the latter possessed a hierarchy of three ranks, so that there were altogether five gradations in the community. These were regarded as a copy of the ranks of the kingdom of light. At the head stood the *teachers* ("the sons of meekness," Mani himself and his successors); then follow the *administrators* ("the sons of knowledge," the bishops); then the *elders* ("the sons of understanding," the presbyters); the *electi* ("the sons of mystery"); and finally the *auditores* ("the sons of

[1] Analogous to this is the veneration in which the Catholic monks and the Neo-Platonic "philosophers" were held, but the prestige of the Manichæan electi was greater than that of the monks and the philosophers.

insight"). The number of the electi must always have been small. According to Augustine the teachers were twelve, and the bishops seventy-two in number. One of the teachers appears to have occupied the position of superior at the head of the whole Manichæan Church. At least Augustine speaks of such a personage, and the *Fihrist* also has knowledge of a chief of all Manichæans. The constitution, therefore, had a monarchic head.

The worship of the Manichæans must have been very simple, and must have essentially consisted of prayers, hymns, and ceremonies of adoration. This simple service promoted the secret dissemination of their doctrines. The Manichæans too, at least in the West, appear to have adapted themselves to the church's system of festivals. The electi celebrated special feasts; but the principal festival with all classes was the "Bema" (βῆμα) the feast of the "teacher's chair," held in commemoration of the death of Mani in the month of March. The faithful prostrated themselves before an adorned but empty chair, which was raised upon a podium of five steps. Long fasts accompanied the feasts. The Christian and Mohammedan historians could learn little of the Manichæan mysteries and "sacraments," and hence the former charged them with obscene rites and abominable usages. It may be held as undoubted that the later Manichæans celebrated mysteries analogous to Christian baptism and the Lord's Supper, which may have rested upon ancient consecration rites and other ceremonies, instituted by Mani himself and having their origin in nature worship.

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From the foregoing account it will be evident, as indeed from modern investigation it is certain, that Manichæism did not originate on Christian ground. It would be more proper to speak of Mohammedanism than of Manichæism as a Christian sect; for Mohammed stands in a far closer relation to the Jewish and Christian religions than did Mani. It is Kessler's merit to have shown that the ancient Babylonian religion, the original source of all the gnosis of western Asia, was the basis of the Manichæan system. Hence the erroneousness of the assumption, which formerly prevailed, that Manichæism was a reform movement of Parsism, a modification of Zoroastrianism under the influence of Christianity. Manichæism is a system which rather belongs to the Semitic group of religions. It is the Semitic religion of nature, withdrawn from national limits, modified by Christian and Persian elements, elevated into a gnosis, and transforming human life by the influence of stringent regulations. But the recognition of this fact only supplies us with a very general explanation of the origin of Manichæism. The question still remains, through what channels and to what extent Mani adopted those Persian and Christian elements, and further, in what form the ancient nature religion of Babylonia was utilized by him. As far as the latter point is concerned it is known that, two centuries before Mani, the Semitic nature-religions had already been taken up by various enthusiastic or speculative spirits, who had given them philosophic depth and moulded than into "systems," which were propagated with the aid of mysterious rites. Mani's undertaking, then, was by no means a novel one, but was rather the last in a long series of similar efforts. Again, even in the earlier of these attempts, from that of Simon Magus onward, Christian elements had been adopted to a greater or less extent; and the sects of the Christian gnostic schools of Syria and western Asia may all be traced back to the nature-religions of ancient Semitism, transformed into a philosophy of the world and of life. It is the Babylonian sect of the Moghtasilah that seems to have furnished Mani with the matter of his religious philosophical speculations, and the religion of this sect was purely Semitic (see MANDÆANS; the Mandæans were related to the Moghtasilah). This was the source of the thorough-going dualism which forms the basis of Mani's system; for the ancient Persian religion was not essentially dualistic, but was at bottom monistic, since Ahriman is created by Ormuzd. At the same time Mani turned the theologumena of ancient Persia also to account. The fact that the two opposed elements are called "light" and "darkness" can hardly be independent of Parsism, and Manichæism uses other *termini technici* of the Persian religion. Whether Mani's idea of redemption is to be traced to the ancient Babylonian or to the Zoroastrian religion we do not venture to decide. The idea of "the prophet" and "the primal man" is at all events Semitic.

It is very difficult to determine what was the extent of Mani's knowledge of Christianity, how much he himself borrowed from it, and through what channels it reached him. In any case it is certain that Manichæism, in those districts where it was brought much into contact with Christianity, became additionally influenced by the latter at a very early period. The Western Manichæans of the 4th and 5th centuries are much more like Christians than their Eastern brethren. In this respect Manichæism experienced the same kind of development as Neo-Platonism. As regards Mani himself, it is safest to assume that he held both Judaism and Catholic Christianity to be entirely false religions. It is indeed true that he not only described himself as the promised Paraclete—for this designation probably originated with himself—but also conceded a high place in his system to "Jesus;" we can only conclude from this, however, that he distinguished between Christianity and Christianity. The religion which had proceeded from the historical Jesus he repudiated together with its founder, and Catholicism as well as Judaism he looked upon as a religion of the devil. But he distinguished between the Jesus of darkness and the Jesus of light who had lived and acted contemporaneously with the former. This distinction agrees with that made by the gnostic Basilides no less strikingly than the Manichæan criticism of the Old Testament does with that propounded by the Marcionites (see the *Acta Archelai*, in which Mani is made to utter the antitheses of Marcion). Finally the Manichæan doctrines exhibit points of similarity to those of the Christian Elkesaites; but, as it is possible, and even probable, that such resemblances are to be ascribed to a common ancient Semitic source, they do not here call for further consideration. The historical relation of Mani to Christianity is then as follows. From Catholicism, which he very probably had no detailed knowledge of, he borrowed nothing, rejecting it as devilish error. On the other hand, he looked upon what he considered to be Christianity proper, that is, Christianity as it had been developed among the sects of Basilidians, Marcionites, and perhaps Bardesanites, as a comparatively valuable and sound religion. He took from it, however, as from the Persian religion, hardly anything but names, and, perhaps we may add, a criticism of the Old Testament and of Judaism so far as he required it. Indications of the influence of Marcionitism are found in the high estimation in which Mani held the apostle Paul, and in the fact that he explicitly rejects the Book of Acts. Mani appears to have given recognition to a portion of the historical matter of the Gospels, and to have interpreted it in accordance with his own doctrine. In conclusion, it remains to be asked whether Buddhistic elements can also be detected in Manichæism. Most modern scholars since F. C. Baur have answered this question in the affirmative. According to Kessler, Mani made use of the teaching of Buddha, at least as far as ethics was concerned. It cannot be doubted that Mani, who undertook long journeys as far as India, knew of Buddhism. The name Buddha (Buddas) which occurs in the legendary account of Mani, and perhaps in the latter's own writings, indicates further that he had occupied his attention with Buddhism when engaged in the work of founding his new religion. But his borrowings from this source must have been quite insignificant. A detailed comparison shows the difference between Buddhism and Manichæism in all their principal doctrines to be very great, while it becomes evident that the points of resemblance are almost everywhere accidental. This is also true of the ethics and the asceticism of the two systems. There is not a single point in Manichæism which demands for its explanation an appeal to Buddhism. Such being the case, the relationship between the two religions remains a mere possibility, a possibility which the inquiry of Geyler (*Das System des Manichæismus und sein Verhältniss zum Buddhismus*, Jena, 1875) has not been able to elevate into a probability.

How are we to explain the rapid spread of Manichæism, and the fact that it really became one of the great religions? One answer is that Manichæism was the most complete gnosis, the richest, most consequent, and most artistic system formed on the basis of the ancient Babylonian religion (so Kessler). This explanation is insufficient, for no religion operates mainly through the perfection of its system of doctrine; and it is not strictly correct, for the older gnostic systems were not less richly equipped than the Manichæan. What gave strength to Manichæism was rather that it united an ancient mythology and a thoroughgoing materialistic dualism with an exceedingly simple spiritual worship and a strict morality. On comparing it with the Semitic religions of nature, we perceive that it retained their mythologies, after transforming them into "doctrines," but abolished all their sensuous cultus, substituting instead a spiritual worship as well as a strict morality. Manichæism was thus able to satisfy the new wants of an old world. It offered revelation, redemption, moral virtue, and immortality, spiritual benefits on the basis of the religion of nature. A further source of strength lay in the simple yet firm social organization which was given by Mani himself to his new institution. The wise man and the ignorant, the enthusiast and the man of the world, could all find acceptance here, and there was laid on no one more than he was able and willing to bear. Each one, however, was attached and led onward by the prospect of a higher rank to be attained, while the intellectually gifted had an additional inducement in the assurance that they did not require to submit themselves to any authority, but would be led to God by pure reason. Thus adapted from the first to individual requirements, this religion also showed itself able to appropriate from time to time foreign elements. Originally furnished from fragments of various religions, it could increase or diminish this possession without rupturing its own elastic framework. And, after all, great adaptability is just as necessary for a universal religion as a divine founder in whom the highest revelation of God Himself may be seen and reverenced. Manichæism indeed, though it applies the title "redeemer" to Mani, has really no knowledge of a redeemer, but only of a physical and gnostic process of redemption; on the other hand, it possesses in Mani the supreme prophet of God. If we consider in conclusion that Manichæism gave a simple, apparently profound and yet convenient solution of the problem of good and evil, a problem that had become peculiarly oppressive to the human race in the 2d and 3d centuries, we shall have named the most important factors which account for the rapid spread of the system.

Manichæism first gained a firm footing in the East, *i.e.*, in Persia, Mesopotamia, and Transoxania. The persecutions it had to endure did not hinder its extension. The seat of the Manichæan pope was for centuries in Babylon, at a later period in Samarkand. Even after the conquests of Islam the Manichæan Church continued to maintain itself, indeed it seems to have become still more widely diffused by the victorious campaigns of the Mohammedans, and it frequently gained secret adherents among the latter themselves. Its doctrine and discipline underwent little change in the East; in particular, it drew no nearer to the Christian religion. More than once, however, Manichæism experienced attempts at reformation; for of course the auditores very easily became worldly in character, and movements of reformation led temporarily to divisions and the formation of sects. Towards the close of the 10th century, at the time the *Fihrist* was written, the Manichæans in Mesopotamia and Persia had already been in large measure ousted from the towns, and had withdrawn to the villages. But in Turkestan, and as far as the Chinese frontier, there existed numerous Manichæan communities, and even whole tribes that had adopted the name of Mani. Probably it was the great migrations of the Mongolian race that first put an end to Manichæism in Central Asia. But even in the 15th century there were Manichæans living beside the Thomas-Christians on the coast of Malabar in India (see Germann, *Die Thomas-Christen*, 1875). Manichæism first penetrated the Greek-Roman empire about the year 280, in the time of the emperor Probus (see the *Chronicon* of Eusebius). If we may take the edict of Diocletian against the Manichæans as genuine, the system must have gained a firm footing in the West by the beginning of the 4th century, but we know that as late as about the year 325 Eusebius had not any accurate knowledge of the sect. It was only subsequent to about 330 that Manichæism spread rapidly in the Roman empire. Its adherents were recruited on the one hand from the old gnostic sects (especially from the Marcionites,—Manichæism exerted besides this a strong influence on the development of the Marcionite churches of the 4th century), on the other hand from the large number of the "cultured," who were striving after a "rational" and yet in some manner Christian religion. Its polemics and its criticism of the Catholic Church now became the strong side of Manichæism, especially in the West. It admitted the stumbling-blocks which the Old Testament offers to every intelligent reader, and gave itself out as a Christianity without the Old Testament. Instead of the subtle Catholic theories concerning divine predestination and human freedom, and instead of a difficult theodicæa, it offered an exceedingly simple conception of sin and goodness. The doctrine of the incarnation of God, which was especially objectionable to those who were going over to the new universal religion from the old cults, was not proclaimed by Manichæism. In its rejection of this doctrine Manichæism agreed with Neo-Platonism; but, while the latter, notwithstanding all its attempts to conform itself to Christianity, could find no formula by which to inaugurate within its own limits the special veneration of Christ, the Western Manichæans succeeded in giving their teaching a Christian tinge. The only part of the Manichæan mythology that became popular was the crude, physical dualism. The barbaric elements were judiciously screened from view as a "mystery;" they were, indeed, here and there explicitly disavowed even by the initiated. The further Manichæism advanced into the West, the more Christian and philosophic did it become. In Syria it maintained itself in comparative purity. In North Africa it found its most numerous adherents, gaining secret support even among the clergy. The explanation of this perhaps lies in the fact that one part of the population of North Africa was of Semitic origin. Augustine was an

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auditor for nine years, while Faustus was at that time the most esteemed Manichæan teacher in the West. Augustine in his later writings against the Manichæans deals chiefly with the following problems:—(1) the relation between knowledge and faith, and between reason and authority; (2) the nature of good and evil, and the origin of the latter; (3) the existence of free will, and its relation to the divine omnipotence; (4) the relation of the evil in the world to the divine government.

The Christian Byzantine and Roman emperors, from Valens onwards, enacted strict laws against the Manichæans. But at first these bore little fruit. The auditores were difficult to trace out, and besides they really gave little occasion for persecution. In Rome itself between 370 and 440 Manichæism gained a large amount of support, especially among the scholars and public teachers. It also made its way into the life of the people by means of a popular literature in which the apostles were made to play a prominent part (*Apocryphal Acts of the Apostles*). Manichæism in the West had also some experience of attempts at reformation from the ascetic side, but of these we know little. In Rome Leo the Great was the first who took energetic measures, along with the state authorities, against the system. Valentinian III. decreed banishment against its adherents, Justinian the punishment of death. In North Africa Manichæism appears to have been extinguished by the persecution of the Vandals. But it still continued to exist elsewhere, both in the Byzantine empire and in the West, and in the earlier part of the Middle Ages it gave an impulse to the formation of new sects, which remained related to it. And, if it has not been quite proved that so early as the 4th century the Priscillianists of Spain were influenced by Manichæism, it is at least undoubted that the Paulicians and Bogomiles as well as the Catharists and the Albigenses are to be traced back to Manichæism (and Marcionitism). Thus the system, not indeed of Mani the Persian, but of Manichæism as modified by Christian influences, accompanied the Catholic Church until the 13th century.

Sources.—(*a*) Oriental. Among the sources for a history of Manichæism, the most important are the Oriental. Of these the Mohammedan, though of comparatively late date, are distinguished by the excellent manner in which they have been transmitted to us, as well as by their impartiality. They must be named first, because ancient Manichæan writings have been used in their construction, while, with the exception of some small and rather unimportant pieces, we possess no other original Manichæan works dating from the 3d century. At the head of all stands En-Nedím, *Fihrist* (*circa* 980), edited by Flügel (1871–72); comp. the latter's work *Mani, seine Lehre u. seine Schriften*, 1862. See also Shahrastání, *Kitáb al-milal wan-nuhal* (12th cent.), edited by Cureton (1846) and translated into German by Haarbrücker, 1851, and individual notes and excerpts by Tabarí (10th cent.), Al-Bírúní (11th cent.), and other Arabian and Persian historians.

Of the Christian Orientals those that afford most information are Ephraem Syrus (ob. 373), in various writings; the Armenian Esnik (see *Zeitsch. f. hist. Theol.*, 1840, ii.; Langlois, *Collection*, ii. 375 *sq.*), who wrote in the 5th century against Marcion and Mani; and the Alexandrian patriarch Eutychius (*ob.* 916), *Annales*, ed. Pococke, 1628. There are besides scattered pieces of information in Aphraates (4th cent.), Barhebræus (13th cent.), and others.

(*b*) Greek and Latin. The earliest mention of the Manichæans in the Græco-Roman empire is to be found in an edict of Diocletian (see Hänel, *Cod. Gregor.*, tit. xv.), which is held by some to be spurious, while others assign it to one or other of the years 287, 290, 296, 308 (so Mason, *The Persec. of Diocl.*, p. 275 *sq.*). Eusebius gives a short account of the sect (*H. E.*, vii. 31). It was the *Acta Archelai*, however, that became the principal source on the subject of Manichæism for Greek and Roman writers. These *Acta* are not indeed what they give themselves out for, viz., an account of a disputation held between Mani and the bishop Archelaus of Cascar in Mesopotamia; but they nevertheless contain much that is trustworthy, especially regarding the doctrine of Mani, and they also include Manichæan documents. They consist of various distinct pieces, and originated in the beginning of the 4th century, probably at Edessa. They were translated as early as the first half of the same century from the Syriac (as is maintained by Jerome, *De Vir. Illust.*, 72; though this is doubted by modern scholars) into Greek, and soon afterwards into Latin. It is only this secondary Latin version that we possess (edited by Zacagni, 1698; Routh, *Reliq. Sac.*, vol. v., 1848; translated in Clark's *Ante-Nicene Library*, vol. xx.); small fragments of the Greek version have been preserved. Regarding the *Acta Archelai*, see Zittwitz in *Zeitschr. f. d. histor. Theol.*, 1873, and Oblasinski, *Acta disp. Arch. et Manetis*, 1874. In the form in which we now possess them, they are a compilation after the pattern of the *Clementine Homilies*, and have been subjected to manifold redactions. These *Acta* were used by Cyril of Jerusalem (*Catech.*, 6), Epiphanius (*Hær.*, 66), and a great number of other writers. All the Greek and Latin heresiologists have included the Manichæans in their catalogues; but they seldom adduce any independent information regarding them (see Theodoret, *Hær. fab.*, i. 26). Important matter is to be found in the resolutions of the councils from the 4th century onwards (see Mansi, *Acta Concil.*, and Hefele, *Conciliengeschichte*, vol. i.–iii.), and also in the controversial writings of Titus of Bostra (6th cent.), Πρὸς Μανιχαίους (ed. Lagarde, 1859), and of Alexander of Lycopolis, Λόγος πρὸς τὰς Μανιχαίου δόξας (ed. Combefis; transl. in *Ante-Nic. Lib.*, vol. xiv. Of the Byzantines, the most worthy of mention are John of Damascus (*De Hæres.* and *Dialog.*) and Photius (*cod.* 179 *Biblioth.*). The struggle with the Paulicians and the Bogomiles, who were often simply identified with the Manichæans, again directed attention to the latter. In the West the works of Augustine are the great repertory for information on the subject of Manichæism (*Contra epistolam Manichæi, quam vocant fundamenti*; *Contra Faustum Manichæum*; *Contra Fortunatum*; *Contra Adimantum*; *Contra Secundinum*; *De actis cum Felice Manichæo*; *De Genesi c. Manichæos*; *De natura boni*; *De duabus animabus*; *De utilitate credendi*; *De moribus eccl. cathol. et de moribus Manichæorum*; *De hæres.*). The more complete the picture, however, which may here be obtained of Manichæism, the more cautious must we be in making generalizations from it, for it is beyond doubt that Western Manichæism adopted Christian elements which are wanting in the original and in the Oriental Manichæism.

Literature.—The most important works on Manichæism are Beausobre, *Hist. critique de Manichée et du Manichéisme*, 2 vols., 1734 *sq.* (the Christian elements in Manichæism are here strongly, indeed too strongly, emphasized); Baur, *Das manich. Religionssystem*, 1831 (in this work Manichæan speculation is exhibited from a speculative standpoint); Flügel, *Mani*, 1862 (a very careful investigation on the basis of the *Fihrist*); Kessler, *Untersuchung zur Genesis des manich. Religionssystems*, 1876; and the article "Mani, Manichäer," by the same writer in Herzog-Plitt's *R.E.*, ix. 223–59. This article is very thorough, and leads to most favourable expectations regarding the author's forthcoming work. The accounts of Mosheim, Lardner, Walch, and Schröckh, as well as the monograph by Trechsel, *Ueber Kanon, Kritik, und Exegese der Manichäer*, 1832, may also be mentioned as still useful. The various researches which have been made regarding Parsism, the ancient Semitic religions, Gnosticism, &c., are of the greatest importance for the investigation of Manichæism. (A. HA.)

MANILA (less correctly MANILLA), the capital of Luzon and the Philippine Islands, and the centre of Spanish commerce in the East, was founded by Legaspí in 1571, and is situated on the eastern shore of a circular bay 120 nautical miles in circumference, 14° 36′ N. lat. and 120° 52′ E. long. The country around the bay is more or less flat in character, and in the dry season almost bare of vegetation, so that, excepting the Mafonso and Matéo mountains behind Manila, and the chains of mountains running north and south of the entrance to the bay, there is really nothing attractive about the harbour. It is unsafe in the north-east and south-west monsoons, and vessels over 300 tons have to run for shelter to the naval port of Cavité, the smaller craft finding a safe anchorage behind a breakwater facing the mouth of the Pasig. A new breakwater, however, was commenced in 1880 for large vessels. This river Pasig, which is about 14 miles long, is fed by an inland lake called the Laguna de Bayo, and on its way into the harbour it divides Manila into two parts. On its northern bank are large commercial warehouses, a bazaar occupied chiefly by Chinese, known as the Escolta, and trending eastwards an extensive suburb of native dwellings extending some miles up the Pasig. Beyond the Escolta lie Binondo, the business part of Manila, and San Miguel, the fashionable quarter where Spaniards and foreigners have their residence, and where since the earthquake of 1880 two palaces have been erected for the governor or captain-general and for the admiral of the fleet. There are numerous churches and barracks in this part of the town, and several public buildings, of which the following may be mentioned,—the hospital of St Lazarus, the *garnero* or large military storehouse, and the famous cigar factory, covering a space of about 6 acres, and employing daily 10,000 women. Beyond and blending as it were with Binondo are villages in which the governor has his country house, and where Europeans have built pretty villa residences. A stone bridge and a new suspension bridge connect Binondo or modern Manila with the suburb opposite and the old fort of St Iago, situated on the south bank and about a mile from the mouth of the Pasig. Within the fort wall lies the old city, or, as it is commonly called, the Plaza de Manila. It is approached by several gates—the principal being the Entrada, near which stands the custom-house. It has several squares, and the streets running at right angles with each other are fairly broad and clean, but, as no trade is carried on in this part of the town, they are dull by day, and, as only oil lamps are used, gloomy by night. The public edifices, such as the governor's palace, the town-hall, and the cathedral, are in a large square, in the centre of which is a statue of Charles IV. surrounded by a garden of flowers. To these may be added the civil and military hospitals, the mint and museum, the university and the academy of arts, the arsenal, the prison, and numerous barracks, convents, and monasteries. Beyond the walls is the *calzada* or esplanade, with a small *paseo* or promenade facing the bay, where three or four military bands play twice a week to a large concourse of people. This forms the chief out-door attraction for the élite of Manila. There are two theatres—occasionally visited by European companies; but there is a want of the cafés and bull fights so associated with Spanish life. Evening receptions are given by the Spaniards, where cards and music serve to while away the time, and the well-to-do *Tagalo*, besides imitating his masters in all their amusements, has another to which he is passionately addicted, viz., cock-fighting. This is under Government control, and in town can only be held in licensed cockpits, which in 1878 yielded above £33,000 to the revenue. The native officials may sometimes be a little officious and overbearing; but the natives generally, especially those out of Manila, are as hospitable to the stranger as the Spaniard.

The population in the walled town, inclusive of the garrison, is given in the consular reports for 1880 as 12,000, and that of Binondo and the suburbs as 250,000 to 300,000. In 1842 the total was rather more than 150,000.

The climate is healthy, and though hot is not unbearably so, the mean temperature being about 82°·6 Fahr. The hot season prevails from March to the end of June; the rest of the year may be said to be showery and stormy. The chief climatic drawbacks to a residence in Manila are hurricanes, earthquakes, and fearful thunderstorms. Great damage was done to property by a tornado of exceptional severity in October 1882.

The cemetery of Manila is well suited for a hot climate and the backward condition of its sanitary arrangements. It is a large circular area, surrounded by an outer and an inner wall, with horizontal recesses between them placed one above another in tiers. On the arrival of a body for sepulture it is taken out of its coffin and put into one of these recesses; quicklime is then spread upon it and the mouth of the recess bricked up. If the recess is the property of the relatives of the dead, the body remains undisturbed for ever. If otherwise, it remains until the recess is absolutely required for another inmate, when the bones, the only remains left of the deceased, are collected and carefully deposited in a large hollow or fosse kept for that purpose.

For two centuries after the Spanish settlement the trade of Manila with the Western world was carried on *via* Acapulco and Mexico; and it was not till 1764 that even the Spanish vessels began to come round by the Cape. The port, however, was opened with some restrictions to foreign vessels in 1789; permission for the establishment of an English commercial house was granted in 1809; the same liberty was before long extended to other nationalities; and in 1834 the privileges of the Royal Company of the Philippines expired and left the commercial movement to its natural tendencies. Since that time the trade of Manila has greatly increased. While in 1840 the port was entered by 187 vessels with a burden of about 57,000 tons, the corresponding figures for 1881 are, including 182 steamers, 317 vessels (British, 118; Spanish, 95; German, 38), with a burden of 244,000 tons. Manila hemp (*abaca*), sugar, cigars, and coffee are the chief articles of export; and sapan wood, mother of pearl, and gum are regular though secondary items. The quantity of hemp shipped at Manila has increased from 528,206 piculs (1 picul=139 lb) in 1877 to 662,886 in 1881, and in the same period the quantity of sugar has risen from 1,215,066 piculs to 2,001,310. Britain and the United States are the great markets for both. The average number of cigars exported is 92,620,000, the greater proportion going to Singapore and China. The total value of the exports was £5,460,000 in 1881, against £2,679,000 in 1864; and a corresponding increase has taken place in the imports.

Telegraphic communication between Manila and Hong-Kong was established in 1880.

MANILA HEMP, the most valuable of all fibres for cordage, is the produce of the leaf-stalks of *Musa textilis*, a native of the Philippine Islands. The plant, called *abaca* by the islanders, throws up a spurious stem from its rhizome, consisting of a cluster of sheathing leaf-stalks which rise to a height of from 20 to 30 feet, and spread out into a crown of huge undivided leaves characteristic of the various species of *Musa* (plantain, banana, &c.). In its native regions the plant is rudely cultivated solely as a source of fibre; it requires little attention, and when about three years old develops flowers on a central stem, at which stage it is in the most favourable condition for yielding fibre. The stock is then cut down, and the sheathing stalks torn asunder and reduced to small strips. These strips in their fresh succulent condition are drawn between a sharp knife-edged instrument and a hard wooden block to which it is fixed, and by repeated scraping in this way the soft cellular matter which surrounds the fibre is removed, and the fibre so cleaned has only to be hung up to dry in the open air, when, without further treatment, it is ready for use. Each stock yields, on an average, a little under 1 lb of fibre; and two natives cutting down plants and separating fibre will prepare not more than 25 lb per day. The fibre yielded by the outer layer of leaf-stalks is hard, fully developed, and strong, but the produce of the inner stalks is increasingly thin, fine, and weak. The finer fibre is used by the natives, without spinning or twisting (the ends of the single fibres being knotted together), for making exceedingly fine, light, and transparent yet comparatively strong textures, which they use as articles of dress and ornament. The hemp exported for cordage purposes is a somewhat woody fibre, of a bright brownish-white colour, and possessing great durability and strain-resisting power. It contains a very considerable amount of adherent pectinous matter, and an unusually large proportion, as much as 12 per cent., of water in a dry condition. In a damp atmosphere the fibre absorbs moisture so freely that it has been found to contain not less than 40 per cent. of water, a circumstance which dealers in the raw fibre should bear in mind. The plant has been introduced into many tropical lands; but the cheapness of labour in its native regions, and its abundance there, prevent its being a profitable substance for general cultivation. The entire supply comes from Manila and Cebu in the Philippine Islands, where its cultivation and preparation must give employment to a very large population. The exports, which are increasing with great rapidity, amounted in 1881 to about 400,000 bales of $2\frac{1}{2}$ cwts. each, almost the whole of which goes to the United Kingdom, the United States, and the Australian colonies. The quantity imported into the United Kingdom in 1881 was 346,908 cwts., valued at £678,514. The fibre is now so valuable that manila hemp cordage is freely adulterated by manufacturers, chiefly by admixture of phormium (New Zealand flax) and Russian hemp.

MANILIUS, a Roman poet, was the author of a poem in five books called *Astronomica.* Nothing is recorded of the author; he is neither quoted nor mentioned by any ancient writer. His very name is uncertain, but was probably Marcus Manilius. From the work itself it may be gathered with much probability that the writer lived under Augustus or Tiberius, and that he was a citizen of and resident in Rome. He bears the name of a distinguished plebeian family. His work is one of great learning; he had studied his subject in the best writers, and generally represents the most advanced views of the ancients on astronomy. It is, however, destitute of poetical or literary merit. It is difficult to explain how a work of such learning on a subject which was studied with such interest by the ancients should have remained so neglected. Firmicus, who wrote in the time of Constantine, has so many points of resemblance with the work of Manilius that he must either have used him or have followed some work that Manilius also followed. As Firmicus says that hardly any Roman except Cæsar, Cicero, and Fronto had treated the subject, it is probable that he did not know the work of Manilius. The latest event referred to in the poem is the great defeat of 9 A.D.

MANIN, DANIELE (1804–1857), president of the Venetian republic in 1848–49, and one of the principal founders of Italian independence, was born in Venice on the 13th May 1804. He studied at Padua, graduating as doctor of laws when only seventeen years of age, and soon after translated Pothier's large treatise *Sur le Droit Romain.* To his father, an eminent barrister, he was indebted not only for much of his skill in jurisprudence but for his strong republican bias, having as a boy constantly heard him denounce indignantly the injustice of Bonaparte in handing Venice over to Austria by the scandalous treaty of Campio Formio. In 1830 Manin commenced practice as an advocate, but only to become conscious of the harsh restrictions laid by Austria upon the administration of law. That and the following year showed some stirrings of political life in Italy; and Manin, already the leading spirit in Venetia of the new national party, strove to train his countrymen to united purpose and action. The question of a railway to Milan, for instance, or whether the Indian mail should go by Venice, was utilized to quicken the patriotic instinct by thwarting the Government, and that without neglecting the great principle "legality and publicity"—which till 1848 was his unswerving rule of conduct.

In 1847 he spoke ably on political economy at the scientific congress held in Venice, and soon after presented two petitions to the "congregation,"—a shadowy deliberative assembly which was tolerated by Austria. His principal demands were—separate government of Venice and Lombardy, revision of the code, an annual budget, freedom of the press, and religious equality. On the 18th January 1848, soon after Radetsky's cruel treatment of Milan, he was arrested, but only to intensify the patriotic enthusiasm of the people. The population of Venice marched past his prison silently and mournfully, every head uncovered. The carnival (that year spent in gloom) was scarcely over, however, when the glad news from Sicily, Naples, and Paris so worked upon their minds that the Austrian authorities were forced to feel that the revolutionary wave had reached Venice. On the 17th March Manin was carried in triumph to the Place St Mark, and virtually declared dictator. Now that the moment for action was come he immediately formed a civic guard, and by his energy and earnestness inspired all classes of the citizens to act as one man. On the 22d the dictator became president of the new republic of St Mark, to cope alone with all the difficulties of administration, organization, and finance. In March 1849, on the defeat of King Charles Albert, Venice had to prepare herself resolutely for defence; and on the 2d April there was passed in the palace of the Doges a decree in two clauses:— "(1) Venice will resist the Austrians at whatever cost; (2) the president Manin is invested with unlimited powers." On the 26th May one outlying fort was taken, but on the 3d July, when Rome and Mazzini had succumbed to the French, Venice and Manin were still strenuous in their heroic defence. Only when cholera had also attacked them, when food and ammunition were spent and people were dying of hunger, when every house not burned down was riddled by the shot and shell of the bombardment, and no gleam of hope from without was visible, was the capitulation signed, 24th August, on terms of amnesty to all except the president and thirty-nine other citizens.

Leaving Venice on the 27th, with his wife and two children, Manin spent the rest of his life in Paris, where he maintained a modest independence by teaching his native language. His energies were still devoted to the unification of Italy, so that, whether as a republic or as a kingdom, she might be freed from Austrian domination. He died of heart disease on the 22d September 1857, and was buried in the family tomb of Ary Scheffer. In 1868 the remains were removed to Venice, and honoured with a public funeral.

See Henri Martin, *D. Manin*, 1859, and *L'Unité Italienne*, 1861 (Martin also wrote the article in the *Biogr. Universelle*); C. L. Chassin, *Manin et l'Italie*; Errera's *Vita di D. Manin*, Venice, 1872; P. de La Faye's *Documents, &c., de D. Manin*, 1860. Other writers are Ernest Legouvé, A. de La Forge, and Edmund Flagg (New York).

MANIOC or MANDIOC. See CASSAVA and ARROWROOT.

MANIPUR, a native state in north-eastern India, lying between 24° 35′ and 24° 48′ 30″ N. lat., and between 93° and 94° 40′ E. long., is bounded on the N. by the Nága country and the hills overlooking the Assam valley, on the W. by Cáchár district, and on the E. by Independent Burmah. On the south the boundary is undefined, and abuts on the country inhabited by various independent wild hill tribes of Lushais, Kukis, &c. The state consists of an extensive valley, estimated at about 650 square miles in extent, and a large surrounding unsurveyed tract of difficult mountainous country stretching between Assam, Cáchár, Burmah, and Chittagong. The total area is estimated at about 7600 square miles. The population of the Manipur valley and the surrounding hills is supposed to be about 74,000 hill-men and 65,000 Manipuris. The hill ranges generally run north and south, with occasional connecting spurs and ridges of lower elevation between. Their greatest altitude is in the north, where they reach to upwards of 8000 feet above sea-level. The principal geographical feature in the valley is the Logtak Lake, an irregular sheet of water of considerable size, but said to be yearly growing smaller. The valley is watered by numerous rivers, the Bárak being the most important. The hills are densely clothed with tree jungle and large forest timber. There are large herds of wild elephants, as well as tigers, leopards, bears, buffaloes, &c. The country seems to be singularly free from poisonous snakes; the cobra does not appear to exist in the valley, but the boa constrictor is found in the dense forests to the south.

The first relations of the British with Manipur date from 1762, when the rájá solicited British aid to repel a Burmese invasion, and a treaty was entered into. The force was recalled, and but little communication between the two countries took place until 1824, on the outbreak of the first British Burmese war. British assistance was again invoked by the rájá, and the Burmese were finally expelled both from the Assam and Manipur valleys. A political agent acts as a means of communication between the state and the British Government. Manipur valley appears to have been originally occupied by several tribes which came from different directions. Although their general facial characteristics are Mongolian, there is a great diversity of feature among the Manipuris, some of them showing a regularity approaching the Aryan type. In the valley the people are chiefly Hindus, that religion being apparently of recent introduction. They have a caste system of their own, different from that of India, and chiefly founded on what is known as the system of *lallûp* or forced labour. Every male between the ages of seventeen and sixty is obliged to place his services at the disposal of the state for a certain number of days each year, and to different classes of the people different employments are assigned. About four hundred Mohammedan families, descendants of settlers from Bengal, reside to the east of the capital. The aboriginal hill-men belong to one of the two great divisions of Nágas and Kukis, and are subdivided into innumerable clans and sections with slight differences in language, customs, or dress. The state is noted for the excellence of its breed of ponies. The now popular English game of polo was introduced from Manipur, where it forms a great national pastime. The trade is but small, owing chiefly to the want of means of transport, none of the roads being available for wheeled carts.

MANIS. See PANGOLIN.

MANISA, or MANISSA, a town of Asia Minor or Anatolia, situated on the north side of Mount Sipylus, 28 miles northeast of Smyrna. This town was anciently called *Magnesia ad Sipylum* (see MAGNESIA). It is situated on the banks of the Hermus, and is noted as being one of the neatest and cleanest cities in Asia Minor. It contains above twenty mosques, two of which are adorned on the exterior with double minarets, and in the inside with paintings and other articles. The Armenians, Greeks, and Jews have also their respective places of worship. There is also a fine khan, and a citadel, which stands on a lofty rock, and commands an extensive view. The surrounding country is rich and productive, especially of saffron, which is exported. The town is the seat of some considerable trade, and many of the inhabitants are employed in the manufacture of cotton and silk goods and goats' hair shawls. Population about 40,000. The town is now connected with Smyrna by a railway, which is continued on to Ala-Shehr (Philadelphia). A few miles from Manisa is a colossal statue cut in the rock, which is generally supposed to be the figure of Niobe, alluded to by ancient authors.

MANISTEE, a city of the United States, the county seat of Manistee county, Michigan, is situated 135 miles north-west of Lansing, on the east side of Lake Michigan, at the mouth of the Manistee river, which is navigable for vessels drawing 10 to 12 feet of water for the distance of $1\frac{1}{2}$ miles to Manistee Lake. It is a great seat of the lumber trade, shipping annually 200,000,000 feet of timber, and having a score of saw-mills and about as many shingle mills, the latter of which produce in the year 400,000,000 shingles,—the largest quantity made at any one place in the world. Planing-mills and foundries are also maintained; and, in consequence of the discovery in 1881 of a bed of solid salt 30 feet thick, extensive salt factories are being built. The surrounding district is especially adapted for fruit-growing; and sportsmen are attracted to the Manistee river and its tributaries by the abundance of the rarely found grayling. The population, 3373 in 1870, was 7080 in 1880.

MANITOBA, one of the western provinces of the Dominion of Canada, is situated midway between the Atlantic and the Pacific coasts of the Dominion, about 1090 miles due west of Quebec (see vol. iv. plate xxxv.). It is bounded on the S. by the parallel 49° N. lat., which divides it from the United States; on the W. by 101° 20′ W. long; on the N. by 52° 50′ N. lat.; and on the E. by the western boundary of Ontario. Manitoba formerly belonged to the HUDSON'S BAY COMPANY (*q.v.*), and was, after the transfer of their territory to Canada, admitted in 1870 as the fifth province of the Dominion. At that time the infant province had an area of 13,500 square miles, and some 12,000 people, chiefly Indian half-breeds. In 1881 the limits were increased to the extent indicated above, and now contain, taking the Lake of the Woods as the eastern boundary, upwards of 80,000 square miles, an area only 8782 square miles less than that of England and Scotland together, extending 264 miles from north to south and upwards of 300 from east to west. The old district of Assiniboia, the result of the efforts in colonization by the earl of Selkirk in 1811 and succeeding years, was the nucleus of the province. Manitoba was so called by the Dominion parliament after the lake of that name; the designation is usually considered to be a compound of the Ojibway words, Manito, great spirit, and Waba, straits between lakes, or a word meaning echo.

The drainage of Manitoba is entirely north-eastward to Hudson's Bay. The three lakes—whose greatest lengths are 250, 150, and 130 miles respectively—are Winnipeg, Winnipegoosis, and Manitoba. They are all of a very varying and irregular shape, but average respectively 30, 18, and 10 miles in width. They are fresh, shallow, and tideless. Winnipegoosis and Manitoba at high water, in spring time, discharge their overflow through small streams into Winnipeg. The chief rivers emptying into Lake Winnipeg are the Winnipeg, the Red, and the Saskatchewan. The Assiniboine river, with its source in the province, and navigable from 250 to 350 miles for steamers of light draught, enters the Red river 45 miles from Lake Winnipeg, and at the confluence of the rivers ("The Forks") is situated the city of Winnipeg. The Winnipeg, which flows from the territory lying southeast of Lake Winnipeg, is a noble river some 200 miles long, that after leaving Lake of the Woods, dashes with its clear water over many cascades, and traverses very beautiful scenery. At its falls from Lake of the Woods is one of the greatest and most easily utilized water-powers in the world. Like most rivers in the New World, the Red river is at intervals of years subject to freshets. In the seventy years' experience of the Selkirk colonists there have been four "floods." The highest level of the site of the city of Winnipeg is said to have been under 5 feet of water for several weeks in May and June in 1826, under $2\frac{1}{2}$ feet in 1852, not covered in 1861, and only under water on the lowest levels in 1882. The extent of overflow has thus on each occasion been less. The loose soil on the banks of the river is every year carried away in great masses, and the channel has so widened as to render the recurrence of an overflow unlikely. The Saskatchewan, though not in the province, empties into Lake Winnepeg less than half a degree from the northern boundary. It is a mighty river, rising in the Rocky Mountains, and crossing eighteen degrees of longitude. Near its mouth are the Grand Rapids. Above these, steamers ply to Fort Edmonton, a point upwards of 800 miles north-west of the city of Winnipeg. Steamers run from Grand Rapids, through Lake Winnipeg, up Red river to the city of Winnipeg.

Geologically Manitoba may be said to be the resumption of the Secondary rocks left behind in the fertile portions of Ontario. The whole north-east of North America, running from Labrador, crossing the Ottawa, and skirting the Georgian Bay and Lake Superior, is a region of Laurentian or Primary rocks—containing copper, silver, and probably gold-bearing rocks. From Lake Superior north-westward to within 40 miles of Red river and up to the eastern shore of Lake Winnipeg the same region continues for about 500 miles, including near its western limits the Lake of the Woods. This barren region left behind, the fertile plains of Manitoba begin—a district resting on Silurian limestones. For 100 or 150 miles these rocks continue. This is the first prairie steppe. At very few points does an outcrop of limestone occur. A range of hills running from south-east to north-west bounds this region on the west. These are Pembina Mountains, Riding Mountains, and Duck Mountain, varying from 200 to 700 feet in height. Before the Riding Mountains are reached, on the shores and islands of Lakes Manitoba and Winnipegoosis are found a few buff-coloured Devonian limestones. From this line of hills westward spreads out the second prairie steppe, extending some 400 or 500 miles. Beyond this for an equal distance, at a still higher elevation, is the third prairie steppe, till the Rocky Mountains are reached. From the Pembina and Riding Mountains to the Rocky Mountains, say 1000 miles, Cretaceous beds underlie the plains and crop out at long intervals. The most striking feature of this formation, of which only the eastern 100 or 150 miles are within Manitoba, is the presence of coal. It is, like most of the Tertiary varieties, a lignite; a specimen analysed gives water 7·82 per cent., volatile combustible matter 31·35 per cent., fixed carbon 54·97 per cent., and ash 5·86 per cent. The supply of this coal is, according to Professor Selwyn, practically inexhaustible. Mr G. M. Dawson, Government explorer, has figured exposures of lignite 1 foot, 7 feet, and even 18 feet in thickness in the Souris valley, 250 miles south-west of Winnipeg. As a fuel for domestic purposes, this coal in general answers very well. The drift deposit on the first and second prairie levels varies from 20 to 100 feet, and consists of clay and boulders. A clay lying near the surface is used for making the white brick of which Winnipeg is built. The most recent geologic deposit is a rich vegetable mould, sometimes 4 feet in thickness. It is this that gives the reputation for fertility which the soil of the province enjoys.

The surface of Manitoba is somewhat level and monotonous. It is chiefly a prairie region, with treeless plains of from 5 to 40 miles extent, covered in summer with an exuberant vegetable growth, which dies every year. The river banks are, however, fringed with trees, and in the more undulating lands the timber belts vary from a few hundreds of yards to 5 or 10 miles in width, forming at times forests of no inconsiderable size. The chief trees of the country are the aspen (*Populus tremuloides*), the ash-leaved maple (*Negundo aceroides*), oak (*Quercus alba*), elm (*Ulmus americana*), and many varieties of willow. The strawberry, raspberry, currant, plum, cherry, and grape are indigenous.

The climate of Manitoba, being that of a region of wide extent and of similar conditions, is not subject to frequent variations. Winter, with cold but clear and bracing weather, usually sets in about the middle of November, and ends with March. In April and May the rivers have opened, the snow has disappeared, and the opportunity has been afforded the farmer of sowing his grain. The month of June is often wet, but most favourable for the springing crops; July and August are warm, but, excepting two or three days at a time, not uncomfortably so; while the autumn months of August and September are very pleasant. Harvest generally extends from the middle of August to near the end of September. The chief crops of the farmer are wheat (which from its flinty hardness and full kernel is the specialty of the Canadian north-west), oats, barley, and pease. Hay is made of the native prairie grasses, which grow luxuriantly. From the richness and mellowness of the soil potatoes and all tap-roots reach a great size. Heavy dews in summer give the needed moisture after the rains of June have ceased. The traveller and farmer are at times annoyed by the mosquito. This troublesome insect is chiefly found near swampy ground or on the uncultivated prairie. It usually continues through June and July.

The population of the province is very mixed. In 1870 there were 2000 whites and 10,000 Indian half-breeds. Of the latter, one half are of English-speaking parentage, and chiefly of Orkney origin; the remainder are known as Metis or Bois-brûlés, and are descended from French-Canadian voyageurs. In 1875 a number of Russian Mennonites (descendants of the Anabaptists of the Reformation) came to the country. Some fifty years ago they originally emigrated from Germany to the plains of southern Russia, but came over to Manitoba to escape the conscription. They number nearly 8000. About 4000 French Canadians, who had emigrated from Quebec to the United States, have also made the province their home, as well as a number of Icelanders. The remainder of the population is chiefly made up of English-speaking people from the other provinces of the Dominion, from the United States, from England and Scotland and the north of Ireland. Though somewhat difficult to estimate, the population of Manitoba is estimated by competent authorities at upwards of 120,000 in 1882.

In 1881 the religious opinions of the people were as follows:—Episcopalians, 22 per cent; Presbyterians, 22; Roman Catholics, 19; Methodists, 14; Baptists, 2½; Lutherans, 1½ per cent.

There is a system of primary and secondary free school education for Protestants, and another for Roman Catholics. For the higher education there are the three colleges of St Boniface (Roman Catholic), St John's (Episcopalian), and Manitoba College (Presbyterian). These are affiliated to the university of Manitoba, which is an examining and degree-conferring body.

Like other provinces of the Dominion, Manitoba is under a lieutenant-governor, with a council of five ministers responsible to the local legislature, which again is composed of thirty-one members. The province is represented by three senators in the Dominion senate, and by five members in the Dominion house of commons. There are three judges of the superior court, and a number of county court judges. The whole province is divided into municipalities, each of which chooses a warden and six councillors annually.

The city of Winnipeg, the provincial centre of government, law, education, and religion, had in 1882 upwards of 20,000 inhabitants. The trade of the country has chiefly grown up since Winnipeg was connected in 1878 with the United States railroad system, and it has received a further impulse from the construction of the Canadian Pacific Railway, which traverses the territory. (G. BR.)

MANITOWOC, a city of the United States, the county seat of Manitowoc county, Wisconsin, is situated on the west side of Lake Michigan, at the mouth of Manitowoc river, 77 miles north of Milwaukee by the Milwaukee, Lake Shore, and Western Railway. It has a good harbour, and is the seat of an active trade in lumber, leather, and wheat. Shipbuilding is also extensively carried on. Population in 1870, 3059; in 1880, 6367.

MANKATO, a city of the United States, the county seat of Blue Earth county, Minnesota, is situated in the midst of a good agricultural district on the right bank of the Minnesota river, and is a station on the Chicago, Milwaukee, and St Paul, the Chicago and North Western, and the Chicago, St Paul, Minneapolis, and Omaha railways. From St Paul it is distant 86 miles. Besides carrying on an extensive trade Mankato manufactures woollen goods, linseed oil, flour, beer, carriages and waggons, iron wares, and furniture. It has a fine park and fair ground, three public halls, a public library, and a State normal school. The population increased from 3482 in 1870 to 5550 in 1880.

MANLEY, MARY DE LA RIVIER (1672–1724), dramatist, political writer, and novelist, the most eminent female "wit" of the reign of Queen Anne, was the daughter of a studious and literary royalist, Sir Roger Manley, governor of the Channel Islands, part author of *The Turkish Spy*, and author of several military histories. Mrs Manley is herself the chief authority for such particulars of her private life as are known. Towards the close of Anne's reign, finding that Curll had announced *The Adventures of Rivella, or the History of the Author of Atalantis*, and suspecting this to be the work of an enemy, she contrived with dexterous tact to supplant Curll's author, and wrote her own biography under the announced title. Her mother died when she was a child, her father when she was a girl of sixteen. A kinsman, already married, took advantage of her position, went through a mock ceremony of marriage, and deserted her basely three years afterwards. She was patronized for a short time by the duchess of Cleveland, and in 1696 made good a position among writers of established reputation by two plays, a comedy and a tragedy. The dialogue of the comedy, *The Lost Lover*, is extremely brilliant and witty, overflowing with high animal spirits; in freedom of speech it goes almost beyond the most licentious male writers of comedy in that generation. The play was at once published. In the preface she thanks the town for not keeping her long in suspense: her comedy was damned with promptitude. A similar fate befel her tragedy, *The Royal Mischief*, though great literary power was shown in it. The splendid energy of the characters, and the hyperbolical vigour of their language, may be compared with the undisciplined youth of the Elizabethan drama; but it was not without reason that even contemporary critics complained of the "warmth" of certain passages. She pleaded in defence the example of Dryden; but Dryden in his most indecent moments falls short of it. From 1696 Mrs Manley was a favourite member of witty and fashionable society; she admits that she never had any pretensions to beauty, but the charms of her eyes and her conversation made her very fascinating. She achieved her principal triumph as a writer by her *Secret Memoirs of Several Persons of Quality*, a scandalous chronicle "from the New Atalantis, an island in the Mediterranean," published in 1709. Henceforth she was known as "the author of *Atalantis*." The *Atalantis* had a political purpose. Mrs Manley was a warm Tory partisan, and she sought in this scandalous narrative to expose the private vices of the ministers whom Swift, Bolingbroke, and Harley combined to drive from office. There are many references to her in Swift's *Journal to Stella*. "She has very good principles for one of her sort, and a great deal of good sense and invention." Mrs Manley was in fact one of the most romantically public-spirited and disinterested politicians of that corrupt time, and next to Swift the most effective writer on the side of Harley and Bolingbroke. During the keen political campaign in 1711 she wrote several pamphlets, and many numbers of the *Examiner*, criticizing persons and policy with equal vivacity. After the accession of George, she wrote a tragedy *Lucius* (1717)—a failure, and two so-called novels, *Bath Intrigues*, and *A Stage-Coach Journey to Exeter*. The story in these novels is told in letters between the principal characters.

MANLIUS is the name of a Roman gens, chiefly patrician, but, in later times at least, also containing plebeian families. The Roman historians represent them as intrepid, but stern even to cruelty.

I. Marcus Manlius Capitolinus, a brave and distinguished soldier, was one of the garrison of the Capitol while besieged by the Gauls; when they attempted to scale the rock by night, Manlius, aroused by the cackling of the sacred geese, rushed to the spot and threw down the foremost. Several years after, seeing a centurion led to prison for debt, he freed him with his own money, and even sold his estate to relieve other poor debtors, while he accused the senate of embezzling public money. He was charged with aspiring to kingship, and condemned by the comitia, but not until the assembly had adjourned to a place without the walls, where they could no longer see the Capitol which he had saved. His house on the Capitol was razed, and the Manlii resolved that no patrician Manlius should henceforth bear the name of Marcus.

II. Titus Manlius Imperiosus Torquatus went to the tribune Pomponius, who had brought his father to trial for overstepping the limits of his office, and threatened to kill him unless he desisted from the accusation (365 B.C.). Shortly after he slew a gigantic Gaul in single combat, and took from him a torques or neck-ornament, whence his surname is said to have been derived. When the Latins demanded an equal share in the government of the confederacy, Manlius vowed to kill with his own hand the first Latin he saw in the senate-house. The Latins and Campanians revolted, and Manlius, consul for the third time, marched into Campania and gained two great victories, near Vesuvius (where Decius his colleague devoted himself to gain the day), and at Trifanum. In this campaign Manlius executed his own son, who had killed an enemy in single combat, and thus disobeyed the express command of the consuls.

Both these Manlii belong to a great extent to legend, much of which is probably due to attempts to explain their surnames.

III. Titus Manlius Torquatus in his first consulship (235 B.C.) subjugated Sardinia, recently acquired from the Carthaginians; he was consul again (224) during the Gallic war. In 216 he opposed the ransoming of the Romans taken prisoners at Cannæ; and in 215 he was sent to Sardinia and defeated a Carthaginian attempt to regain possession of the island.

IV. Cnæus Manlius Vulso, consul in 189 B.C., received Asia as his province. Starting from Ephesus in the spring, he marched into Pamphylia, levying enormous contributions. He then attacked the Celts of Galatia on the pretext that they had aided Antiochus. They took refuge in Mounts Olympus and Magaba, but the missiles of the Roman light troops won each position with great slaughter. In the winter, assisted by ten delegates sent from Rome, he settled the terms of peace with Antiochus. He returned to Rome in 187, and triumphed after much opposition. The discipline of his army was loose, and his soldiers brought into Rome many foreign luxuries.

MANN, Horace, one of the best-known of American educationists, was born at Franklin, Massachusetts, May 4, 1796, and died at Yellow Springs, Ohio, August 2, 1859. His childhood and youth were passed in great poverty. "It was the misfortune of his family that it belonged to the smallest district, had the poorest schoolhouse, and employed the cheapest teachers, in a town which was itself small and poor." His health was early injured by hard manual labour, which left him no time for recreation either in summer or winter. He lost his father at the age of thirteen. He was from his childhood an eager reader; but his only means of gratifying this desire was a very small library in his native town. Up to the age of fifteen he had never been able to attend school for more than eight or ten weeks in any one year. He remained at home, working for his mother and the rest of the family, till the age of twenty. At that age he was taught the rudiments of Latin and Greek and a little English grammar by an itinerant schoolmaster, and entered the junior classes in Brown University in the year 1816. Symptoms of consumption, poverty, the necessity of supporting himself while at college, and other circumstances interfered with his studies. He, however, graduated in 1819. In 1821 he entered the school of law at Litchfield, Connecticut, and was called to the bar in 1823. In 1827 he was elected to the State legislature of Massachusetts, and in 1833 he was returned to the upper house. He suggested and organized the State lunatic asylum of Worcester. In 1837 the legislature appointed a board of education to revise and reorganize the common school system of the State; and Mann was appointed secretary. To give his whole time to the work, he gave up his profession and also his seat in the senate. He was secretary for twelve years. For these twelve years he worked fifteen hours a day, held teachers' conventions, gave lectures, and carried on an enormous correspondence. He started a periodical, *The Common School Journal*, in which he explained his views on education. He also published a series of *Annual Reports*; these American critics call "a classic on the subject." His seventh annual report gave the substance of his observations in Europe, and compared the systems of instruction followed in Prussia with those in use in Massachusetts, much to the disadvantage of the latter.[1]

In 1848 Mann was elected to Congress to fill the vacancy caused by the death of John Quincy Adams. He tried to induce the Government to establish a bureau of education at Washington, but this was not done till much later. He resigned his seat in Congress in 1853, and became the first president of Antioch College, at Yellow Springs,—a college for the combined education of men and women. Mann's chief work in American education is the reform which he brought about in the common and normal school system of Massachusetts; and this reform is largely due to his twelve annual reports.

Mann's other works are—*Lectures on Education*, 1848; *A Few Thoughts for a Young Man*, 1850; *Slavery, Letters and Speeches*, 1851; *Powers and Duties of Women*, 1853, &c. A complete edition of his writings, with a biography, was published in Cambridge, Massachusetts, in 1867; and a selection, under the title of *Thoughts Selected from the Writings of Horace Mann*, in 1869.

MANNA, a concrete saccharine exudation obtained by making incisions in the trunk of the flowering or manna ash tree, *Fraxinus Ornus*, L. At the present day the manna of commerce is collected exclusively in Sicily from cultivated trees, chiefly in the districts around Capaci, Carini, Cinisi, and Favarota, small towns 20 to 25 miles west of Palermo, and in the townships of Geraci, Castelbuono, and other places in the district of Cefalù, 50 to 70 miles east of Palermo. In the *frassinetti* or plantations the trees are placed about 7 feet apart, and after they are eight years old, and the trunk at least 3 inches in diameter, the collection of manna is begun. This operation is performed in July or August during the dry weather, by making transverse incisions $1\frac{1}{2}$ to 2 inches long, and about 1 inch apart, through the bark, one cut being made each day, the first at the bottom of the tree, another directly above the first, and so on. In succeeding years the process is repeated on the untouched sides of the trunk, until the tree has been cut all round and exhausted. It is then cut down, and a young plant arising from the same root takes its place. The finest or flaky manna appears to have been allowed to harden on the stem. A very superior kind, obtained by allowing the juice to encrust pieces of wood or straws inserted in the cuts, and called *manna a cannolo*, is not found in commerce in England. The fragments adhering to the stem after the finest flakes have been removed are scraped off, and form the small or Tolfa manna of commerce. That which flows from the lower incisions is often collected on tiles or on a concave piece of the prickly pear (*Opuntia*), but is less crystalline and more glutinous, and is less esteemed.

Manna of good quality dissolves at ordinary temperatures in about 6 parts of water, forming a clear liquid. Its chief constituent is mannite or manna sugar, a hexatomic alcohol, $C_6H_8(OH)^6$, which likewise occurs, in much smaller quantity, in certain species of *Fucus* and in plants of several widely separated natural orders. Of this substance the best manna contains 70 to 80 per cent. It crystallizes in shining rhombic prisms from its solution in boiling alcohol. Manna possesses mildly laxative properties, and on account of its sweet taste is employed as a mild aperient for children. It is less used in England now than formerly, but is still largely consumed in South America. In Italy mannite is prepared for sale in the shape of small cones resembling loaf sugar in shape, and is frequently prescribed in medicine instead of manna.

The manna of the present day appears to have been unknown before the 15th century, although a mountain in Sicily with the Arabic name Gibelman, *i.e.*, "manna mountain," appears to point to its collection there during the period that the island was held by the Saracens, 827–1070. In the 16th century it was collected in Calabria in Italy, and until recently was produced in the Tuscan Maremma, but neither from that locality nor from the States of the Church is any now brought into commerce, although the name of Tolfa, a town near Civita Vecchia, is still applied to an inferior variety of the drug.

Various other kinds of manna are known, but none of these have been found to contain mannite. Alhagi manna (Persian and Arabic *tar-angubín*) is the produce of *Alhagi camelorum*, Fisch., a small, spiny, leguminous plant, growing in Persia, Afghanistan, and Baluchistan. This manna occurs in the form of small, roundish, hard, dry tears, varying from the size of a mustard seed to that of a coriander, of a light-brown colour, sweet taste, and senna-like odour. The spines and pods of the plant are often mixed with it. It is collected near Kandahar and Herat, and imported into India from Cabul and Kandahar to the extent of about 2000 ℔. annually, and is valued, at about thirty shillings per ℔. Tamarisk manna (Persian *gaz-angubín*, tamarisk honey) exudes in June and July from the slender branches of *Tamarix gallica*, var. *mannifera*, Ehrenb., in the form of honey-like drops, which, in the cool temperature of the early morning, are found in the solid state. This secretion is caused by the puncture of an insect, *Coccus manniparus*, Ehrenb. In the valleys of the peninsula of Sinai, especially in the Wády el-Sheikh, this manna (Arabic *man*) is collected by the Arabs and sold to the monks of St Catherine, who supply it to the pilgrims visiting the convent. It is found also in Persia and the Punjab, but does not appear to be collected in any quantity. This kind of manna seems to be alluded to by Herodotus (vii. 31). Under the same name of *gaz-angubín* there are sold commonly in the Persian bazaars round cakes, of which a chief ingredient is a manna obtained to the south-west of Ispahan, in the month of August, by shaking the branches or scraping the stems of *Astragalus florulentus* and *A. adscendens*, Boiss. and Hausskn.[2] *Shírkhist*, a kind of manna known to writers on materia medica in the 16th century, is still found in the bazaars of north-west India, being imported from Afghanistan and Turkestan to a limited extent. Haussknecht states that it is the produce of *Cotoneaster nummularia*, Fisch. and Mey. (*Rosaceæ*), and *Atraphaxis spinosa*, L. (*Polygonaceæ*), and that it is brought chiefly from Herat.

Oak manna, according to Haussknecht, is collected from the twigs of *Quercus Vallonea*, Kotschy, and *Q. persica*, Jaub. and Spach, on which it is produced by the puncture of an insect during the month of August. This manna occurs in the state of agglutinated tears, and forms an object of some industry among the wandering tribes of Kurdistan at the present day. It is collected before sunrise, by shaking the grains of manna on to linen cloths spread out beneath the trees, or by dipping the small branches in hot water and evaporating the solution thus obtained. A substance collected by the inhabitants of Laristan from *Pyrus glabra*, Boiss., strongly resembles oak manna in appearance.

Australian manna is found on the leaves of *Eucalyptus viminalis*, Lab.; the Lerp manna of Australia is of animal origin.

Briançon manna is met with on the leaves of the common LARCH (*q.v.*), and a kind of manna was at one time obtained from the cedar, but none of these are now collected for commercial purposes.

The manna of Scripture, notwithstanding the miraculous circumstances which distinguish it in the Biblical narrative from anything now known, answers in its description very closely to the tamarisk manna.

See *Pharmacographia*, p. 409; Hanbury, *Science Papers*, p. 355–368; Stewart, *Punjab Plants*, Lahore, 1869, pp. 57–92; Geoffroy, *Mat. Med.*, ii. (1741) p. 584; Dobson, *Proc. Roy. Soc. Van Diemen's Land*, i. (1851) p. 234.

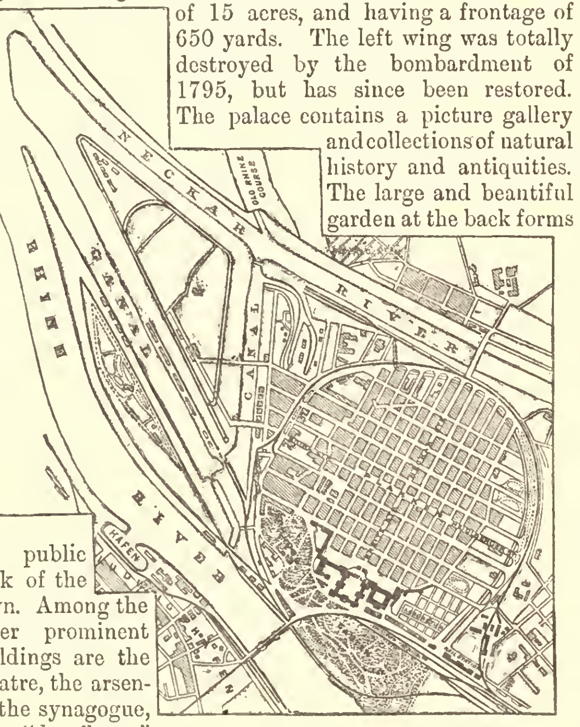
MANNHEIM, the most populous town and the second capital of the grand-duchy of Baden, lies on the right bank of the Rhine, in the triangular piece of low-lying ground enclosed between that river and the Neckar. It

[1] This report has been published and edited, with preface and notes, by Dr W. B. Hodgson, under the title of *Report of an Educational Tour in Germany, France, Holland, and parts of Great Britain and Ireland*, London, 1846.

[2] See *Bombay Lit. Tr.*, vol. i. art. 16, for details as to the gaz-angubín. A common Persian sweetmeat consists of wheat-flour kneaded with manna into a thick paste.

is the most regularly built town in Germany, consisting of twelve parallel streets intersected at right angles by ten others, which cut it up into about 130 square sections of equal size. These blocks are distinguished, after the American fashion, by letters and numerals. Except on the south side all the streets debouch on the promenade, which forms a circle round the town on the site of the old ramparts. Outside this ring are the suburbs of Schwetzinger Gärten to the south and Neckargärten to the north. Mannheim is connected by a handsome bridge with Ludwigshafen, a rapidly growing commercial and manufacturing town on the left bank of the Rhine, in Bavarian territory. The Neckar is spanned by a suspension bridge. In 1880 Mannheim contained 53,545 inhabitants, of whom about 4500 were Jews, and the rest Roman Catholics and Protestants in nearly equal proportions. Ludwigshafen contained 15,012 inhabitants.

Nearly the whole of the south-west side of the town is occupied by the palace, built in 1720–29, and formerly the residence of the elector of the Palatinate. It is one of the largest buildings of the kind in Germany, covering an area of 15 acres, and having a frontage of 650 yards. The left wing was totally destroyed by the bombardment of 1795, but has since been restored. The palace contains a picture gallery and collections of natural history and antiquities. The large and beautiful garden at the back forms the public park of the town. Among the other prominent buildings are the theatre, the arsenal, the synagogue, the "kaufhaus," the town-hall, the railway station, and the observatory. The only noteworthy church is that of the old Jesuit college, the interior of which is lavishly decorated with marble and painting. The square in front of the theatre is embellished with statues of Schiller, Iffland the actor, and Dalberg, intendant of the theatre in the time of Schiller. Mannheim is the chief commercial town on the upper Rhine, and yields in importance to Coblentz and Cologne alone among the lower Rhenish towns. The staple commodities of its trade are tobacco, grain, petroleum, hops, timber, and coffee. Its new harbour, constructed at a cost of £650,000, and measuring 2300 yards in length, is the most extensive inland harbour in Germany. It is entered annually by 3000 river craft, carrying nearly 700,000 tons of goods. The railway goods station and warehouses in connexion with the harbour cover 100 acres of ground. The principal industrial products of Mannheim are machinery, iron, brass, india-rubber, sugar, mirrors, chemicals, wall-paper, and cigars. The manufactories of Ludwigshafen produce aniline dyes, soda, tartaric acid, alum, artificial manures, and lime. Mannheim is the seat of the central board for the navigation of the Rhine, of a chamber of commerce, and of the supreme court of Baden. Ten or twelve different countries are represented here by their consuls. The schools and public institutions of Mannheim include a gymnasium, a "realschule," an industrial school, a high school for girls, a public library, a large poorhouse, three hospitals, and an orphanage.



Plan of Mannheim.

History.—The name of Mannheim was connected with its present site as early as the 8th century, when a small village belonging to the abbey of Lorsch lay in the marshy district between the Neckar and the Rhine. To the south of this village, on the Rhine, was the castle of Eicholzheim, which acquired some celebrity as the place of confinement assigned to Pope John XXIII. by the council of Constance. The history of the modern Mannheim begins, however, with the opening of the 17th century, when Elector John Frederick IV. founded a town here, which he peopled chiefly with Protestant refugees from Holland. The strongly fortified castle which he erected at the same time had the unfortunate result of making the infant town an object of contention in the Thirty Years' War, during which it was five times taken and retaken. In 1689 Mannheim, which had in the meantime recovered from its former disasters, was captured by the French under Melac, and ruthlessly destroyed. Ten years later it was rebuilt on an extended scale and provided with fortifications. For its subsequent importance it was indebted to Elector Charles Philip, who, owing to ecclesiastical disputes, transferred his residence from Heidelberg to Mannheim in 1720. It remained the capital of the Palatinate for nearly sixty years. In 1794 Mannheim fell into the hands of the French, and in the following year it was retaken by the Austrians after a severe bombardment, which left scarcely a single building uninjured. In 1802 it was assigned to the grand-duke of Baden, who caused the fortifications to be razed. Ludwigshafen, originally only the *tête-du-pont* of Mannheim, received its present name in 1843, and became a town in 1859. Towards the end of last century Mannheim attained great celebrity in the literary world as the place where Schiller's early plays were performed for the first time. It was at Mannheim that Kotzebue was assassinated in 1819.

See Feder, *Geschichte der Stadt Mannheim*, 1875; and Unglenk, *Praktischer Führer durch Mannheim*, 1880.

MANNING, Robert, commonly known as Robert of Brunne, a monk of the priory of Brunne or Bourne in Lincolnshire, wrote in the beginning of the reign of Edward III. a metrical history of England from the landing of the imaginary Brute to the end of the reign of Edward I. The work has no independent historical value; it professedly follows Peter of Langtoft's *Chronicle* from the Anglo-Saxon or "Inglis" invasion downwards, and Wace for the previous "British" story. It is a lively narrative, written "not for the lered bot for the lewed," and it has a certain interest as a landmark, not only in the history of the English language, but also in the history of national sentiment. Manning is warm in praise of the deeds and the character of Edward I., "Edward of Inglond," although he deplores the Norman Conquest as a "bondage," and says concerning the death of Harold that "our freedom that day for ever took the leave." The old monk is our first avowedly "popular" historian. He wrote for the entertainment of men who knew neither Latin nor French, and in his prologue comments humorously on the "quaint English" and subtle rhymes of his predecessors, claiming for himself purity of language and simplicity of metre. A passage in this prologue has often been quoted as bearing on the authorship of the romance of *Sir Tristram*. Manning also translated William of Waddington's *Manuel des Pechiez* under the title of *Handlying Synne*, in 1303, and is plausibly conjectured to be the author of *Medytacyuns of the Soper of oure Lorde Ihesu*, translated from Bonaventura's *Vita Christi*. He is not a bald rhymester, but uses language with skill and effect, and in some places where he departs from his originals shows genuine poetical rapture.

MANOMETER, or Pressure Gauge, is an instrument for measuring the hydrostatic pressure exerted by gases, vapours, or liquids against the sides of the closed vessels in which they are confined,—as, for instance, the pressure of steam in a steam-boiler.

The simplest and at the same time most accurate form of manometer is that known as the "mercury manometer," sometimes also called the "free-air manometer," and represented in fig. 1. It consists essentially of two vertical communicating tubes. One of these, AB, open at both ends, and made of thick glass, with a narrow uniform bore, is fixed hermetically in the neck of a large wrought-iron cylinder C, its lower end dipping below the surface of mercury contained in the cylinder. The other tube, EF, is attached at its lower end to the cylinder by the cross pipe D, and at its upper end can be put in communication with the vessel the pressure in which is to be ascertained. Usually the tube EF, the cross pipe D, and the space above the mercury in C are filled with water. At first the tube EF is left open to the atmosphere, and the height of the mercury in AB noted. When EF is then put in communication with the vessel in which the pressure (above atmospheric) is to be determined, the mercury in AB rises, and from the height to which it rises the pressure is deduced. For accurate work corrections must be made for the fall of the mercury in C as it rises in AB, and for the temperature and the height of the barometer at the time of the experiment.

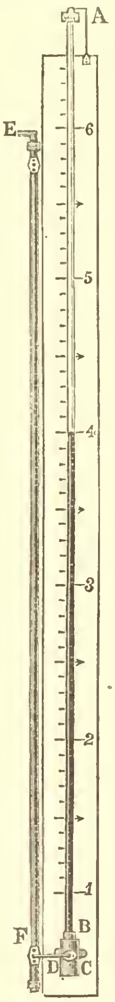


FIG. 1.—Mercury Manometer.

The great drawback to the employment of the simple mercury manometer for measuring very great pressures is the mechanical difficulty of obtaining a sufficiently long column of mercury. E. H. M. Amagat, however, has lately (1880) worked with a column *one-fifth of a mile* high. His experiments were undertaken to find out how the various gases, nitrogen, oxygen, air, hydrogen, &c., departed from Mariotte's law when subjected to enormous pressures. At the bottom of a coal-mine at Verpilleux, near St Étienne, which had a depth of 327 metres, was placed the glass manometer tube containing the compressed gas, while the mercury tube (made of steel) extended up the shaft, being gradually built up in sections. See *Nature*, vol. xxii. pp. 62, 63. By means of Amagat's tables of the volume and corresponding pressure of the several gases, and with special forms of manometer to suit particular circumstances, accurate and delicate measures of enormous pressures can now be obtained. Professor Tait, for instance, has recently applied these tables along with a manometer of his own devising for testing the behaviour of the thermometers supplied to the "Challenger" expedition under a pressure of as much as 10 tons to the square inch.

"Regnault's manometer" is shown in fig. 2. AB is a strong metal tube, closed at the lower end, and carrying at the upper a bent pipe for admitting the compressed gas and a stop-cock R pierced with holes in a T form. DE and FG are two graduated glass tubes communicating at their lower ends by a narrow passage in the metal block to which they are hermetically fixed. DE and AB also communicate at the upper ends by a passage in a metal piece attached hermetically to them. By the stop-cock R′, having radial holes at right angles to each other, DE can communicate either with AB or with the atmosphere at O; and by the stop-cock R″ it can communicate either with FG or with the open air. The three tubes are surrounded by a cylinder MM′ containing water to keep the temperature constant. The tube AB is filled with the compressed gas whose pressure is to be ascertained. The stop-cock R′ being then placed as in fig. 2, mercury is poured into FG till it fills DE and runs out at O. The stop-cocks R and R′ are then turned as in fig. 2*a*, so that AB and DE communicate with each other. Part of the compressed gas flows over into DE, and the mercury in FG rises. By manipulating the stop-cock R″ as shown in fig. 2*b*, part of the mercury is allowed to run out of DE till a conveniently measurable difference of level between the mercury surfaces in DE and FG is attained.

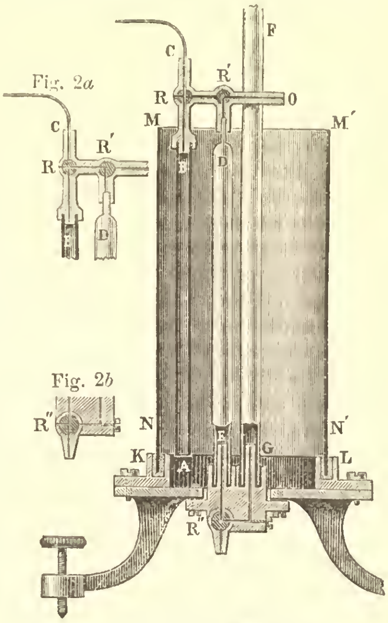


FIG. 2.—Regnault's Manometer.

Let h be this difference. Also let x be the pressure of the gas originally filling the volume V of AB, V′ the additional volume occupied by the expanded gas, and H be the height of the barometer at the time; then we have by Mariotte's law

$$xV = (V + V')(H + h),$$

from which

$$x = \frac{V + V'}{V}(H + h) \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

V′ is determined by weighing the mercury required to fill the space it occupies, and V can be calculated from (1) when AB is filled with dry air at pressure H.

In Regnault's apparatus the length of AB and DE was 1 metre, the diameter of AB 5 mm. and of DE 20 mm. The section of DE was thus sixteen times that of AB, and in this way a very great pressure could be measured by a comparatively small difference of level between the mercury surfaces in FG and DE. The instrument, however, is subject to errors, arising chiefly from the difficulty of measuring accurately the volumes V and V′.

The "compressed air manometer" (fig. 3) consists of a strong graduated glass tube of uniform narrow bore, closed at the top and fixed hermetically into the neck of a wide iron cylinder. The tube contains dry air, and its lower end dips below the surface of mercury contained in the cylinder. Attached to the side of the cylinder is a tube A, with a stop-cock, to afford communication with the vessel the pressure in which is to be measured. When the manometer is attached to the vessel containing compressed gas the mercury rises in the glass tube till the pressure of the air confined in the tube (reckoned in millimetres of mercury) plus the height of the mercury column above the level of the mercury in the cylinder is equal to the pressure on the surface of mercury in the cylinder.

FIG. 3.—Compressed Air Manometer.

"Desgoffe's manometer" depends upon the same principle as the hydraulic press, and can be employed to measure the enormous pressure reached in the cylinder of that instrument. It is represented in perspective in fig. 4 and in section in fig. 5. V is a strong circular iron vessel, in which moves up and down for a short distance a flat piston D attached to a cylindrical plug T. The lower part of V contains mercury which has free communication with a graduated vertical glass tube AB fixed hermetically into the side of V. Above the mercury in V is placed a thin layer of water, and above that is stretched a thin membrane of india-rubber bolted down water-tight by an iron ring. The chamber C contains a cavity in which the plug T moves water-tight. By means of the tube t the instrument can be put in communication with the vessel containing the fluid whose pressure is to be measured. The compressed fluid acting upon T depresses the piston D and causes the mercury to rise in AB.

Let p be the pressure of the fluid per unit of area, s the area of T, and S the area of D; also let P be the pressure per unit of area as recorded by the height of the mercury in AB. Thus evidently we have

$$ps = PS, \text{ or } p = \frac{S}{s}P.$$

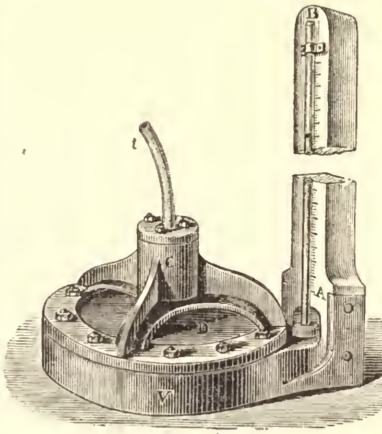


Fig. 4.—Desgoffe's Manometer.

Hence by making S very great and s very small a very great pressure can be measured by a comparatively short column of mercury in AB. As part of the pressure p is employed to stretch the india-rubber membrane, the ratio $S:s$ should be made very great, so that D will only sink a very short distance. Cailletet, who employed this manometer in his experiments on the compressibility of fluids, had it so arranged that (neglecting the stretching of the india-rubber) the mercury in AB rose 4·3 metres while the piston in D sunk only one-eighth of a millimetre.

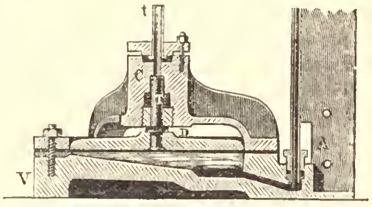


Fig. 5. Section of Desgoffe's Manometer.

Metallic manometers depend on the principle exemplified in the aneroid barometer. Suppose a long tube, preferably of elliptic section, and having thin walls of elastic material, to be closed at one end and either bent or coiled up in the form of a spiral. Let the open end be attached to an apparatus whereby the pressure inside the tube can be either increased or diminished. If the pressure inside the tube be made greater than that outside, the tube has a tendency to straighten or uncoil itself, but if the pressure outside be greater than that inside the tube has a tendency to bend or coil itself up farther. Fig. 6 represents an early form of metallic manometer made on this principle by Bourdon, the first to construct such instruments. A metallic tube ab, closed at b, is coiled in a spiral and rigidly attached at the open end a to a tube with stop-cock m, whereby it can communicate with the compression apparatus. A light index e is attached to b and moves over a graduated scale. The scale is graduated by applying known pressures inside the tube. This form of manometer is very convenient for rough practical work, but has no pretensions to scientific accuracy, as changes of temperature affect the elasticity of the tube in a way which is difficult to discover and allow for. Various forms of metallic manometers have been recently invented, the best-known of which are perhaps those of Bourdon and Schäfer, in which the index is moved by a train of wheels actuated by the free end of the elastic tube.

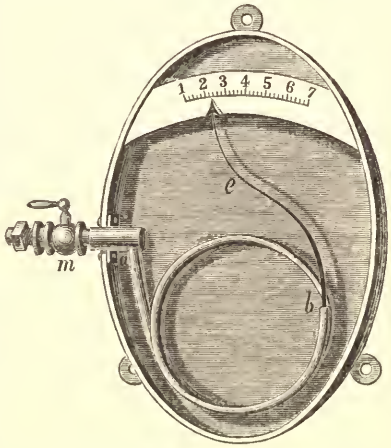


Fig. 6.—Bourdon's Metallic Manometer.

Air-pump Manometer.—For measuring pressures less than that of the atmosphere, as in the receiver of an air-pump, a special form of mercury manometer is employed, consisting of a glass U tube with each leg over 30 inches long and half filled with mercury. One leg communicates by an air-tight communication with the receiver of the air-pump, and the other is left open. As the exhaustion proceeds, the mercury falls in the open leg and rises in the other. When only considerable degrees of exhaustion are to be measured, the instrument takes the form of a short U tube closed at one end and open at the other, and has its closed leg completely filled with mercury, the mercury being held up by the atmospheric pressure. The whole is enclosed in a wide glass tube closed at the top and hermetically fixed at the lower end to a brass piece, provided with a stop-cock, whereby it can be screwed on to the sole plate of the air-pump. The difference of level in the two legs gives the degree of exhaustion obtained.

See Ganot's *Physics*; Wüllner's *Lehrbuch der Experimentalphysik*; Amagat in *Annales de Chemie et de Physique*, March 1880; *Report of H.M.S. Challenger*, in regard to pressure corrections supplied by thermometers, by Professor Tait. (J. BL.)

MANOR, in English law, is an estate in land, to which is incident the right to hold certain courts called courts baron. It might be described as the unit of tenure under the feudal system, and it is historically connected with the territorial divisions of the mark and the parish or township.[1] The legal theory of the origin of manors refers them to a grant from the crown, as stated in the following extract from Perkins's *Treatise* on the laws of England:—"The beginning of a manor was when the king gave a thousand acres of land, or a greater or lesser parcel of land, unto one of his subjects and his heirs, which tenure is knight's service at the least. And the donor did perhaps build a mansion house upon parcel of the same land, and of 20 acres, parcel of that which remained, or of a greater or lesser parcel before the statute of *Quia Emptores* did enfeoff a stranger to hold of him and his heirs to plow 10 acres of land, parcel of that which remained in his possession, and did enfeoff another of another parcel thereof to go to war with him against the Scots, &c., and so by continuance of time made a manor." It is still, as Mr Joshua Williams terms it, a "fundamental rule" that all lands were originally derived from the crown, and that the queen is lady paramount mediate or immediate of all the land in the realm. A manor then arises where the owner of a parcel so granted or supposed to have been granted by the crown (and who is called in relation thereto the lord) has in turn granted portions thereof to others who stand to him in the relation of tenants. Of the portion reserved by the lord for his own use (his demesne) part was occupied by villeins, with the duty of cultivating the rest for the lord's use. These were originally tenants at will, and in a state of semi-serfdom, but they became in course of time the copyhold tenants of the later law. (See Copyhold.) It is of the essence of copyhold that it should be regulated by the custom of the manor; and that, according to some authorities, is one reason why a manor cannot be created at the present day. "Length of time being of the very essence of a manor, such things as receive their perfection by the continuance of time come not within the compass of a king's prerogative" (Scriven, *Copyholds*, chap. i.). But the effect of the statute of *Quia Emptores* was to make the creation of manors henceforward impossible, inasmuch as it enacted "that upon all sales or feoffments of land, the feoffee shall hold the same, not of his immediate feoffor, but of the chief lord of the fee of whom such feoffor himself held it." The statute did not apply to the king's tenants *in capite*, who might have aliened their land under a licence. Accordingly it is assumed that all existing manors are "of a date prior to the statute of *Quia Emptores*, except perhaps some which may have been created by the king's tenants *in capite* with licence from the crown" (Williams, *Real Property*, chap. iv.; see also Scriven, *Copyholds*, chap. i.). When a great baron had granted out smaller

[1] Laveleye (*Primitive Property*, chap. xviii.) observes that in the 10th century, even before the Norman Conquest, the mark had already been transformed into the manor, although the term was not yet in use. The country was covered with a great number of domains (*maneria*), of very different extent, from the maneriolum of one plough to the latifundium of fifty ploughs.

manors to others, the seignory of the superior baron was frequently termed an honour.

MANRESA, a town of Catalonia, Spain, 39 miles north-west of Barcelona, with a population of 15,264. It was formerly Bacasis, one of the cities of the Jaccetani, the most important of the small tribes at the foot of the Pyrenees. It lies on the left bank of the Cardonero, 2 miles above its junction with the Llobregat, in the midst of a fertile and well-irrigated district, and its chief manufactures are cloth, cotton, silk, gunpowder, and brandy. Building stone is quarried near the town. The Cardonero is crossed by two bridges,—one ancient, the other erected in 1804. The two principal sights of Manresa are the collegiate church, El Seo, commenced in 1328, and finished in the 15th century, and the Cueva de San Ygnacio. The late Mr G. E. Street has minutely described the church in his *Gothic Architecture of Spain*. Among its greatest treasures he specializes a magnificent altar frontal as "the most beautiful work of its age." It is 10 feet long by 2 feet 10 inches in height, and is divided into nine compartments, at the bottom of which is the inscription in Lombardic characters :—GERI : LAPI : RECHAMATORE : MEFECIT : INFLORENTIA. In the Cueva de San Ygnacio, Ignatius Loyola lived for a year, fasting and submitting himself to the severest penances, constantly gazing at the shrine of the Virgin of Montserrat, who, he asserted, encouraged him in his austerities. A great monastery surrounds the cave, which is visited by thousands of pilgrims, and from the esplanade there is a magnificent view of the "pinnacles, spires, turrets, sugar-loaves, and pyramids of faint grey rocks," constituting the famous mountain of Montserrat. At Cardona, a little more than 20 miles to the north-west of Manresa, there is a remarkable hill of rock-salt 3 miles in circumference, and 350 feet in height, which is estimated to contain 400 million cubic yards of salt.

MANS, LE, a town of France, formerly capital of Maine and now of the department of Sarthe, lies 118 miles (131 by rail) W.S.W. from Paris, near the confluence of the Sarthe and the Huisne, on an elevation rising from the left bank of the former river. Three bridges besides that of the railway connect the town with the quarter on the right bank. Of the wide and commodious thoroughfares which are gradually superseding the old winding and narrow streets, the most worthy of notice is the tunnel by which the Place des Jacobins is connected with the river side. The principal building is the cathedral, originally founded by St Julian, to whom it is dedicated. Rebuilt in the 6th century by St Innocent, in the 9th by St Aldric, and a third or fourth time in the 11th by Vulgrin, who was at once architect and bishop, it was completed by the addition of two towers in the 12th. Destroyed by two fires, the roof was reconstructed in the Gothic style, and the transept and south portal were added. In the 13th century the choir was enlarged in the grandest and boldest style of that magnificent period. Finally a new transept and a bell tower were added in the 15th century. In the large window of the west front the ten divisions which have for their subject the legend of St Julian are the oldest extant specimens of stained glass in France (end of 11th century). The side portal (12th century) is richly decorated, and its statuettes exhibit many interesting costumes of the period. The aisles have ten bays, but the nave only five; the transept is much higher; from it rises the only tower of the building. The austere simplicity of the nave is in striking contrast with the lavish richness of the ornamentation in the choir and apse. The former is 115 feet in height, and has twelve chapels besides the sacristy; its windows almost entirely date from the middle of the 13th century. The glass of the north transept is of the 15th century, and represents the Last Judgment; it contains many historical figures. The cathedral has also curious tapestries and some remarkable tombs, including that of Berengaria, queen of Richard Cœur de Lion. The entire length of the building is 427 feet. Close to the western wall is a megalithic monument nearly 15 feet in height. The church of La Couture, which belonged to an old abbey founded in the 7th century by St Bertrand or Bertram, has a remarkable porch of the 13th century; the rest of the building is older. Of the other churches of Le Mans, none require special mention except that of Notre Dame du Pré, on the right bank of the Sarthe. Of the secular buildings may be mentioned the hôtel de ville, built about a century ago on the site of the former castle of the counts of Maine, and the prefecture, occupying the site of the monastery of La Couture (1760). The latter contains the library (50,000 volumes, 700 MSS.), the communal archives, and the museum of paintings, archæology, and natural history. Other prominent buildings are the general hospital, the lyceum, the seminary, the palais de justice, and the cavalry barracks; the house occupied by Scarron is still pointed out, and there are considerable remains of the old Gallo-Roman enceinte. The principal promenades are those of the Jacobins, of the horticultural garden, Du Greffier (on the right bank of the river), and Des Sapins (on the road to Tours). The industries of Le Mans, which are carried on chiefly in the faubourg of Pontlieue, include metal-working, the manufacture of agricultural implements, and weaving. For some years there has been a Government tobacco factory. A local specialty is the fattening of poultry. The population in 1876 was 50,175 (including 5282 representing the garrison, &c.). Le Mans is an important railway junction.

As the capital of the Aulerci Cenomani, Le Mans was called Suindinum or Vindinum. The Romans surrounded it with walls in the 3d century; it was evangelized by St Julian in the 4th. The countship of Maine was made hereditary by Hugh Capet in the 10th century. Le Mans was seized by William the Conqueror, but his son Robert was unable to retain it. Having chosen the side of Richard Cœur-de-Lion, it was taken by Philip Augustus, recaptured by John, subsequently confiscated, and afterwards ceded to the widow of Richard. Maine was next held by Margaret, the wife of St Louis, who gave it to his brother Charles of Anjou. Le Mans was five times besieged during the Hundred Years' War, and was subsequently devastated by the Huguenots in 1562. In 1793 it was seized by the Vendeans, who were expelled by Marceau after a sanguinary battle in the streets of the town. In 1799 it was again occupied by the Chouans; and in January 1871 the second army of the Loire sustained in the neighbourhood of Le Mans a defeat which made the relief of Paris impossible. The town is the birthplace of Henry II. of England, of John the Good, king of France, and of Chappe, the inventor of the aerial telegraph.

MANSEL, HENRY LONGUEVILLE (1820–1871), metaphysician and theologian, was born at Cosgrove, Northamptonshire (where his father was rector) in 1820, and educated at Merchant Taylors' School and St John's College, Oxford. He succeeded to a fellowship in 1842, graduated in 1843, and became tutor of his college. He was appointed reader in moral and metaphysical philosophy at Magdalen College in 1855, becoming Waynflete professor in 1859. In 1867 he succeeded Dean Stanley as professor of ecclesiastical history, and in the following year was appointed dean of St Paul's. He died July 31, 1871.

The philosophy of Mansel, like that of his older contemporary Sir W. Hamilton of Edinburgh, was mainly due to three sources,—the works of Aristotle, the speculations of Kant, and the philosophy of Reid. Like Hamilton, Mansel maintained the purely formal character of logical science, the duality of consciousness as testifying to both self and the external world, and the limitation of knowledge to the finite and "conditioned." His logical doctrines were developed in his edition of Aldrich's *Artis Logicæ Rudimenta* (1849)—his chief contribution to the reviving study of Aristotle—and in his *Prolegomena Logica,—an Inquiry into the Psychological Character of Logical Processes* (1851), in which the limits of logic as the "science of formal thinking" are rigorously determined. In his Bampton Lectures on *The Limits of Religious Thought* (1858) he applied to Christian theology the metaphysical agnosticism which seemed to result from Kant's criticism, and which had been developed in Hamilton's *Philosophy of the Unconditioned*. Showing the contradictions which arise when we attempt to conceive God under the categories of substance or cause, Mansel contends that we can have no positive conception either of the metaphysical or moral attributes of the Absolute and Infinite Being, though we are compelled to believe in His existence, the religious consciousness being built up by reflexion from the feeling of dependence and the conviction of moral obligation. Hence he infers the invalidity of all objections to revelation from its alleged inconsistency with the Divine character, maintaining the dependence of its claim to acceptance upon the evidences accompanying it. While denying all knowledge of the supersensuous, Mansel deviated from Kant in contending that cognition of the ego as it really is is itself a fact of experience. Consciousness, he held,—agreeing thus with the doctrine of "natural realism" which Hamilton developed from Reid,—implies knowledge both of self and of the external world. The latter Mansel's psychology reduces to consciousness of our organism as extended; with the former is given consciousness of free-will and moral obligation. These views and a summary of his whole philosophy are contained in his article "Metaphysics" contributed to the 8th edition of the *Encyclopædia Britannica* (separately published, 1860). Mansel was also the author of an essay on *The Philosophy of the Conditioned* (1866) in reply to Mill's criticism of Hamilton, of other controversial and occasional writings republished in *Letters, Lectures, and Reviews* (1873), and of lectures on *The Gnostic Heresies* (edited by J. B. Lightfoot, 1875).

MANSFELD, COUNT ERNEST OF (1585–1626), a natural son of Peter Ernest, governor of Luxemburg and Brussels, was born in 1585. Trained by his godfather, the archduke Ernest of Austria, in the Roman Catholic religion, he devoted himself to the service of the king of Spain in the Netherlands, and to that of the emperor in Hungary. The emperor Rudolf II. conferred on him the rights of legitimate birth, and promised to put him in possession of his father's lands in the Netherlands. As this promise was not fulfilled, he joined the Reformed Church, and in 1610 formally associated himself with the Protestant princes. From the outbreak of the Thirty Years' War in 1618 he fought steadily on behalf of the elector of the Palatinate both in Bohemia and in the Rhine country. In 1625 he was able to collect a powerful force with which he intended to attack the hereditary territories of Austria, but, on the 25th of April 1626, he was defeated by Wallenstein at Dessau. He pressed forward to effect a junction with Bethlen Gabor, prince of Transylvania, but as the latter changed his policy Mansfeld had no alternative but to disband his army. When preparing to go to England by Venice, he became ill at a village near Zara, and died on the 20th of November 1626. He was a man of great courage and resource, and ranks among the most brilliant generals of his age.

See Reuss, *Graf Ernst von Mansfeld im böhmischen Kriege* 1618–21 (1865); Villermont, *Ernest de Mansfeld* (1866); and Graf Uetterodt zu Scharffenberg, *Ernest Graf zu Mansfeld, historische Darstellung* (1867).

MANSFIELD, a market-town in the county of Nottingham, England, is situated in Sherwood Forest, near the north bank of the river Mann or Maun, 17 miles north-west from Nottingham, and 140 north-north-west of London by rail. The town is built of stone, with regular streets radiating from the market place, and several good houses. The church of St Peter is partly Early Norman and partly Perpendicular. There is a grammar school founded by Queen Elizabeth in 1561, for which new buildings have lately been erected at a cost of £10,000. Twelve almshouses were founded by Elizabeth Heath in 1693, and to these six were afterwards added. In addition there are a number of other charities. The other principal buildings are the town-hall, the mechanics' institute, and the public baths. In the market place there is a monument to Lord George Bentinck. The industries of the town are the manufacture of lace thread, cotton hose, machines, engines, and bricks and tiles, iron-founding, and brewing. In the neighbourhood there are quarries of limestone, sandstone, and freestone. Population in 1871, 11,824; in 1881, 13,651.

From coins found at Mansfield and the remains of a Roman villa in the neighbourhood, it is believed to have been a Roman station. During the heptarchy it was occasionally the residence of the Mercian kings, and it was afterwards a favourite resort of Norman sovereigns. By Henry VIII. the manor was granted to the earl of Surrey. Afterwards it went by exchange to the duke of Newcastle, and from the Newcastles to the Portland family. The town obtained a fair from Richard II. in 1377.

MANSFIELD, the county seat of Richland county, Ohio, U.S., pleasantly situated on high ground, 54 miles south of Sandusky, in the midst of a prosperous farming district. It is the terminus of the North-Western Ohio Railroad, and is at the junction of the Baltimore and Ohio, the Pittsburgh, Fort Wayne, and Chicago, and the New York, Pennsylvania, and Ohio lines. It possesses a flourishing trade, and extensive manufactories of agricultural implements, machinery, flour, boilers, carriages, and household furniture, with many minor industries. Mansfield has public water-works on the "Holly" system, a public library, and an opera-house. The population was 8029 in 1870 and 9859 in 1880.

MANSFIELD, WILLIAM MURRAY, EARL OF (1705–1793), was born at Scone, in Perthshire, on 2d March 1705. He was the eleventh child and fourth son of David, fifth Viscount Stormont, a nobleman whose family possessions had shrunk within so narrow limits that he had to bring up his numerous family with exceedingly strict economy. The family was Jacobite in its politics, and the second son, being apparently mixed up in some of the plots of the time, joined the court of the Pretender at the accession of George I., and was created by him earl of Dunbar. William Murray was sent first to the grammar school at Perth, where he remained until he was thirteen, and at that age was sent to Westminster at the suggestion of his exiled brother, who had been in close relation with Atterbury (then dean of Westminster), and probably desired to bring the boy under his influence. He was elected a king's scholar a year after his entrance, and in 1723 was first on the list of scholars sent on the foundation to Christ Church, where he remained for nearly four years. It had been originally intended that he should enter the English church, as, although his own inclination while at school pointed strongly towards the bar, the circumstances of his family seemed to forbid the expense of a legal education. But this obstacle was removed by the kindness of the father of one of his schoolfellows, and he was entered at Lincoln's Inn. Soon after he went to Oxford. In 1727 he took chambers in Lincoln's Inn, and in 1730 was called to the bar. His studies from the time he left Westminster seem to have been steadily directed towards his future profession, but in a manner far more liberal than was then usual among lawyers. He had made himself at Westminster and Oxford an admirable classical scholar; he paid particular attention to English composition and to the art of debate; his historical studies were extensive, and in the more strictly professional sphere his wide view of the education necessary for a lawyer was shown by the knowledge he acquired of Roman law and of the juridical writers of Scotland and France. At the same time he enjoyed the advantage of mixing extensively with the best literary society. He had early become an intimate friend of Pope, and his own ability and accomplishments soon made him everywhere a man of mark.

For two or three years he made little or no progress at the bar, but at length his appearance in some important Scotch appeal cases brought him into notice, and in Scotland at least he acquired an immense reputation by his appearance for the city of Edinburgh when it was threatened with disfranchisement for the affair of the Porteous mob. His English business had as yet been scanty, but in 1737 a single speech in a jury trial of note may be said to have placed him at the head of the bar, and from this time he enjoyed a great business. In 1738 he married Lady Elizabeth Finch, daughter of the earl of Winchelsea. His political career commenced in 1742 with his appointment as solicitor-general. Probably his political opinions were not of a marked party character; he had been bred a Jacobite, and many of his earlier associates belonged to the high Tory camp, but his calm sense and temper disinclined him to extreme factions, and indeed his interest in politics seems at all times to have been subordinate to the love of his profession. He had kept entirely aloof during the struggles which preceded the fall of Sir Robert Walpole; he refused any purely political appointment, and only took office as solicitor when he felt assured of the permanence of the new administration. During the next fourteen years Murray was one of the most conspicuous figures in the parliamentary history of the time. Although holding an office of subordinate rank, and not sharing, nominally at least, in the councils of the administration, he was the chief defender of their measures in the House of Commons, and during the time that Pitt was in opposition had to bear the brunt of his attacks. He was especially conspicuous in the great debates on the employment of the Hanoverian troops, the treaty of Aix-la-Chapelle, and the Regency Bill. In 1754 he became attorney-general, and for the next two years acted as leader of the House of Commons under the administration of the duke of Newcastle. During these years he had to defend a weak Government against the incessant, vehement assaults of Pitt, and, according to the testimony of contemporaries, acquitted himself brilliantly in the contest. But in 1756, when the Government was evidently approaching its fall, an unexpected vacancy occurred in the chief justiceship of the king's bench, and he claimed the office. Newcastle made every effort to retain him in the House of Commons, feeling as he did that his departure would hasten the fall of the Government, but Murray was inexorable. He seems to have been thoroughly tired of his parliamentary life, and to have long looked forward to the bench as the proper sphere of his work. He was at the same time raised to the peerage as Baron Mansfield.

From this time the chief interest of his career lies in his judicial work, but he did not wholly dissever himself from politics. He became by a singular arrangement, only once repeated subsequently in the case of Lord Ellenborough, a member of the cabinet, and remained in that position through various changes of administration for nearly fifteen years, and, although he persistently refused the chancellorship, he acted as speaker of the House of Lords while the great seal was in commission. During the time of Pitt's ascendency he took but little part in politics, but while Lord Bute was in power his influence was very considerable, and seems mostly to have been exerted in favour of a more moderate line of policy. He was on the whole a supporter of the prerogative, but within definite limits. Macaulay terms him, justly enough, "the father of modern Toryism, of Toryism modified to suit an order of things in which the House of Commons is the most powerful body in the state." In this spirit he continued to act a conspicuous though not a foremost part in political life during the rest of his career. During the stormy session of 1770 he came into violent collision with Lord Chatham and Lord Camden in the questions that arose out of the Middlesex election and the trials for political libel, and in the subsequent years he was made the subject of the bitter attacks of Junius, in which his early Jacobite connexions, and his apparent leanings to arbitrary power, were used against him with extraordinary ability and virulence. In 1776 he was created earl of Mansfield. In 1783, although he declined to re-enter the cabinet, he acted as speaker of the House of Lords during the coalition ministry, and with this his political career may be said to have closed. He continued to act as chief justice until his resignation in June 1788, and after five years spent in quiet retirement died peacefully on 20th March 1793. He left no family, but his title had been re-granted (in 1792) with a direct remainder to his nephew, Lord Stormont.

Lord Mansfield's great reputation rests chiefly on his judicial career. The political trials in which he presided, although they gave rise to numerous accusations against him, were conducted with singular fairness and propriety. He was accused with especial bitterness of favouring arbitrary power by the law which he laid down in the trials for libel which arose out of the publications of Junius and Horne Tooke, and which at a later time he reaffirmed in the case of the dean of St Asaph (see LIBEL). But, although his political opinions led him to look with disfavour on the popular view, and although it was unquestionably unfortunate that in some of these instances he was a member of the cabinet which directed the proceedings, we must remember that his view of the law was concurred in by the great majority of the judges and lawyers of that time, and was supported by undoubted precedents. In other instances, when the Government were equally concerned, he was wholly free from suspicion. He supported Lord Camden's decision against general warrants, and reversed the outlawry of Wilkes. While on the whole he leaned in opinion to a view of the law which we should now call oppressive, there is no instance in which he can justly be accused of wresting it, and in every instance he treated the accused with a fairness and decency which had not always been shown by his predecessors. In another way he came into conflict with popular prejudices. He was always ready to protect the rights of conscience, whether they were claimed by Dissenters or Catholics, and the popular fury which led to the destruction of his house during the Gordon riots was directed against him very much because a Catholic priest, who was accused of saying mass, had escaped the penal laws by his charge to the jury. His chief celebrity, however, is founded upon the consummate ability with which he discharged the civil duties of his office. He has always been recognized as the founder of English mercantile law. The common law as it existed before his time was wholly inadequate to cope with the new cases and customs which arose with the increasing development of commerce. The facts were left to the jury to decide as best they might, and no principle was ever extracted from them which might serve as a guide in subsequent cases. Lord Mansfield found the law in this chaotic state, and left it in a form that was almost equivalent to a code. Working patiently with the guildhall juries, whom he trained to act in thorough understanding with him, he defined almost every principle that governed commercial transactions in such a manner that his successors had only to apply the rules he had laid down. His knowledge of Roman and foreign law, and the general width of his education, freed him from the danger of relying too exclusively upon narrow precedents, and afforded him a storehouse of principles and illustrations, while the grasp and acuteness of his intellect enabled him to put his judgments in a form which almost always commanded assent. A similar influence was exerted by him in other branches of the common law; and although, after his retirement, a reaction took place, and he was regarded for a while as one who had corrupted the ancient principles of English law, these prejudices passed rapidly away, and the value of his work in bringing the older law in harmony with the needs of modern society has long been fully recognized.

The chief defect of Lord Mansfield's character was a certain coldness and want of moral courage. He had no very warm attachment either to persons or opinions, although invariably kindly and considerate in his demeanour. Even his greatest speeches owe their impressiveness to a certain intellectual nobleness and breadth of view. His attachment to justice was not impassioned, but of the type which is bred from highest professional custom, and from the kind of intellectual taste which led him so frequently to the ethical writings of Cicero. He could not always face the enthusiasm of Chatham, and we cannot feel certain that his courage would have sustained him through any very perilous stand for righteousness. But in the sphere in which he was chiefly famous these defects were scarcely disadvantages. His sense of duty and of personal dignity was amply sufficient to bear him perfectly unstained through life. No suitor had ever to complain of delay or neglect. His want of strong feeling only permitted him to use his magnificent intellect with greater impartiality; and, if at any time he was affected by personal prejudice, no trace of it was ever allowed to appear. Nothing ever disturbed the perfect dignity and propriety of his judicial conduct, which is apparent in every trial at which he presided. He impressed himself on the mind of his contemporaries as one of the best examples of what a great judge ought to be, and from that estimate a closer examination of his claims will scarcely lead us to differ. (A. GI.)

MANSLAUGHTER. See MURDER.

MANSON, GEORGE (1850–1876), a Scottish water-colour painter, was born in Edinburgh on the 3d of December 1850. When about fifteen he was apprenticed as a woodcutter with Messrs W. & R. Chambers, with whom he remained for over five years, designing and engraving vignettes distinguished by singular rightness and directness of technical method, diligently employing all his spare time in the study and practice of art, and producing in his morning and evening hours water-colours of much delicacy and beauty, like the Milking Time and the Cottage Door. In 1871 he left the Messrs Chambers, and devoted himself exclusively to painting. His subjects were derived from humble Scottish life—especially child life, varied occasionally by portraiture, by landscape, and by views of picturesque architecture. In 1873 he visited Normandy, Belgium, and Holland; in the following year he spent several months in Sark; and in 1875 he resided at St Lô, and in Paris, where he mastered the processes of etching. He afterwards produced a series of plates which promised excellence in the art. Meanwhile in his water-colour work he had been adding more of breadth and power to the tenderness and richness of colour which distinguished his early pictures, and he was planning more complex and important subjects. But his health had been gradually failing, and he was ordered to Lympstone in Devonshire, where he died on the 27th of February 1876. Among his chief productions are the High School Wynd; the Companions—a gipsy girl and her donkey; Waiting for the Boats; What is It?—a child examining an antique clock; and his own portrait as a Sark fisherman. Since his death several exhibitions of his works have been held in London and Edinburgh, and a volume of photographs from his water-colours and sketches, with a memoir by J. M. Gray, was published in 1880. For an account of Manson's technical method as a wood engraver see P. G. Hamerton's *Graphic Arts*, p. 311.

MANSUR, MANSOOR, or more properly, with the article, AL-MANṢÚR, "the victorious," a surname (*laḳab*) assumed by not a few Mohammedan princes. Among the personages commonly referred to by this title the following may be noticed.

1. Abú Ja'far ibn Mohammed, second caliph of the house of 'Abbás, who reigned 754–775 A.D. See MOHAMMEDAN EMPIRE.

2. Abú Ṭáhir Isma'íl ibn Al-Ḳáim, third Fatimite caliph of Africa (946–953). Under Al-Ḳáim, his father, the Fatimites, already weakened by their conflict with the Omayyads of Spain, were threatened with utter ruin by a Berber rising under Abú Yezíd, a poor nonconformist ('Ibáḍí) schoolmaster, who appeared as a religious reformer, and gathered round him the Sunnites, who detested the Fatimites. In 944 Abú Yezíd conquered the capital Ḳairawán, and recognized the spiritual headship of the Spanish caliph. While the Spanish caliph and his vassals stripped the Fatimite of his remoter possessions, Abú Yezíd pressed him at home, and during the siege of Súsa Al-Ḳáim died, and was succeeded by Al-Manṣúr. Then the fortunes of war rapidly turned. Abú Yezíd alienated many of his followers by lapsing into habits of arrogant luxury and by treachery towards the Sunnites. At length he lost all he had won, fell into the hands of Al-Manṣúr, and was put to death (947). The caliph built the city of Manṣúríyah on the field of the decisive battle and made it his residence; the empire was rapidly restored, and the Spanish vassals driven from Africa. Al-Manṣúr died at Manṣúríyah, and was succeeded by Al-Mo'izz, the conqueror of Egypt (see vol. vii. p. 750 *sq.*).

3. Ibn Abí 'Ámir Mohammed, commonly called Almanzor by European writers, of an ancient but not illustrious Arab family, which had its seat at Torrox near Algeciras, was born 939 A.D., and began life as a lawyer at Cordova. In 967 he obtained a place at the court of Ḥakam II., the Andalusian caliph, and by an unusual combination of the talents of a courtier with administrative ability and address in dealing with men, rapidly rose to distinction, enjoying in particular the powerful support of Subḥ, the favourite of the caliph and mother of his heir Hishám. On the death of Ḥakam (976) the accession of a minor gave fresh scope to the genius of Ibn Abí 'Ámir, who threaded his way with consummate but unscrupulous talent through the intrigues of the court, and in 978 became prime minister. He now aimed at absolute dominion. The weak young caliph, absorbed in exercises of piety, was easily reduced to a cipher, but at first Ibn Abí 'Ámir had to share the power with his father-in-law Ghálib, the best general of Andalusia, and his chief aid, along with the mother of Hishám, in the steps that had raised him to power. At last a rupture took place between the two ministers, and ended in a war in which Ghálib professed himself the champion of the caliph and called in the aid of the Christians of Leon. But his rival had anticipated the struggle; he had long before found means to add military to administrative reputation, and since he rose to the direction of affairs had remodelled the army so as to make it more formidable and more devoted to his cause. Ghálib fell in battle (981); a victorious campaign chastised the Leonese; and on his return to Cordova the victor assumed the regal surname of Al-Manṣúr billah, and became practically sovereign of Andalusia. The caliph was a mere prisoner of state, holding a nominal dignity, and Al-Manṣúr ultimately assumed the title as well as the prerogatives of king (996). Unscrupulous in the means by which he rose to power, he wielded the sovereignty nobly. His strict justice and the enlightened excellence of his internal administration were not less notable than his military prowess. But it is by the latter that he is best known. His arms were the terror of the Christians, and raised the Moslem power in Spain to a pitch it had never before attained. He fought more than

fifty campaigns, all glorious, and destroyed many cities, including the three capitals of Leon, Pampeluna, and Barcelona, and the sacred shrine of Santiago de Compostella. In Africa his armies were for a time hard pressed by the revolt of Zírí, viceroy of Mauretania, but before his death this enemy had also fallen. Al-Mansúr died at Medinaceli 10th August 1002, and was succeeded by his son Modaffar.[1]

4. Abú Yúsuf Ya'kúb ibn Yusuf (Jacob Almanzor), of the Moorish dynasty of the Almohades, the conqueror of Alphonso III. in the great battle of Alarcos (1195), reigned 1184-99.

MANTEGNA, Andrea (1431–1506), one of the chief heroes in the advance of painting in Italy, was born in or near Padua, of very humble parentage. It is said that in his earliest boyhood Andrea was, like Giotto, put to shepherding or cattle-herding; but this can have lasted only a very short while, as his natural genius for art developed with singular precocity, and excited the attention of Francesco Squarcione, who entered him in the guild of painters before he had completed his eleventh year.

Squarcione, whose original vocation was tailoring, appears to have had a remarkable enthusiasm for ancient art, and a proportionate faculty for acting, with profit to himself and others, as a sort of artistic middleman; his own performances as a painter were merely mediocre. He travelled in Italy, and perhaps in Greece also, collecting antique statues, reliefs, vases, &c., forming the largest collection then extant of such works, making drawings from them himself, and throwing open his stores for others to study from, and then undertaking works on commission for which his pupils no less than himself were made available. As many as one hundred and thirty-seven painters and pictorial students passed through his school, established towards 1440, which became famous all over Italy. Mantegna was, as he deserved to be, Squarcione's favourite pupil. Squarcione adopted him as his son, and purposed making him the heir of his fortune. Andrea was only seventeen when he painted, in the church of St Sophia in Padua, a Madonna picture of exceptional and recognized excellence. He was no doubt fully aware of having achieved no common feat, as he marked the work with his name and the date, and the years of his age. This painting was destroyed in the 17th century.

The affectionate relation between Squarcione and Mantegna was not destined to continue long. As the youth progressed in his studies, he came under the influence of Jacopo Bellini, a painter considerably superior to Squarcione, father of the celebrated painters Giovanni and Gentile, and of a daughter Niccolosia; and at some date, which may have been towards 1450, Jacopo gave Niccolosia to Andrea in marriage. This connexion of Andrea with the pictorial rival of Squarcione is generally assigned as the reason why the latter became alienated from the son of his adoption, and always afterwards hostile to him. Another suggestion, which rests, however, merely on its own internal probability, is that Squarcione had at the outset used his pupil Andrea as the unavowed executant of certain commissions, but that after a while Andrea began painting on his own account, thus injuring the professional interests of his chief, and incurring his animosity. The remarkably definite and original style formed by Mantegna may be traced out as founded on the study of the antique in Squarcione's atelier, followed by a diligent application of principles of work exemplified by Paolo Uccello and Donatello, with the practical guidance and example of Jacopo Bellini in the sequel.

Among the other early works of Mantegna are the fresco of two saints over the entrance-porch of the church of S. Antonio in Padua, 1452, and an altarpiece of St Luke and other saints for the church of St Justina, now in the Brera Gallery in Milan, 1453. It is probable, however, that before this time some of the pupils of Squarcione, including Mantegna, had already begun that series of frescos in the chapel of St Christopher, in the church of S. Agostino degli Eremitani, by which the great painter's reputation was fully confirmed, and which remain to this day conspicuous among his finest achievements.[2] The now censorious Squarcione found much to carp at in the earlier works of this series, illustrating the life of St James; he said the figures were like men of stone, and had better have been coloured stone-colour at once. Andrea, conscious as he was of his great faculty and mastery, and of the transcendent display he had here made of these, seems nevertheless to have felt that there was something in his old preceptor's strictures; and the later subjects, from the legend of St Christopher, combine with his other excellences more of natural character and vivacity. Trained as he had been in the study of marbles and the severity of the antique, and openly avowing that he considered the antique superior to nature as being more eclectic in form, he now and always affected precision of outline, dignity of idea and of figure, and he thus tended towards rigidity, and to an austere wholeness rather than gracious sensitiveness of expression. His draperies are tight and closely folded, being studied (as it is said) from models draped in paper and woven fabrics gummed. Figures slim, muscular, and bony, action impetuous but of arrested energy, tawny landscape, gritty with littering pebbles, mark the athletic hauteur of his style. He never changed, though he developed and perfected, the manner which he had adopted in Padua; his colouring, at first rather neutral and undecided, strengthened and matured. There is throughout his works more balancing of colour than fineness of tone. One of his great aims was optical illusion, which he carried out by a mastery of perspective that, though not always impeccably correct, nor absolutely superior in principle to the highest contemporary point of attainment, was worked out by himself with strenuous labour, and an effect of actuality astonishing in those times.

Successful and admired though he was in Padua, Mantegna left his native city at an early age, and never afterwards resettled there; the hostility of Squarcione has been assigned as the cause. The rest of his life was passed in Verona, Mantua, and Rome—chiefly Mantua; Venice and Florence have also been named, but without confirmation.

It may have been in 1459 that he went to Verona; and he painted, though not on the spot, a grand altarpiece for the church of S. Zenon, a Madonna and angels, with four saints on each side. The Marquis Lodovico Gonzaga of Mantua had for some time been pressing Mantegna to enter his service; and the following year, 1460, was perhaps the one in which he actually established himself at the Mantuan court, residing at first from time to time at Goito, but, from December 1466 onwards, with his family in Mantua itself. His engagement was for a salary of 75 lire (about £30) a month, a sum so large for that period as to mark conspicuously the high regard in which his art was held. He was in fact the first painter of any eminence

[1] His life is brilliantly described in vol. iii. of Dozy, *Histoire des Musulmans d'Espagne.*

[2] His fellow-workers were Bono of Ferrara, Ansuino of Forlì, and Niccolò Pizzolo, to whom considerable sections of the fresco-paintings are to be assigned. The acts of St James and St Christopher are the leading subjects of the series. St James Exorcising may have been commenced by Pizzolo, and completed by Mantegna. The Calling of St James to the Apostleship appears to be Mantegna's design, partially carried out by Pizzolo; the subjects of St James baptizing, his appearing before the judge, and going to execution, and most of the legend of St Christopher, are entirely by Mantegna.

ever domiciled in Mantua. He built a stately house in the city, and adorned it with a multitude of paintings. The house remains, but the pictures have perished. Some of his early Mantuan works are in that apartment of the Castello which is termed the Camera degli Sposi,—full compositions in fresco, including various portraits of the Gonzaga family, and some figures of genii, &c. In 1488 he went to Rome at the request of Pope Innocent VIII., to paint the frescos in the chapel of the Belvedere in the Vatican; the duke of Mantua created him a cavaliere before his departure. This series of frescos, including a noted Baptism of Christ, was ruthlessly destroyed by Pius VI. in laying out the Museo Pio-Clementino. The pope treated Mantegna with less liberality than he had been used to at the Mantuan court; but on the whole their connexion, which ceased in 1490, was not unsatisfactory to either party. Mantegna then returned to Mantua, and went on with a series of works—the nine tempera-pictures, each of them 9 feet square, of the Triumph of Cæsar—which he had probably begun before his leaving for Rome, and which are now in Hampton Court. These superbly invented and designed compositions, gorgeous with all splendour of subject-matter and accessory, and with the classical learning and enthusiasm of one of the master-spirits of the age, have always been accounted of the first rank among Mantegna's works. They were sold in 1628 along with the bulk of the Mantuan art treasures, and were not, as is commonly said, plundered in the sack of Mantua in 1630. They are now greatly damaged by patchy repaintings. Another work of Mantegna's later years was the so-called Madonna della Vittoria, now in the Louvre. It was painted in tempera about 1495, in commemoration of the battle of Fornovo, which Gonzaga found it convenient to represent to his lieges as an Italian victory, though in fact it had been a French victory; the church which originally housed the picture was built from Mantegna's own design. The Madonna is here depicted with various saints, the archangel Michael and St Maurice holding her mantle, which is extended over the kneeling Francesco Gonzaga, amid a profusion of rich festooning and other accessory. Though not in all respects of his highest order of execution, this counts among the most obviously beautiful and attractive of Mantegna's works,—from which it must be said that the qualities of beauty and attraction are often excluded, in the stringent pursuit of those other excellences more germane to his severe genius, tense energy passing into haggard passion.

Vasari eulogizes Mantegna for his courteous, distinguished, and praiseworthy deportment, although there are indications of his having been not a little litigious in disposition. With his fellow-pupils at Padua he had been affectionate; and for two of them, Dario da Trevigi and Marco Zoppo, he retained a steady friendship. That he had a high opinion of himself was natural, for no artist of his epoch could produce more manifest vouchers of high and progressive attainment. He became very expensive in his habits, fell at times into difficulties, and had to urge his valid claims upon the duke's attention. After his return to Mantua from Rome his prosperity was at its height, until the death of his wife. He then formed some other connexion, and became at an advanced age the father of a natural son, Giovanni Andrea; and at the last, although he continued launching out into various expenses and schemes, he had serious tribulations, such as the banishment from Mantua of his son Francesco, who had incurred the duke's displeasure. Perhaps the aged master and connoisseur regarded as barely less trying the hard necessity of parting with a beloved antique bust of Faustina. Very soon after this transaction he died in Mantua, on 13th September 1506 In 1517 a handsome monument was set up to him by his sons in the church of S. Andrea, where he had painted the altarpiece of the mortuary chapel.

We have spoken as yet of Mantegna as a painter and architect; he was no less eminent as an engraver, and is reported to have been a sculptor and poet as well, though we are not aware that any verses of his are extant, or that his sculptural practice extended beyond making a drawing for a statue of Virgil. As an engraver his history is somewhat obscure, partly because he never signed or dated any of his plates, unless in one single disputed instance, 1472. The account which has come down to us is that Mantegna began engraving in Rome, prompted by the engravings produced by Baccio Baldini of Florence after Sandro Botticelli; nor is there anything positive to invalidate this account, except the consideration that it would consign all the numerous and elaborate engravings made by Mantegna to the last sixteen or seventeen years of his life, which seems a scanty space for them. To get over this difficulty, it has been suggested, but without any evidence, that he began engraving while still in Padua, under the tuition of a distinguished goldsmith, Niccolò. He engraved about fifty plates, according to the usual reckoning; some thirty of them are indisputable—often large, full of figures, and highly studied. Among the principal examples are Roman Triumphs (not the same compositions as the Hampton Court pictures), A Bacchanal Festival, Hercules and Antæus, Marine Gods, Judith with the Head of Holophernes, the Deposition from the Cross, the Entombment, the Resurrection, the Man of Sorrows, the Virgin in a Grotto. Mantegna has sometimes been credited with the important invention of engraving with the burin on copper. This claim cannot be sustained on a comparison of dates, but at any rate he introduced the art into upper Italy. Several of his engravings are supposed to be executed on some metal less hard than copper. The technique of himself and his followers is characterized by the strongly marked forms of the design, and by the oblique formal hatchings of the shadows. The prints are frequently to be found in two states, or editions. In the first state, the prints have been taken off with the roller, or even by hand-pressing, and they are weak in tint; in the second state, the printing press has been used, and the ink is stronger.

The influence of Mantegna on the style and tendency of his age was very marked, and extended not only to his own flourishing Mantuan school, but over Italian art generally. His vigorous perspectives and trenchant foreshortenings pioneered the way to other artists: in solid antique taste, and the power of reviving the aspect of a remote age with some approach to system and consistency, he distanced all contemporary competition. He did not, however, leave behind him many scholars of superior faculty. His two legitimate sons were painters of only ordinary ability. His favourite pupil was known as Carlo del Mantegna; Caroto of Verona was another pupil, Bonsignori an imitator. Giovanni Bellini, in his earlier works, obviously followed the lead of his brother-in-law Andrea.

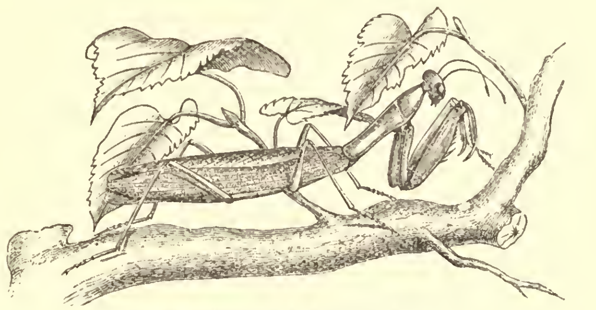
The works painted by Mantegna, apart from his frescos, are not numerous; thirty-three or thereabouts are regarded as fully authenticated. We may name, besides those already specified—in the Naples museum, St Euphemia, a fine early work; in Casa Melzi, Milan, the Madonna and Child with Chanting Angels, 1461; in the Tribune of the Uffizi, Florence, three pictures remarkable for scrupulous finish; in the Berlin Museum, the Dead Christ with two Angels; in the Louvre, the two celebrated pictures of mythic allegory—Parnassus, and Minerva Triumphing over the Vices; in the London National Gallery, the Virgin and Child enthroned, with the Baptist and the Magdalen, a late example; the monochrome of Vestals, lately bought from Hamilton Palace; the Triumph of Scipio (or Phrygian Mother of the Gods received by the Roman Commonwealth), a tempera in chiaroscuro, painted only a few months before the master's death; in the Brera, Milan, the Dead Christ, with the two Maries weeping, a remarkable *tour de force* in the way of foreshortening, which, though it has a stunted appearance, is in correct technical perspective as seen from all points of view. With all its exceptional merit, this is an eminently ugly picture. It remained in Mantegna's studio unsold at his death, and was disposed of to liquidate debts. (W. M. R.)

MANTELL, Gideon Algernon (1790–1852), born in 1790 at Lewes, Sussex, rose to eminence as a popular exponent of geology, and contributed many original papers to the literature of the science. Educated for the medical profession, he first practised in his native town, afterwards in Brighton, and finally at Clapham, near London. While devoting himself with industry and success to the duties of a medical man, he yet found time to prosecute researches in the palæontology of the Secondary rocks, particularly in Sussex—a region which he has made for ever classical in the history of discovery. While he was still a country doctor at Lewes his eminence as a geological investigator was fully recognized on the publication of his work on *The Fossils of the South Downs*, 1822. His most remarkable discoveries were made in the Wealden formations, whence he brought to light and described the remarkable Dinosaurian reptiles known as *Iguanodon*, *Hylæosaurus*, *Pelorosaurus*, and *Regnosaurus*. The memoirs in which he sketched the structure of these strange creatures, and pointed out the probable conditions in which they lived, were recognized by the Geological Society as deserving of its highest honour—the Wollaston medal. The Royal Society also awarded him a Royal medal. Besides these and other contributions to the literature of palæontology and geology, he published from time to time various popular works which had a large sale and did much to spread a knowledge of and interest in the science.[1] Towards the end of his life Dr Mantell retired to London. Though for many years suffering from a severe spinal disease, the result of an accident, he continued with unabated enthusiasm the prosecution of his favourite scientific pursuits, sparing neither pains nor expense towards the attainment of his objects, and kindling in others a spirit of eager desire to further the cause of science. He wrote with great clearness and attractiveness, so that his general works were deservedly popular. As a lecturer also he was almost unrivalled for fluency and eloquence. His name appeared on the list of membership of many learned societies both at home and abroad. He died in 1852.

MANTINEIA was one of the most famous cities of Arcadia. It was situated in the long narrow valley, running north and south, which is now called after the chief town Tripolitza. Tegea was in the same valley, about 10 miles south of Mantineia, and the two cities continually disputed the supremacy of the valley. In every great war we find them ranged on opposite sides, except when superior force constrained both. In the Peloponnesus the disputes between Argos and Sparta lasted for centuries; and Mantineia was always an ally of the former. In the war between Sparta and Athens, Mantineia was at first forced to be an ally of Sparta, but in 421 it joined Argos in making an alliance with Athens. The city is said by Strabo to have been founded under Argive instigation, by the union of several villages of the valley; there can be no doubt that this was done in order to maintain a party in the valley hostile to Tegea and Sparta. It is impossible here to trace the varying history of the town. It was one of the chief members of the Arcadian league that helped Epaminondas to break the power of Sparta. It was one of the original members of the Achæan league, but deserted it for the Ætolian. The Achæans and Antigonus Doson captured the city in 222 B.C., and changed its name to Antigoneia, but the emperor Hadrian restored the ancient name. The worship and mysteries of Cora at Mantineia were famous. The valley in which the city lies has no opening to the coast, and the water finds its way, often only with much care and artificial aid, through underground passages (*catabothra*) to the sea. It is bounded on the west by Mount Mænalus, on the east by Mount Artemision. The river Ophis flowed through the city. The position of the town in the centre of this valley route made it of great military importance, and five important battles were fought beside it: in 418 B.C. Sparta defeated the alliance above mentioned; in 362 Epaminondas defeated the Spartans and lost his own life; in 295 Demetrius Poliorcetes defeated the Spartans; in 242 Aratus defeated the Spartans; in 207 Philopœmen defeated the Spartans. In the beginning of the 4th century B.C. Mantineia had 3000 citizens capable of bearing arms.

[1] Of these the following may be enumerated—*The Wonders of Geology*, 2 vols.; *The Medals of Creation*, 2 vols.; *Thoughts on a Pebble, or First Lessons in Geology*; *A Geological Excursion round the Isle of Wight*; *Pictorial Atlas of Fossil Remains*; *Thoughts on Animalcules, or a Glimpse at the Invisible World as revealed by the Microscope*; *Petrifactions and their Teachings*.

MANTIS. Probably no other insect has been the subject of so many and widespread legends and superstitions as the common "praying mantis," *Mantis religiosa*, L. (see INSECTS, *Orthoptera*, fam. *Mantidæ*, vol. xiii. p. 152). The ancient Greeks endowed it with supernatural powers (μάντις, "a diviner"); the Turks and Arabs hold that it prays constantly with its face turned towards Mecca; the Provençals call it *Prega-Diou* (*Prie-Dieu*); and numerous more or less similar names—preacher, saint, nun, mendicant, soothsayer, &c.,—are widely diffused throughout southern Europe. Children ask it to show them the way, and Mouffet assures us that it rarely or never deceives them; and it is even recorded that one specimen, which alighted on the hand of St Francis Xavier, and which he commanded to sing the praise of God, loudly intoned a very beautiful canticle. In Nubia it is held in great esteem, and the Hottentots, if not indeed worshipping the local species (*M. fausta*), as one traveller has alleged, at least appear to regard its alighting upon any person both as a token of saintliness and an omen of good fortune.



Praying Mantis (*Mantis religiosa*).

Yet these are "not the saints, but the tigers, of the insect world." The front pair of limbs are very peculiarly modified,—the coxa being greatly elongated, while the strong third joint or femur bears on its curved underside a channel armed on each edge by strong movable spines. Into this groove the stout tibia is capable of closing like the blade of a penknife, its sharp, serrated edge being adapted to cut and hold. The arrangement is essentially similar to the sub-chela of *Squilla* and Amphipods among CRUSTACEA (*q.v.*), as well as to the chelicerae of spiders (see ARACHNIDA). Thus armed, with head raised upon the much-elongated and semi-erect prothorax, and with the half-opened fore limbs held outwards in the characteristic devotional attitude, it rests motionless upon the four posterior limbs waiting for prey, or occasionally stalks it with slow and silent movements, finally seizing it with its knife-blades and devouring it. Although apparently not daring to attack ants, these insects destroy great numbers of flies, grasshoppers, and caterpillars, and the larger South-American species even attack small frogs, lizards, and birds. They are very pugnacious, fencing with their sword-like limbs "like hussars with sabres," the larger frequently devouring the smaller, and the females the males. The Chinese keep them in bamboo cages, and match them like fighting cocks.

The elytra of the common mantis have been compared to a withering willow leaf, a circumstance which not improbably aids in concealing them from their prey. Some of the tropical forms exhibit as perfect mimicry of the leaves as the leaf insects proper (*Phasmidæ*). Bates found a mantis on the Amazon which exactly resembled the white ants it preyed upon, while Wallace mentions a Javanese species which mimics a pink orchid flower, and "is said to feed largely on butterflies,—so that it is really a living trap, and forms its own bait!"

The common species fixes its somewhat nut-like egg capsules on the stems of plants in September. The young are hatched in early summer, and resemble the adults, but are without wings.

See Westwood's *Introd. Mod Class. of Insects*, 1840, and forthcoming monograph of the family.

MANTUA (Italian, *Mantova*), a fortified city of Italy, the chief town of a province, the see of a bishop, and the centre of a military district, lies 95 miles east-south-east of Milan, and 25 miles by rail south of Verona on the way to Modena, occupying, at the height of 88 feet above the level of the Adriatic, an almost insular site in the midst of the swampy lagoons of the Mincio, with their vast reaches of reeds and bulrushes. As the belt of marshy ground along the south side can be laid under water at pleasure, the site of the city proper, exclusive of the considerable suburbs of Borgo di Fortezza to the north and Borgo di San Giorgio to the east, may still be said to consist, as it formerly did more distinctly, of two islands separated by a narrow channel and united by a number of bridges. On the west side lies Lago Superiore, on the east side Lago Inferiore —the boundary between the two being marked by the *Argine del Mulino*, a long covered wooden bridge stretching northward from the north-west angle of the city. As approached from the north by the old road, Mantua presents a beautiful prospect with its "towers and walls and waters." On the highest ground in the city rises the cathedral, built after his death according to the plans of Giulio Romano on the site of the ancient church of Sts Peter and Paul; it has double aisles, a dome-covered transept, and a large tower, popularly assigned to the Roman governor Arius. Architecturally much more important is the church of St Andrew, built towards the close of the 15th century, after plans by Leon Battista Alberti, and consisting of a single barrel-vaulted nave 350 feet long by 62 feet wide. It has a noble façade, with a deeply recessed portico, and a brick campanile of earlier date than the main building. The interior is richly decorated with 18th century frescos. S. Maria delle Grazie, consecrated in 1399 as an act of thanksgiving for the cessation of the plague, has a curious collection of *ex voto* pictures and the tombs of the Gonzaga family. The old ducal palace—one of the largest buildings of its kind in Europe—was commenced in 1302 for Guido Bonaccolsi, and probably completed in 1328 for Ludovico Gonzaga; but many of the accessory apartments are of much later date, and the interior decorations are for the most part the work of Giulio Romano and his pupils. Outside of the city, to the south of Porta Pusterla, stands the Palazzo del Te, Giulio's architectural masterpiece, erected for Frederick Gonzaga; of the numerous fresco-covered chambers which it contains, perhaps the most celebrated is the Sala dei Giganti, where, by a combination of mechanical with artistic devices, the rout of the Titans still contending with artillery of uptorn rocks against the pursuit and thunderbolts of Jove appears to rush downwards on the spectator. Among the educational institutions in Mantua are an academy of arts and sciences (*Accademia Vergiliana*) occupying a fine building erected by Piermarini, a public library founded in 1780 by Maria Theresa, a museum of antiquities dating from 1779, a good botanical garden, and an observatory. The Monte di Pietà was established in 1484, the civil hospital in 1449. Oil, beer, leather, and playing cards are the chief products of the limited local industry. The population increased from 26,687 in 1871 to 28,048 in 1881. As a fortress Mantua was long one of the most formidable in Europe, a force of thirty to forty thousand men finding accommodation within its walls; but it had two serious defects—the marshy climate told heavily on the health of the garrison, and effective sorties were almost impossible.

Mantua was originally an Etruscan town, and had still a strong Etruscan element in its population during the Roman period. It was a Roman municipium; but Martial calls it little Mantua, and, had it not been for Virgil's interest in his native place and in the expulsion of a number of the Mantuans from their lands in favour of Octavian's soldiers, we should probably have heard almost nothing of its existence. In 568 the Lombards found Mantua a walled town of some strength; recovered from their grasp in 590 by the exarch of Ravenna, it was again captured by Agilulf in 601. The 9th century was the period of episcopal supremacy, and in the 11th the city formed part of the vast possessions of Bonifacio, marquis of Canossa. From him it passed to Geoffrey, duke of Lorraine, and afterwards to the Countess Matilda, whose support of the pope led to the conquest of Mantua by the emperor Henry IV. in 1090. Reduced to obedience by Matilda in 1113, the city obtained its liberty on her death, and instituted a communal government of its own, *salva imperiali justitia*. It afterwards joined the Lombard League; and the unsuccessful attack made by Frederick II. in 1236 brought it a confirmation of its privileges. But after a period of internal discord Ludovico Gonzaga attained to power (1328), and was recognized as imperial vicar (1329); and from that time till the death of Ferdinando Carbo in 1708 the Gonzagas were masters of Mantua (see GONZAGA, vol. x. p. 772). Under Gian Francesco II., Ludovico, and Federico II., the first duke of Mantua, the city rose rapidly into importance as a seat of industry and culture. Claimed in 1708 as a fief of the empire by Joseph I., it was governed for the greater part of the century by the Austrians. In June 1796 it was besieged by Napoleon; but in spite of terrific bombardments it held out till February 1797. A three days' bombardment in 1799 again placed Mantua in the hands of the Austrians; and, though restored to the French by the peace of Lunéville (1801), it became Austrian once more from 1814 till 1866. In the years between 1849 and 1859 the city was the scene of violent political persecution.

Besides Virgil, Mantua counts among its celebrities Sordello the Provençal poet, Castiglioni, Folengo the writer of macaronics, and Pomponazzi the philosopher; and it has a long roll of local historians—Donesmondi (ecclesiastical affairs), Possevino, Daino, Amedei, Visi, Tonelli, and Count Carlo d'Arco.

Gaet. Susani, *Nuovo prospetto delle pitture, &c., di Mantova*, Mantua, 1830; Carlo d'Arco, *Delle arti e degli artefici di Mantova*, Mantua, 1857, and *Storia di Mantova*, Mantua, 1874.

MANUCODE, from the French, an abbreviation of *Manucodiata*, and the Latinized form of the Malay *Manuk-dewata*, meaning, says Crawfurd (*Malay and Engl. Dictionary*, p. 97), the "bird of the gods," and a name applied for more than two hundred years apparently to Birds-of-paradise in general. In the original sense of its inventor, Montbeillard (*Hist. Nat. Oiseaux*, iii. p. 163), *Manucode* was restricted to the King Bird-of-paradise and three allied species; but in English it has curiously been transferred[1] to a small group of species whose relationship to the *Paradiseidæ* has been frequently doubted, and must be considered uncertain. These Manucodes have a glossy steel-blue plumage of much beauty, but are easily distinguished from other birds of similar coloration by the outer and middle toes being united for some distance, and they are very remarkable for the extraordinary convolution of the trachea, in the males at least, with which singular structure is correlated the loud and clear voice of the birds. The convoluted portion of the trachea lies on the breast, between the skin and the muscles, much as is found in the females of the genus *Rhynchæa*, in the males of the Curassows (*Cracidæ*), and in a few other birds, but wholly unknown elsewhere among the *Passeres*. The Manucodes are peculiar to the Papuan Sub-region (including therein

[1] *Manucodiata* was used by Brisson (*Ornithologie*, ii. p. 130) as a generic term equivalent to the Linnæan *Paradisea*. In 1783 Boddaert, when assigning scientific names to the birds figured by Daubenton, called the subject of one of them (*Pl. enlum.* 634) *Manucodia chalybea*, the first word being apparently an accidental curtailment of the name of Brisson's genus to which he referred it. Nevertheless some writers have taken it as evidence of an intention to found a new genus by that name, and hence the importation of *Manucodia* into scientific nomenclature, and the English form to correspond.

the peninsula of Cape York), and comprehend, according to Mr Sharpe (*Cat. B. Brit. Museum*, iii. p. 164), two genera, for the first of which, distinguished by the elongated tufts on the head, he adopts Lesson's name *Phonygama*, and for the second, having no tufts, but the feathers of the head crisped, that of *Manucodia*; and Mr W. A. Forbes (*Proc. Zool. Society*, 1882, p. 349) observes that the validity of the separation (which has not yet been generally acknowledged) is confirmed by what is now known of their tracheal formation. Of *Phonygama* Mr Sharpe recognizes three species, *P. keraudreni* (the type) and *P. jamesi*, both from New Guinea, and *P. gouldi*, the Australian representative species; but the first two are considered by Mr Elliot (*Ibis*, 1878, p. 56) and Count Salvadori (*Ornitol. della Papuasia*, ii. p. 510) to be inseparable. There is a greater unanimity in regard to the species of the so-called genus *Manucodia* proper, of which four are admitted—*M. chalybeata* or *chalybea* from north-western New Guinea, *M. comriei* from the south-eastern part of the same country, *M. atra* of wide distribution within the Papuan area, and *M. jobiensis* peculiar to the island which gives it a name. Little is known of the habits of these birds, except that they are as already mentioned remarkable for their vocal powers, which, in *P. keraudreni*, Lesson describes (*Voy. de la Coquille*, Zoologie, i. p. 638) as enabling them to pass through every note of the gamut. Mr Wallace (*Ann. Nat. History*, ser. 2, xx. p. 476) remarked that *M. atra* was very powerful and active, clinging suspended to the smaller branches of trees, on the fruits of which alone it appears to feed. *M. gouldi*, according to an informant quoted by Mr Forbes (*ut supra*), frequents in pairs the dense palm-forests, perching high up, uttering a very deep and loud guttural note; it is graceful in its movements, evincing more curiosity than timidity on being approached. As with members of the *Paradiseidæ* generally, the nidification of the Manucodes is still shrouded in mystery. (A. N.)

MANUEL I., COMNENUS, emperor of Constantinople from 1143 to 1184, was the fourth son of John II. (Calo-Joannes), and was born about the year 1120. He succeeded to the imperial crown on April 8, 1143, having for his martial qualities been nominated by John to the inheritance in preference to his elder surviving brother. During his reign of thirty-seven years he was involved in almost perpetual war, in which he displayed much more of the courage of a soldier than of the prudence and skill of a commander. In 1144 the imperial general Demetrius Branas brought back Raymond, the Latin prince of Antioch, to his allegiance, and in 1145 Manuel in person drove out the Turks who had invaded Isauria, and compelled them to accept peace on his own terms. In 1147 he granted a passage through his dominions to the crusaders under Louis VII. of France and Conrad III. of Germany, but secretly harassed them by every means in his power, and sent word to the Turks of their approach. In the following year he became involved, along with the Venetians, in a war with Roger of Sicily, who had taken Corfu and invaded Greece; an episode of the campaign towards its beginning was his repulse beyond the Danube of the Patzenegues, of whom he took hostages for their future good behaviour. Disembarking his host at Corfu before the end of the year, he invested the fortress in co-operation with the Venetian army; the inhabitants, after a long siege, in which he displayed prodigies of personal strength and valour, surrendered in 1149. Manuel was now prevented from invading Sicily by a diversion made by the Servians and Hungarians on the Danube, who were not completely vanquished until 1152. In that year Manuel was repulsed by the Turks in Cilicia, but in the west his troops obtained possession of Bari, Brundisium, and other places of importance in Apulia and Calabria. The course of Italian politics, however, deprived him of the means on which he had reckoned for enabling him to reunite southern Italy with the Byzantine empire, and after the defeat of his fleet at Negropont he concluded a peace with William, Roger's successor, in 1155. The next important war of Manuel's reign was waged against the Hungarians from 1163 to 1168; it came to an end in the latter year with the hard-won victory of the Byzantine arms at Zeugminum (Semlin). Less successful was the expedition under Andronicus Contostephanus against Egypt in 1169, when the combined forces of Manuel and King Amalric were compelled to withdraw from before Damietta. From 1171 to 1174 Manuel had a war with the Venetians; and in 1176 he led in person an expedition against Kilidj Arslan, the sultan of Iconium when he sustained a disastrous defeat at Myriocephalus, and was compelled to sign a dishonourable peace. This disgrace, although partially retrieved by a somewhat more successful expedition in 1177, so preyed upon the spirit of Manuel that he ultimately succumbed to a slow fever on September 24, 1180. He was first married to Bertha (Irene), a relative of Conrad III. of Germany, and afterwards to Maria (Xene), daughter of Raymond of Antioch; Alexis II., his son by the latter, succeeded him.

MANUEL II., PALÆOLOGUS, emperor of Constantinople, was born in 1348, and succeeded his father, John VI. (with whom he had been associated since 1375), in 1391. At the time he was a hostage at the court of Bajazet at Nicæa, but succeeded in making his escape; he was forthwith besieged in Constantinople by the sultan, whose victory over the Christians at Nicopolis, however (September 28, 1395), did not secure for him the capital. Manuel subsequently set out in person to seek help from the West, and for this purpose visited Italy, France, and Germany, but without material success; the victory of Timur in 1402, and the death of Bajazet in the following year, were the first events to give him a genuine respite from Ottoman oppression. He stood on friendly terms with Mahomet I., but was again besieged in his capital by Amurath II. in 1422. He died in 1425, and was succeeded by his son, John VII.

MANUEL I., emperor of Trebizond, surnamed the Great Captain (ὁ στρατηγικώτατος), was the second son of Alexius I., first emperor of Trebizond, and ruled from 1238 to 1263. Whatever may have been his military skill, or his personal character for bravery, he was unable to deliver his empire from vassalage first to the Seljuks and afterwards to the Mongols. He was the founder of the church and monastery of St Sophia at Trebizond. His predecessor was John I., Axuchus, and his eldest son, Andronicus II., succeeded him.

Manuel II., the descendant of Manuel I., reigned only a few months in 1322–33. Manuel III. reigned from 1390 to 1417, but the only interest attaching to his name arises from his connexion with Timur, whose vassal he was.

See Finlay, *Mediæval Greece and Trebizond*, 1851.

MANURE. The term "manure," though formerly applied only to the excrements of animals, either alone or mixed with straw, is now more widely used, and is given to all substances, or mixtures of substances, which are added to the soil in order to increase its productiveness or to restore the natural fertility lost by repeated cropping.

The subject of manures and their application involves a prior consideration of plant life and its requirements. The plant, growing as it does in the soil, and surrounded by the atmosphere, derives from these two sources its nourishment and means of growth through the various stages of its development. From these sources, each equally indispensable, the plant obtains the materials which it has the power of elaborating and building up to form its own structure.

Chemical analysis has shown that plants are composed of water, organic or combustible matters, and inorganic, incombustible, or mineral matters. These last are left as the ash when the plant is burnt. The elements forming the organic portion of plants are carbon, hydrogen, oxygen, and nitrogen; the mineral portion, or ash, consists principally of lime, magnesia, potash, soda, oxide of iron, phosphoric acid, sulphuric acid, chlorine, and silica.

The atmosphere is the great storehouse of organic plant-food. The carbonic acid always present in the air is, as is well known, eagerly taken up by the leaves of plants, all of which have the power of decomposing carbonic acid, giving off its oxygen, and assimilating its carbon. Roughly speaking, three-fourths of the dry substance of all plants is derived from the atmosphere.

Under conditions of natural growth and decay, when no crops are gathered in, or consumed on the land by live stock, the herbage on dying down and decaying returns to the atmosphere and the soil the elements taken from them during life; but under cultivation a succession of crops deprives the land of the constituents which are essential to healthy and luxuriant growth. Without an adequate return to the land of the matters removed in the produce, its fertility cannot be maintained for many years. In newly-opened countries, where old forests have been cleared and the land brought into cultivation, the virgin soil often possesses at first a high degree of fertility, but gradually its productive power decreases from year to year. Generally speaking, it is more convenient to clear fresh forest land than to improve more or less exhausted virgin land by the application of manure, labour, and skill. In all densely peopled countries where such a mode of cultivation cannot be followed it is necessary to resort to artificial means to restore the natural fertility of the land and maintain and increase its productiveness.

The researches of Liebig, Wiegmann, Polstorff, and others have proved beyond doubt the important functions of the mineral constituents of the soil in relation to plant life. The gradual removal of phosphate of lime in the tillage of dairy districts, or the removal of other mineral matters essential to the healthy growth of farm crops, certainly impoverishes the land. The exhaustion of the soil is caused in a much more marked way, however, by the rapid loss in available nitrogenous plant food which soils sustain when under cultivation without manure.

Agricultural improvements manifest themselves in two different directions—the mechanical and the chemical. Under mechanical improvement the physical condition of the soil is bettered and its latent stores of plant food brought into action by mechanical means, such as ploughing, subsoiling, steam cultivation, &c. The introduction of new and superior agricultural implements, good systems of drainage, and intelligent division of labour characterize the first stage of progress in agriculture. The second stage is marked by the application of chemical principles to practical agriculture, an application shown by the introduction of a rational system of feeding, a proper rotation of crops, and chiefly the use of chemical, or artificial, manures for the purpose of restoring the natural fertility of the soil and increasing its productive powers.

The aid which chemistry has rendered during the last twenty-five or thirty years to practical agriculture has greatly promoted agricultural improvements; and farming, which is in a large measure dependent for success upon an economical use of manures, is now being carried on much more rationally than in former times. The proper application of various kinds of manures is one of the most prominent features of successful modern farming.

In considering the economical use of manures on the land, regard must be had to the following points:—(1) the requirements of the crops intended to be cultivated; (2) the physical condition of the soil; (3) the composition of the soil; and (4) the composition of the manure. Briefly stated, the guiding principle of manuring economically and profitably is to meet the requirements of the crops intended to be cultivated, by incorporating with the soil, in the most efficacious states of combination, the materials in which it is deficient, or which the various crops usually grown on the farm do not find in the land in a sufficiently available condition to ensure an abundant harvest.

Soils vary greatly in composition, and hence it will be readily understood that in one locality or on one particular field a certain manure may be used with great benefit, while in another field the same manure has little or no effect upon the produce. Although increased attention has of recent years been paid to the chemical composition and properties of soils, there is still much room left for improvement, for many farmers disregard almost altogether the composition of their fields in buying artificial manures.

It has been pointed out by Sir John Lawes that in actual English farm-practice there is, speaking practically, a standard of natural produce which varies within certain limits, as influenced by seasons and management, and which cannot be permanently increased or reduced by cultivation; and further, when land is spoken of as being in "good condition," reference is made only to the temporary rise of fertility by means of the manures employed, while by land "out of condition" is signified the exhaustion of the manures by the removal of crops, loss by drainage, &c., and that the soil has merely gone back to its standard of natural productiveness. Some soils, indeed, contain in their natural condition hardly a sufficient proportion of available elements of plant food to yield remunerative crops; such soils are naturally barren, and, although by the constant use of manures they may be improved and may attain some degree of fertility, they will, if left unmanured, speedily revert to their former natural unproductive state.

The principal constituents of manures are—nitrogen, in the form of ammonia, nitrates, and nitrogenous organic matters; organic matters not containing nitrogen (humus); phosphoric acid, potash, soda, lime, magnesia, silica, sulphuric acid, and chlorine. Of these constituents by far the most important are the nitrogen, phosphoric acid, and potash, and these will be considered more in detail.

1. *Nitrogen.*—Nothing so much affects the productiveness of soils as nitrogen, when it is supplied to plants in a form in which it can be assimilated by them, and nothing is more readily removed from the land, either in the crop grown or, in the form of nitrates, by drainage. The "good condition" of land, to which allusion has been made already, is, in a great measure, the fertility which has been imparted to the soil by the nitrogen supplied to it, while the "natural productiveness" may be taken as that due to the phosphoric acid, potash, and other mineral constituents of the soil.

Supply of Nitrogenous Plant Food.—In the case of a crop growing under natural conditions, and not removed from the land, the mineral constituents taken from the soil, and carbonaceous as well as some nitrogenous organic matter, principally derived from the atmosphere, are returned to the land, and a rich carbonaceous soil or humus is produced in the course of years. Such a soil is capable of supplying for a considerable number of years, when under cultivation, the nitrogen needed by the crops grown on the land. This supply of nitrogen, however, gradually becomes exhausted by repeated cropping. The atmosphere, in addition to free nitrogen gas, which constitutes about four-fifths of its volume, contains but very little combined nitrogen in the forms of ammonia or nitric acid.

M. Boussingault's experiments clearly show that plants do not possess the power of taking up by their leaves and of assimilating the free nitrogen of the air. This conclusion has been verified by the extensive researches of Messrs Lawes, Gilbert, and Pugh. The nitrogen contained as nitric acid and ammonia in the air, and descending upon the land in the shape of rain, dew, or snow, though, without doubt, adding to the supply of nitrogen in the soil, is altogether insufficient to meet the requirements of remunerative crops. The experiments of Messrs Lawes and Gilbert and Professor Way show that the average proportion of nitrogen deposited annually upon one acre of land at Rothamsted, St Albans, amounts to 7·21 lb, of which quantity 6·46 lb occur as ammonia and ·75 lb as nitric acid.

The further investigations of Dr Voelcker, Professor Frankland, and Messrs Lawes and Gilbert upon the drainage water from cultivated soils show that a considerable quantity of nitrogen in the shape of nitric acid passes into land drainage, and that this loss of nitrogen is much greater than the total amount supplied to the land by the rain and dew. The results which Messrs Lawes and Gilbert obtained in their experiments on the continuous growth of barley at Rothamsted from 1852 to 1875 afford, as is shown in the following table (I.), direct evidence of the insufficiency of the atmospheric supply of nitrogen, and of that present in the soil in the form of nitrogenous organic matter.

TABLE I.—*Messrs Lawes and Gilbert's Experiments on the Growth of Wheat and Barley, year after year on the same Land, without Manure, and with different kinds of Manure.*

Manures per Acre per Annum.	Produce per Acre (Average per Annum).								
	Dressed Corn.						Total Straw.		
	Quantity.			Weight per Bushel.					
	12 Years 1852–63.	12 Years 1864–75.	24 Years 1852–75.	12 Years 1852–63.	12 Years 1864–75.	24 Years 1852–75.	12 Years 1852–63.	12 Years 1864–75	24 Years 1852–75.
Wheat.[1]	bush.	bush.	bush.	lb	lb	lb	cwts.	cwts.	cwts.
1. Unmanured continuously	15½	12⅝	14	56½	59	57¾	14⅞	9¾	12⅜
2. Mineral manures alone (200 lb sulphate of potash, 100 lb sulphate of soda, 100 lb sulphate of magnesia, and 3½ cwts. of superphosphate made from 200 lb bone ash, 150 lb sulphuric acid of 1·7 specific gravity, and water)	18¼	13¾	16⅛	57⅞	59¾	58⅞	16⅞	14¼	14⅛
3. Ammonia salts alone for 1845, and each year since; mineral manure in 1844 (equal parts of sulphate and muriate of ammonia of commerce)	22⅝	21⅛	21⅞	55⅞	58	56⅞	23¼	18½	20⅞
4. Ammonia salts and minerals. (The same minerals as in No. 2, and 600 lb ammonia salts.)	38	37	37½	57¾	60¼	59	42⅛	40¼	41¼
5. Farmyard manure (14 tons every year)	35⅜	35	35¼	59¼	60⅝	60	34⅝	32⅝	33⅝
Barley.[2]									
1. Unmanured continuously	21⅞	15⅞	18⅞	51½	53¼	52½	12⅞	9⅛	11
2. Mineral manure alone (200 lb sulphate of potash, 100 lb sulphate of soda, 100 lb sulphate of magnesia, and 3½ cwts. of superphosphates)	30⅜	21½	25⅞	52½	54½	53½	15⅞	10⅞	13⅜
3. Superphosphate alone (3½ cwts.)	27⅞	20¾	24¼	52¼	54⅜	53¾	14¾	10⅛	12⅜
4. Ammonia salts alone (200 lb)	34¼	29	31⅝	51¼	53¼	52¼	19⅞	15¾	17⅞
5. Nitrate of soda (275 lb)	39⅞	32¼	36	51	53⅜	52¼	23⅞	18⅜	21⅛
6. Ammonia salts and minerals. (The same minerals as in No. 2, and 200 lb ammonia salts.)	47⅛	44	45½	52⅝	55⅝	54¼	29¾	26½	27⅞
7. Nitrate of soda and minerals. (The same minerals as in No. 2, and 275 lb nitrate of soda.)	50⅝	46⅜	48½	51¾	55½	53⅜	34⅝	28	31¼
8. Farmyard manure (14 tons every year)	46⅝	50¾	48¾	53¼	55½	54⅜	27⅞	29⅝	28¾

The Rothamsted soil is a moderately stiff one, of considerable depth, and contains naturally the mineral elements of plant food in abundance; thus it has been possible to grow corn crops for over twenty-five years without any manure (Plots 1). The crops in the second period of twelve years were, however, less than those of the first period, and in neither case were full crops obtained. While the application of mineral manures alone (Plots 2) produced only a slight increase in the case of the wheat, and rather better, though poor, results with barley, nitrogenous manures, applied to the land either in the shape of ammonia salts or nitrate of soda, produced a strikingly large increase. The experiments further show that while good crops, both of wheat and barley, can be grown by the annual application of 14 tons of farmyard manure per acre, the best results are obtained by the use of a mixture of mineral and nitrogenous manures.

In Messrs Lawes and Gilbert's experiments the amount of nitrogen removed in different crops was determined with the following results:—over a period of thirty-two years (to 1875), wheat yielded an average of 20·7 lb of nitrogen per acre per annum without any manure, but the annual yield has decreased from an average of over 25 lb in the first eight to less than 16 lb in the last twelve years, and since 1875 it has been still less; over a period of twenty-four years, barley, when unmanured, yielded an average of 18·3 lb nitrogen per acre per annum, but with a decline from 22 lb in the first twelve to 14·6 in the last twelve years. Experiments similar to those on wheat and barley have been made on oats, root crops, leguminous and grass crops, all showing the gradual decline in produce when grown continuously without nitrogenous manures, and proving that the soil and not the atmosphere is the chief source of nitrogen in plants. In face of these results the "mineral theory" of Liebig, which attached but small value to nitrogen applied to the soil in the form of nitrogenous manures, and maintained the sufficiency of the ammonia of the atmosphere for supplying the needs of the plant, cannot be accepted without reserve.

Notwithstanding the great effect produced by the nitrogenous manures, two-thirds of the nitrogen supplied was unrecovered in the increase of crops when the ammonia salts were supplied to wheat in autumn. When, however, nitrate of soda was used, which is always applied in the spring, the quantity left unrecovered was not much more than half that supplied.

The following table (II.), by Messrs Lawes and Gilbert, shows the amount of nitrogen recovered, and the amount not recovered, in the increase of the crop for 100 supplied in manure, to wheat and to barley respectively, the result being in each case the average over a period of twenty years:—

[1] Previous cropping:—1839, turnips with farmyard manure; 1840, barley; 1841, pease; 1842, wheat; 1843, oats; the last four crops unmanured. First experimental wheat crop in 1844. Wheat every year since; and, with some exceptions, nearly the same description of manure on the same plots each year—especially during the last twenty-six years (1852 and since). Unless otherwise stated, the manures are sown in the autumn before the seed. Area under experiment about 13 acres.

[2] Previous cropping:—1847, swedish turnips with dung and superphosphate of lime, the roots carted off; 1848, barley; 1849, clover; 1850, wheat; 1851, barley manured with ammonia salts. First experimental crop in 1852. Barley every year since.

TABLE II.

Manuring quantities per Acre per Annum.	Wheat. 20 Years 1852–71. Recovered in Increase.	Wheat. 20 Years 1852–71. Not recovered in Increase.	Barley. 20 Years 1852–71. Recovered.	Barley. 20 Years 1852–71. Not recovered.
Complex mineral manure and 41 lb of nitrogen as ammonia	32·4	67·6	48 1	51·9
Complex mineral manure and 53·3 lb of nitrogen as ammonia	...	...	49·8	50·2
Complex mineral manure and 82 lb of nitrogen as ammonia	32·9	67·1	...	...
Complex mineral manure and 123 lb of nitrogen as ammonia	31·5	68·5	...	...
Complex mineral manure and 164 lb of nitrogen as ammonia	28·5	71·5	...	...
Complex mineral manure and 82 lb of nitrogen as nitrate	45·3	54·7	...	...
Complex mineral and rape cake (61·75 lb of nitrogen)	...	...	36·3	63·7
Farmyard manure (about 200 lb of nitrogen)	14·6	85·4	10·7	89·3

The question will naturally be raised, What becomes of the one-half or two-thirds of the nitrogen which is not recovered in the increase of the crops? The examination of some seventy samples by Dr Voelcker, and a number of independent determinations by Dr Frankland, of the drainage-water from the experimental wheat plots which yielded the above results throw much light on this loss. The following table (III.) contains a summary of some of the more important results obtained.

TABLE III.—*Nitrogen as Nitrates and Nitrites, per* 100,000 *parts of Drainage Water from Plots differently Manured, in the Experimental Wheat-field at Rothamsted, Wheat every year, commencing* 1844.

Mean of Dr Voelcker's and Dr Frankland's Results.	Experiments.	Nitrogen.
Farmyard manure	6	1·264
Without manure	11	0·353
Complex mineral manure	11	0·428
Do. and 41 lb nitrogen as ammonia	11	0·823
Do. and 82 lb nitrogen as ammonia	11	1·439
Do. and 123 lb nitrogen as ammonia	11	1·815
Do. and 82 lb nitrogen as nitrate	10	1·437

These experiments show how great may be the loss of nitrogen by drainage when ammonia salts or nitrates are liberally applied to the land in autumn, should there be much wet weather in winter, or even when applied in spring if there be much heavy rain; also, that the quantity of nitrogen in drainage water as nitrates is increased in proportion to the amounts of ammonia or nitrate employed on the land. Assuming that from one-quarter to nearly one-half the annual rainfall descends more than 40 inches below the surface, every inch of rain passing through the drains and carrying with it one part of nitrogen in 100,000 of water, there will be a loss of 2½ lb of nitrogen per acre from the manure. Dr Voelcker's analysis of the drainage water of a wheat field manured in autumn by ammonia salts supplying 82 lb of nitrogen per acre shows that for every inch of rain passing through the drains in January a loss took place of about 8½ lb of nitrogen, costing about 1s. per lb as manure. The loss of nitrogen thus is very large, and shows that by far the largest proportion of the nitrogen of manure which is not recovered in the crop is lost in drainage. In addition to the nitrogen removed in the crop and to that lost in drainage, some small proportion is found by analysis to be retained in the soil itself. The nitrogen may be of advantage to crops grown subsequently, according to the source from which it was derived; for while ammonia salts and nitrates yield but very small residues, and exert little or no effect beyond the first year, from bones, cake, and other such materials we get large residues of nitrogen in the soil, which tell markedly on future crops. The experiments on drainage water have further shown the absorbent power of soils, and that manuring matters when in contact with soils undergo remarkable changes, being taken up by plants, not in the simple state in which they are applied, but in quite different kinds of combination. Professor Way has the merit of having first proved that all soils possess, in different degrees, the power of absorbing ammonia from its solution in water, and that in passing solutions of salts of ammonia through soils the ammonia alone is absorbed, and the acids of the ammonia salts pass through in combination, generally with lime, or, if lime be deficient, with magnesia or other mineral bases of the soil.

In the drainage investigations at Rothamsted, it was found that, although large quantities of ammonia salts were applied to some of the plots, the drainage water from them contained mere traces of ammonia, but at all times of the year nitrates were present in quantity; from this it would appear that it is chiefly, if not solely, from nitrates that crops build up their nitrogenous organic constituents. Before leaving the subject of drainage water it is worthy of note here that phosphoric acid and potash, the most valuable mineral fertilizing constituents of the manures, passed but little into the drainage water, but were retained almost entirely in the land, while the more abundant and less important mineral matters, such as lime, magnesia, soda, chlorine, sulphuric acid, and soluble silica, passed in large quantities into the drainage water. It follows from these investigations, first, that much more nitrogenous material must be applied to the land than would be needed to produce a given increase in the crop, supposing all the nitrogen to be recoverable; and secondly, that nitrogenous organic matters when applied to the land undergo decomposition, and are gradually resolved into ammonia compounds, which, after being retained a short time by the soil, are finally oxidized into nitrates, in which form they are most available and beneficial to plants, but are not absorbed by the soil, and are readily washed out by rain. Nitrogen has great forcing properties, and is most beneficial when applied to crops in their early stages. Grass land on which nitrate of soda has been put as a top dressing shows very rapidly and markedly the effects of the manure.

Nitrate of soda, unless applied just at the time the crop is ready to take it up, will be largely wasted in drainage; hence it is usual to apply nitrate of soda as a top dressing in spring. Ammoniacal manures, such as Peruvian guano, soot, sulphate of ammonia, &c., when used for winter wheat, are best applied in autumn, either before the wheat is sown or when it is fairly above ground. On light land they are often used as top dressings for wheat early in spring. The gradual decomposition of farmyard manures gives a more constant supply of nitrogen than the manures already noticed, and as the fermentation of dung proceeds but slowly it is best to apply it, when quite fresh, in autumn or winter, allowing it to decompose in the land and to yield nitrogen as nitrates when required in spring by the fresh growth of vegetation. In the case of nitrogenous organic materials, such as wool or hair refuse, which take even longer than farmyard manure to decompose, it is necessary to apply them some three or four months before the seed is sown.

2. *Phosphoric Acid.*—Next in value to nitrogen as a constituent of manures comes phosphoric acid. Of all the mineral or ash constituents of plants, this is the most important, for the simple reason that it occurs in most soils in comparatively small proportions, and is required alike by corn and forage crops in larger quantities than lime, magnesia, and other mineral matters, which occur in most soils in almost inexhaustible quantities, or which, if deficient, can be easily and cheaply incorporated with the land.

Phosphoric acid occurs in soils principally in combination with lime as phosphate of lime, a constituent which enters largely into the composition of recent and fossil bones, coprolites, and guano, and of a variety of phosphatic minerals, such as Norwegian and Canadian apatite, Sombrero and Curaçoa rock phosphate, South Carolina phosphate, Spanish and Portuguese phosphorite, &c. These and other phosphatic materials are now used largely in the manufacture of superphosphate and other artificial manures.

Phosphate of lime is so sparingly soluble in pure water that, for all practical purposes, it may be considered to be insoluble in water; it is, however, attacked by the natural agencies at work in the soil, and rendered available as plant food. According to the more or less porous condition of the phosphatic manuring materials, phosphate of lime is rendered more or less readily assimilable. Thus, while bone dust and guano, on account of their porous condition, may be used with good effect as suppliers of phosphoric acid to the soil, others, such as hard and crystalline Canadian or Norwegian apatite, produce but little or no result when used as manures merely in a powdered state. It was in 1840 that Liebig suggested the treatment of bones with sulphuric acid in order to make their action more rapid. This treatment of bones by acid converts the phosphate of lime into a soluble lime salt called superphosphate, or, speaking chemically, transforms the original tribasic phosphate of lime into the monocalcic phosphate, sulphate of lime being at the same time produced. Following on this, Mr (now Sir) John Lawes treated mineral phosphates similarly with sulphuric acid, and with results which led to the establishment of a new industry, the manufacture of superphosphate and other artificial manures. The yearly importation of phosphatic minerals, &c., into England for this manufacture alone exceeds 500,000 tons.

The acid or soluble phosphate of lime in superphosphate, when applied to the soil, is first dissolved by the rain, and equally distributed in a portion of the soil, in which it must be precipitated and rendered insoluble before it can be assimilated by the plant. It is this intimate distribution and subsequent precipitation in a most finely divided state that would seem to constitute the beneficial effects of superphosphate, and its superiority over undissolved phosphates. It supplies at once phosphoric acid, lime, and sulphuric acid to the soil, and is much used in conjunction with nitrogenous materials. Superphosphates are manufactured of various strengths, the percentage of tribasic phosphate of lime, rendered soluble by acid, being taken as the basis of valuation.

3. *Potash.*—The next to rank after phosphoric acid as a valuable constituent of manures is potash. It enters largely into the composition of all crops, especially root crops. Sandy soils, as a rule, are poor in potash, for which reason they are benefited to a greater extent by the application of potash salts than most clay soils, which contain sufficient potash to meet the requirements of farm crops. In clay soils potash mainly occurs in the form of insoluble silicate of potash together with other silicates. By autumn cultivation, subsoiling, and similar means of facilitating the free access of the air to clay-land potash is gradually liberated from the insoluble silicates and is rendered available as plant food. Lime also seems to be an important agent in the liberation of potash. Potash also occurs in farmyard manure, urine, all excrements, in oil cakes, and largely in wood ashes.

Most potash salts are very soluble in water; this explains their greater abundance in the liquid than the solid excrements of animals. On this account it is a matter of importance, in making farmyard manure, to preserve the urine, and not lose the benefit of the potash salts it contains. On most soils in a good agricultural condition the addition of potash manures produces little or no effect, but on poor sandy soils or worn-out pasture land the use of potash salts, in conjunction with superphosphate, dissolved bones, and guano, is followed by most beneficial results. Potash salts as an addition to manures for potatoes have been found advantageous, while their effect on pasture seems to be to improve the quality of the herbage rather than to increase the yield of grass per acre.

4. *Soda.*—Most soils contain in abundance all the soda that farm crops require. With the exception of chloride of sodium (common salt), which occasionally is applied with more or less benefit to light sandy soils, and of nitrate of soda, which is employed as a nitrogenous manure, soda salts are not used for manuring purposes.

5. *Lime.*—Lime is essential for the production of healthy crops. Experience has shown that, when a soil is deficient in lime, farmyard manure, Peruvian guano, and other manures, though used in abundance, produce comparatively but little effect. Again, on poor sandy soils, lime, marl, or chalk not unfrequently produces better crops than farmyard or expensive artificial manures. Lime not only supplies an essential constituent of plants, but also prevents the loss by drainage of fertilizing matters such as potash, ammonia, and phosphoric acid. One of the functions of lime in the soil is to combine with the acids of the potash and ammoniacal salts of guano and of farmyard and other manures, and to liberate potash and ammonia, which are retained in the land, while the inexpensive lime salts pass into the land drainage.

Lime is used in agriculture in the form of quicklime, chalk (carbonate of lime), gypsum (sulphate of lime), marl, and shell-sand. For liming purposes gas-lime also is frequently employed, and, if well exposed to the air before being put on the land, may be used with safety and advantage.

6. *Magnesia.*—Magnesia is of but slight importance in manures; it occurs with potash in kainite and other potash salts, and the sulphate is sometimes used in making up artificial manures, but apparently without benefit.

7. *Silica.*—Silica is a constituent of the ashes of all plants, and occurs specially in large proportion in the straw of cereal crops. All soils contain such an abundance of silica that no necessity exists of supplying it artificially.

8. *Chlorine, Sulphuric Acid, and Oxide of Iron.*—These ash constituents are of little practical importance, inasmuch as most soils contain a sufficiency of them to meet the requirements of the crops usually cultivated on the farm. It may be observed, however, that chlorine has been found to be essential to plant life, and that iron is necessary for imparting to plants their green colour.

9. *Organic Matter or Humus.*—The importance of organic matter in manures was formerly much exaggerated. It has been conclusively proved that the carbon of which the bulk of the dry substance of all agricultural produce consists is derived from the carbonic acid of the atmosphere, and not from humus of the soil or the non-nitrogenous organic matters supplied in the manure. The organic matters present in dung in the shape of more or less decomposed or rotten straw exert a beneficial effect by improving the physical condition of both light and heavy land.

Farmyard Manure.—Farmyard manure is composed of the urine and solid excrements of animals collected in the stalls or yards, together with the straw used as litter. Its

TABLE IV.—*The Composition of Farmyard Rotted Dung from Horses, Cows, and Pigs, in 100 parts.*

Water		75·42
Soluble[1] organic matter		3·71
Soluble inorganic matter (ash)—		
Soluble silica	·254	
Phosphate of lime	·382	
Lime	·117	
Magnesia	·047	
Potash	·446	
Soda	·023	
Chloride of sodium	·037	
Sulphuric acid	·058	
Carbonic acid and loss	·106	1·47
Insoluble[2] organic matter		12·82
Insoluble inorganic matter (ash)—		
Soluble silica	1·424	
Insoluble silica	1·010	
Oxides of iron and alumina with phosphates (Containing phosphoric acid ·274, equal to bone earth ·573.)	·947	
Lime	1·667	
Magnesia	·091	
Potash	·045	
Soda	·038	
Sulphuric acid	·063	
Carbonic acid and loss	1·295	6·58
		100·00

[1] Containing ·297 of nitrogen, equal to ·36 of ammonia.
[2] Containing ·309 of nitrogen, equal to ·375 of ammonia. The whole manure containing ammonia in free state, ·046; in form of salts, ·057.

composition varies greatly, according to the quantity of straw used as an absorbent, the nature of the animals, the food they have consumed to produce it, the length of time and way in which it has been kept, &c. The analysis by Dr Voelcker of well-made farmyard manure from horses, cows, and pigs, given in Table IV., p. 509, will show its approximate composition.

This analysis shows that farmyard manure contains all the constituents, without exception, which are required by cultivated crops to bring them to perfection, and hence it may be called a perfect manure. Dung, it will be observed, contains a great variety of organic and inorganic compounds of various degrees of solubility, and this complexity of composition—difficult, if not impossible, to imitate by art—is one of the reasons which render farmyard manure a perfect as well as a universal manure.

The excrements of different kinds of animals vary in composition, and those of the same animal will vary according to the nature and quantity of the food given, the age of the animal, and the way it is generally treated. Thus a young animal which is growing needs food to produce bone and muscle, and voids poorer dung than one which is fully grown and only has to keep up its condition. The solid and liquid excrements differ much in composition, for, while the former contains a good deal of phosphoric acid, lime, magnesia, and silica, and comparatively little nitrogen, the urine is almost destitute of phosphoric acid, and abounds in alkaline salts and nitrogenous organic matters, which on decomposition yield ammonia. Unless, therefore, the two kinds of excrements are mixed, a perfect manure supplying all the needs of the plant is not obtained; care must accordingly be taken to absorb all the urine by the litter. Farmyard manure, it is well known, is much affected by the length of time and the way in which it has been kept. Fresh dung is soluble in water only to a limited extent, and in consequence it acts more slowly on vegetation, and the action lasts longer than when dung is used which has been kept some time; fresh dung is therefore generally used in autumn or winter, and thoroughly rotten dung in spring, when an immediate forcing effect is required.

The changes which farmyard manure undergoes on keeping are illustrated by the following table of analyses, by Professor Wolff of Hohenheim in Würtemberg, of farmyard manure in its different stages of decomposition :—

TABLE V.—*Average Percentage Composition of Farmyard Manure.*

	Fresh.	Moderately Rotten.	Thoroughly Rotten.
Water	71·0	75·0	79·0
Organic matters	24·6	19·2	14·5
Ash	4·4	5·8	6·5
	100·0	100·0	100·0
Potash	·52	·63	·50
Soda	·15	·19	·13
Lime	·57	·70	·88
Magnesia	·14	·18	·18
Phosphoric acid	·21	·26	·30
Sulphuric acid	·12	·16	·13
Chlorine	·15	·19	·16
Silica	1·25	1·68	1·70
Nitrogen	·45	·50	·58

These figures represent the composition of farmyard manure of rather poor quality. Well-made good dung, produced by fattening cattle fed upon a fair allowance of cake, roots, hay, and straw, on an average may be said to contain—

Potash	·50 per cent.	
Phosphoric acid	·53	,,
Nitrogen	·64	,,

Forty tons of dung, according to this estimate, contain in round numbers 448 lb of potash, 475 of phosphoric acid, and 573 of nitrogen.

During the fermentation of dung a large proportion of the non-nitrogenous organic matters disappears in the form of carbonic acid and water, while another portion is converted into humic acids which effectually fix the ammonia gradually produced from the nitrogenous constituents of the solid and liquid excrements. The mineral matters remain behind entirely in the rotten dung, if care be taken to prevent loss by drainage.

Well-fermented dung, it will be noticed from the preceding table, is more concentrated and consequently more efficacious than fresh farmyard manure. Neither fresh nor rotten dung contains any appreciable quantity of volatile ammonia, and hence there is no necessity for applying gypsum, dilute acid, green vitriol, or other substances recommended as fixers of ammonia. If dung is carted out into the field and spread out at once it may be left for weeks together before it is ploughed in without the slightest risk of sustaining loss in fertilizing matter by evaporation, for dung does not lose ammonia by evaporation on exposure to the air, and any mineral soluble salts will be washed into the soil where they are wanted. If, however, dung is kept for a length of time in shallow heaps, or in open straw-yards and exposed to rain, it loses by drainage a considerable proportion of its most valuable soluble fertilizing constituents.

With a view to ascertaining the loss in fertilizing substances which farmyard manure sustains when it is kept for a long time exposed in open yards to the deteriorating influences of rain, Dr Voelcker spread a weighed quantity of fresh dung of known composition in an open yard, and after a period of twelve months again weighed the dung and submitted it to analysis, when the results shown in Table VI. were obtained :—

TABLE VI.—*Showing the Loss which Dung sustains by Drainage in Open Yards.*

		Fresh Manure.		After 12 Months' Exposure.
Weight of the manure		1652		793·65
Amount of water in the manure		1093		622·80
,, dry substances		559		170·85
The dry substances consist of—				
A. Soluble organic matters		40·97		3·95
B. Soluble mineral matters		25·43		5·52
C. Insoluble organic matters		425·67		94·45
D. Insoluble mineral matters		66·93		66·93
Whereof		559·00		170·85
A contains nitrogen		3·28		·32
Equal to ammonia	3·98		·39	
B contains nitrogen		6·21		3·56
Equal to ammonia	7·54		4·25	
Total amount of nitrogen in manure		9·49		3·88
Equal to ammonia	11·52		4·64	
The whole manure contained—				
Ammonia in free state		·55		·0055
Ammonia in the form of salts readily decomposed by quicklime		1·45		·28
Total amount of organic matters		466·64		98·40
,, ,, mineral matters		92·36		72·45

These tabulated results showed that the manure lost 69·8 per cent. of its fertilizing matters; or, in round numbers, two-thirds of the dung was wasted and only one-third left behind. Thus, after twelve months' exposure to the weather, nearly all the soluble nitrogen and 78·2 per cent. of the soluble mineral matters were lost by drainage. To prevent this loss, farmyard manure, as had been already pointed out, should, when possible, be carted into the field, spread out at once, and ploughed in at the convenience of the farmer. It is, however, not always practicable to apply farmyard manure just at the time it is made, and, as the manure heap cannot be altogether dispensed with, it is necessary to see how the manure may best be kept. For proper decomposition both air and moisture are requisite, while extreme dryness or too much water will arrest it. Farmyard manure is either prepared in dung-pits, which are put in a separate place, or is accumulated under the animal in the feeding-boxes; of the two plans the latter is the better, the urine being more thoroughly absorbed, and, owing to the box manure being more compact through constant treading on it, air enters less freely and the decomposition goes on less rapidly, the volatile matters in consequence not being so readily lost. External agents, such as rain, wind, sun, &c., do not affect it as they would in the case of dung-pits. If farmyard manure must be stored in heaps, care should be taken to have the bottom and sides of the pit impermeable to water, and the bottom slightly inclined to allow any liquid manure which collects to run off into a tank below, from which, by means of a pump, it may be again poured over the heap. A concrete bottom for the pit is best, or, failing that, one of thick clay or well-beaten earth. The manure heap should be kept as compact as possible, and always moist. The advantage of farmyard manure lies, not only in its supplying all the constituents of plant food, but also in the improved physical condition of the soil through its application, as the land is kept porous, and air is allowed free access. While, however, farmyard manure has these advantages, experience has shown that artificial manures, properly selected to meet the requirements of the crops intended to be grown, due regard being had to the chemical composition of the soil, may be employed to greater advantage. In farmyard manure about two-thirds of the weight is water and one-third dry matter; a large bulk thus contains only a small proportion of fertilizing substances, and expense is incurred for carriage of much useless matter when dung has to be carted to distant fields. When a plentiful supply of good farmyard manure can be produced on the farm or bought at a moderate price in the immediate neighbourhood, it is economy to use it either alone or in conjunction with artificial manures; but when food is dear and fattening does not pay, or farmyard manure is expensive to buy, it will be found more economical to use artificial manures.

Manures from Feeding Stuffs.—The investigations of Messrs Lawes, Gilbert, and Mure have shown that, in estimating the value of animal manure, 90 per cent. of the nitrogen of the food may be reckoned to be recovered in the case of feeding cakes, pulse, and other highly nitrogenous feeding stuffs; 85 per cent. in the case of foods comparatively poor in nitrogen, such as cereals and roots; and less than 65 per cent. in the case of bulky feeding stuffs, such as hay and straw. As a source of manure, the value of fattening foods is greater the more nitrogen they contain. Practically speaking, the whole of the mineral constituents and about nine-tenths of the nitrogen of the food are recovered in the dung and urine. For the same weight of dry substance consumed, oxen void more manure than sheep, and sheep more than pigs. The composition of the different foods given to fattening animals being well known, it is easy to calculate the amounts of nitrogen, phosphoric acid, and potash of the food which will be recovered in the manure. Each constituent having its market value as a manuring constituent, the money value of the manure obtained from the consumption of a ton of any ordinary food of which the composition is known can be determined. Assuming ammonia to be worth 8d. per lb, potash 2d. per lb, and phosphate of lime 1d. per lb, the money value of the manure produced by the consumption of a ton of various foods is given by Mr Lawes in the following table (VII.), which also shows the general composition of the different foods as far as their manurial value is concerned.

In these estimates it is presumed that the manure can be put on the land without loss, but in practice some loss is unavoidable; it may be but slight, as, for instance, when sheep are fed on the land, or when the manure is made in feeding-boxes, but it will be considerable when the food has been consumed in open yards in a very rainy season. Allowances must thus be made for the circumstances under which the manure was produced.

TABLE VII.—*Composition of Ordinary Feeding Stuffs in* 1000 *parts, and their Manuring Value per Ton.*

	Dry Matter.	Nitrogen.	Potash.	Phosphoric Acid.	Money value of the Manure from One Ton of each Food.
					£. s. d.
1. Cotton seed cake (decorticated)	900	66·0	31 0	31·2	6 10 0
2. Rape cake	900	48·0	13·2	24·6	4 18 6
3. Linseed cake	885	45·0	14·7	19·6	4 12 6
4. Cotton cake (undecorticated)	885	37 0	20·1	22·9	3 18 6
5. Linseed	905	36·0	12·3	15·4	3 13 0
6. Palm-kernel meal (English)	930	25·0	5·5	12·2	2 10 0
7. Pease	860	36·0	9·8	8·8	3 2 6
8. Beans	850	40·0	12·0	11·6	3 14 0
9. Lentils	880	43·0	9·6	8·9	3 17 0
10. Malt dust	905	38·0	19·5	17·2	4 5 6
11. Bran	865	25·0	14·8	36·1	2 18 0
12. Oats	860	20·0	4·5	6·2	1 15 0
13. Wheat	850	18·0	5·4	8·0	1 13 0
14. Barley	840	16·5	4·9	7·3	1 10 0
15. Maize	880	16 0	3·6	6·1	1 11 0
16. Locust beans	850	12·5	3·5	5·8	1 2 6
17. Tares	840	42·0	6 6	16 3	3 13 6
18. Coarse pollard	860	25·8	14·9	34·2	2 18 0
19. Fine pollard	860	26·0	14·6	30·3	2 17 0
20. Malt	950	17 0	6·5	7·3	1 11 6
21. Clover hay	840	23·0	19·5	5·6	2 5 6
22. Meadow hay	840	14 6	16·8	3 8	1 10 6
23. Bean straw	825	10·0	11·1	4 1	1 0 6
24. Wheat straw	840	4·0	5·8	2·6	0 12 6
25. Barley straw	850	5·0	9·7	2·0	0 10 9
26. Oat straw	830	5·0	19·4	2·5	0 13 6
27. Pea straw	840	0·3	8·9	3·8	0 18 9
28. Potatoes	250	3·5	5·6	1·8	0 7 0
29. Mangolds	115	2·0	3·9	·7	0 5 3
30. Swedes	107	2·3	2·0	·6	0 4 3
31. Carrots	142	2·0	3·2	1·0	0 4 0
32. Turnips	82	1·9	2·9	·6	0 4 0
33. Parsnips	150	2·2	3·6	1·7	0 5 6

Artificial Manures.—By some a distinction has been drawn between those manures which, like superphosphate, dissolved bones, &c., are manufactured in chemical works and those which are produced naturally, such as guano, nitrate of soda, &c. However, the term artificial manure is generally applied to all manures, natural or manufactured, which are not produced on the farm, as distinguished from farmyard manure and manure from purchased foods, which are essentially farm products. The value of all manures mainly depends on their chemical composition.

As compared with farmyard manure, artificial manures have the disadvantage that they, unlike it, do not improve the physical condition of the soil. Artificial manures have, on the other hand, the advantage over farmyard manure that they can supply in a small compass, and even if used in small quantity, the needed nitrogen, phosphoric acid, and potash, &c., which crops require, and which farmyard manure has but in small proportion; they present the expensive fertilizing matters in a concentrated form, and by their application save expense in labour and carriage.

The following are the principal artificial manures in use:—

1. *Nitrogenous Manures.—Peruvian Guano.*—This is a natural manure, valuable on account of the ammonia, phosphoric acid, and potash it contains. It is the excrement, &c., of sea birds accumulated in parts where no rain falls. The earliest deposits found contained as much as 14 to 17 per cent. of ammonia, *e.g.*, Chinchas Island guano; those now (1882) imported seldom exceed 8 per cent., and generally vary from 4 to 8 per cent., of ammonia. In using guano it should be mixed with earth, &c., to prevent injury to the seeds or plants. Peruvian guano is also treated with sulphuric acid, which renders the phosphates soluble and fixes the ammonia, thereby preventing any loss of it; this constitutes dissolved guano, and is frequently sold upon a guarantee of 20 per cent. of soluble phosphates, 4 per cent. of insoluble phosphates, and 9 per cent. of ammonia. Peruvian guano is used as a top dressing for wheat and barley; in addition to insoluble phosphates, it contains soluble phosphates of the alkalies.

Ammonia Salts.—The principal one is sulphate of ammonia, largely produced in gas works by neutralizing gas liquor with sulphuric acid; it is usually sold on a basis of 24 to 25 per cent. of ammonia.

Soot is valuable on account of the sulphate of ammonia it contains; the percentage of ammonia varies from 1½ to 4.

Nitrate of soda is a natural deposit; it is greatly used as a top dressing for wheat and barley. It usually contains common salt, and when purified is sold on a basis of 95 per cent. of pure nitrate.

Organic Nitrogenous Substances.—Wool, hair, fish, flesh, horn, blood, rape cake, damaged cotton cake and other oil cakes. Wool refuse (shoddy), according to its quality, contains from 4 to 8 per cent. of nitrogen, flesh 14 to 15 per cent., blood (dried) 13 to 15 per cent., rape cake 4 to 5 per cent., linseed cake about 4 per cent., cotton cake (undecorticated) nearly 4 per cent., and cotton cake (decorticated) over 6 per cent. of nitrogen.

2. *Phosphatic Manures.*—(*a*) The following phosphatic minerals are used for the manufacture of superphosphate of various strengths, and of compound manures:—coprolites (Cambridge, Suffolk, and Bedfordshire), containing 50 to 55 per cent. of phosphate of lime; phosphorite (Spanish and Portuguese); apatite (Norwegian and Canadian), containing often as much as 80 per cent. phosphate of lime; South Carolina (land and river) phosphate, 52 to 56 per cent. phosphate of lime; French phosphate; Sombrero phosphate, 70 per cent. phosphate of lime; Curaçoa phosphate, 80 per cent. phosphate of lime; Navassa phosphate; Aruba phosphate, &c.

(*b*) *Bones.*—Raw bones, as ½ inch and ¼ inch bones; bone meal; bone dust, having about 48 per cent. phosphate of lime and 4½ per cent. of ammonia; boiled bones, with 60 per cent. phosphate of lime and about 1·8 per cent. of ammonia; dissolved bones; bone ash, with 70 per cent. phosphate of lime; animal charcoal, with 70 to 80 per cent. phosphate of lime.

(*c*) *Phosphatic Guanos.*—Lacepede Island guano; Mexillones guano; Malden Island guano; Fanning Island guano; and many others varying in composition from 60 to 90 per cent. phosphate of lime.

3. *Saline Materials.*—Potash salts (chloride and sulphate); kainite, with 20 to 25 per cent. sulphate of potash, and also sulphate of magnesia and common salt; wood ashes, with about 10 per cent. of potash; common salt.

4. *Calcareous Manures.*—Lime, chalk, marl, gypsum, shell sand, gas lime, coal ashes, road scrapings, &c.

5. *Carbonaceous Manures.*—Sawdust, peat, sea-weed, vegetable refuse, &c.

6. *Special and Compound Manures.*—The basis of these is superphosphate, which is mixed with other manuring materials to meet the special requirements of particular crops and soils.

The foregoing remarks made on the application of manures to different kinds of crops may now in conclusion be summed up. Farmyard manure, in order to be most beneficial, should be applied as quickly as possible after it is made, the best time being in autumn or early winter. Nitrate of soda should be applied as a top dressing early in spring; its effect will be seen in the first season only. Ammonia salts, guano, dung, &c., are best applied to heavy land in autumn or winter, either before the seed is sown, or after the plant is fairly above ground, but in the case of light land early in spring. The effect of bones in the various form of dissolved bones, bone dust, raw bones, &c., will last two or more seasons according to the quantities used and their respective solubility. Lastly, it may be observed that the presence of lime is essential to the economical use of manures.

As regards cereal crops, it has been found that mineral manures alone, whether simple or complex, do not produce appreciable increase of crop, but that nitrogenous manures, whether as ammonia salts, nitrate of soda, or farmyard manure, greatly benefit the crop; that nitrate of soda does rather better than ammonia salts; and that, while on fairly heavy land farmyard manure will yield good crops, the best results are obtained by using mineral and nitrogenous manures together. On clay soils a top dressing of nitrate of soda often answers all practical purposes, but on light soils nitrate of soda or ammonia salts should not be used without mineral manures, while it is advisable even on heavy land to use superphosphate as well.

For root crops, on cold clays nothing answers so well as mineral superphosphate alone, but on light land dissolved bones, bone dust, precipitated phosphate, or a compound artificial manure will be found to be much preferable to superphosphate. Bone meal mixed with mineral superphosphate makes, for instance, a good manure for roots; for mangolds Peruvian guano and common salt in addition are useful, and for potatoes potash salts with phosphatic and nitrogenous manures.

For pasture land the use of artificial manures is, as a rule, not economical; nitrogenous manures raise the quantity and phosphatic and potash manures improve the quality of the herbage, while, for worn-out pastures, potash with dissolved bones or superphosphate or superphosphate and guano will do much good. The most economical way of manuring pasture land is to apply farmyard manure liberally, or feed it off with cattle, giving cotton cake in addition.

The employment of artificial manures in a judicious manner has shown the occupier of land that it is not necessary for him to be bound down to any system of rotation of crops which may be practised in his particular district, but that he has the means of pursuing the course of cropping, system of manuring, and general management of his farm which will yield him the best returns. No more striking instance of this could be put forward than the experience of Mr Prout, who at Sawbridgeworth, Herts, has grown with much success cereal crops, year after year, on heavy clay land, selling the whole of the growing crops, and restoring the fertility of the soil by artificial manures. The land was purchased in 1861, and up to the present time (1882) the crops have been as good as ever, and the land has not been deteriorated, but on the other hand improved, by continuous corn growing. The experiments of Messrs Lawes and Gilbert at Rothamsted and of Dr Voelcker at Woburn have been thus verified on a large scale in the experience of Mr Prout, and have shown beyond all possibility of doubt the efficacy and economy of a liberal use of artificial manures. (A. V.)

MANUSCRIPTS, ANCIENT. See DIPLOMATICS and PALÆOGRAPHY.

MANUTIUS. I. ALDUS MANUTIUS (1450–1515). Teobaldo Mannucci, better known as Aldo Manuzio, the founder of the Aldine press, was born in 1450 at Sermoneta in the Papal States. He received a scholar's training, studying Latin at Rome under Gasparino da Verona, and Greek at Ferrara under Guarino da Verona. Having qualified himself for the career of a humanist, according to the custom of the century, he went in 1482 to reside at Mirandola with his old friend and fellow-student, the illustrious Giovanni Pico. There he stayed two years, prosecuting his studies in Greek literature. Before Pico removed to Florence, he procured for Aldo the post of tutor to his nephews Alberto and Lionello Pio, princes of Carpi. To Alberto Pio the world owes a debt of gratitude, inasmuch as he supplied Aldo with funds for starting his printing press, and gave him lands at Carpi. It was Aldo's ambition to secure the literature of Greece from further accident by committing its chief masterpieces to type; and the history of his life is the record of the execution of this gigantic task. Before his time four Italian towns had won the honours of Greek publications:—Milan, with the grammar of Lascaris, Æsop, Theocritus, a Greek Psalter, and Isocrates, between 1476 and 1493; Venice, with the *Erotemata* of Chrysoloras in 1484; Vicenza, with reprints of Lascaris's grammar and the *Erotemata*, in 1488 and 1490; Florence, with Alopa's Homer, in 1488. Of these works, only three, the Milanese Theocritus and Isocrates and the Florentine Homer, were classics. Aldo selected Venice as the most appropriate station for his labours. He settled there in 1490, and soon afterwards gave to the world editions of the *Hero and Leander* of Musæus, the *Galeomyomachia*, and the Greek Psalter. These have no date; but they are the earliest tracts issued from his press, and are called by him "Precursors of the Greek Library."

At Venice Aldo gathered an army of Greek scholars and compositors around him. His trade was carried on by Greeks, and Greek was the language of his household. Instructions to type-setters and binders were given in Greek. The prefaces to his editions were written in Greek. Greeks from Crete collated MSS., read proofs, and gave models of calligraphy for casts of Greek type. Not counting the craftsmen employed in merely manual labour, Aldo entertained as many as thirty of these Greek assistants in his family. His own industry and energy were unremitting. In 1495 he issued the first volume of his Aristotle. Four more volumes completed the work in 1497–98. Nine comedies of Aristophanes appeared in 1498. Thucydides, Sophocles, and Herodotus followed in 1502; Xenophon's *Hellenics* and Euripides in 1503; Demosthenes in 1504. The troubles of Italy, which pressed heavily on Venice at this epoch, suspended Aldo's labours for a while. But in 1508 he resumed his series with an edition of the minor Greek orators; and in 1509 appeared the lesser works of Plutarch. Then came another stoppage. The league of Cambray had driven Venice back to her lagoons, and all the forces of the republic were concentrated on a struggle to the death with the allied powers of Europe. In 1513 Aldo reappeared with Plato, which he dedicated to Leo X. in a preface eloquently and earnestly comparing the miseries of warfare and the woes of Italy with the sublime and tranquil objects of the student's life. Pindar, Hesychius, and Athenæus followed in 1514.

These complete the list of Aldo's prime services to Greek literature. · But it may be well in this place to observe that his successors continued his work by giving Pausanias, Strabo, Æschylus, Galen, Hippocrates, and Longinus to the world in first editions. Omission has been made of Aldo's reprints, in order that the attention of the reader might be concentrated on his labours in editing Greek classics from MSS. Other presses were at work in Italy; and, as the classics issued from Florence, Rome, or Milan, Aldo took them up, bestowing in each case fresh industry upon the collation of codices and the correction of texts. Nor was the Aldine press idle in regard to Latin and Italian classics. The *Asolani* of Bembo, the collected writings of Poliziano, the *Hypnerotomachia Poliphili*, Dante's *Divine Comedy*, Petrarch's poems, a collection of early Latin poets of the Christian era, the letters of the younger Pliny, the poems of Pontanus, Sannazzaro's *Arcadia*, Quintilian, Valerius Maximus, and the *Adagia* of Erasmus were printed, either in first editions, or with a beauty of type and paper never reached before, between the years 1495 and 1514. For these Italian and Latin editions Aldo had the elegant type struck which bears his name. It is said to have been copied from Petrarch's handwriting, and was cast under the direction of Francesco da Bologna, who has been identified by Panizzi with Francia the painter.

Aldo's enthusiasm for Greek literature was not confined to the printing-room. He burned with a humanist's enthusiasm for the books he printed; and we may well pause astonished at his industry, when we remember what a task it was in that age to prepare texts of authors so numerous and so voluminous from MSS. Whatever the students of this century may think of Aldo's scholarship, they must allow that only vast erudition and thorough familiarity with the Greek language could have enabled him to accomplish what he did. In his own days Aldo's learning won the hearty acknowledgment of ripe scholars. To his fellow workers he was uniformly generous, free from jealousy, and prodigal of praise. His stores of MSS. were as open to the learned as his printed books were liberally given to the public. While aiming at that excellence of typography which renders his editions the treasures of the book-collector, he strove at the same time to make them cheap. We may perhaps roughly estimate the current price of his pocket series of Greek, Latin, and Italian classics, begun in 1501, at 2s. per volume of our present money. The five volumes of the Aristotle cost about £8. His great undertaking was carried on under continual difficulties, arising from strikes among his workmen, the piracies of rivals, and the interruptions of war. When he died, bequeathing Greek literature as an inalienable possession to the world, he was a poor man. In order to promote Greek studies, Aldo founded an academy of Hellenists in 1500 under the title of the New Academy. Its rules were written in Greek. Its members were obliged to speak Greek. Their names were Hellenized, and their official titles were Greek. The biographies of all the famous men who were enrolled in this academy must be sought in the pages of Didot's *Alde Manuce*. It is enough here to mention that they included Erasmus and the English Linacre.

In 1499 Aldo married Maria, daughter of Andrea Torresano of Asola. Andrea had already bought the press established by Nicholas Jenson at Venice. Therefore Aldo's marriage combined two important publishing firms. Henceforth the names Aldus and Asolanus were associated on the title pages of the Aldine publications; and after Aldo's death in 1515, Andrea and his two sons carried on the business during the minority of Aldo's children. The device of the dolphin and the anchor, and the motto *festina lente*, which indicated quickness combined with firmness in the execution of a great scheme, were never wholly abandoned by the Aldines until the expiration of their firm in the third generation.

II. PAULUS MANUTIUS (1512–1574). By his marriage with Maria Torresano, Aldo had three sons, the youngest of whom, Paolo, was born in 1512. He had the misfortune to lose his father at the age of two. After this event his grandfather and two uncles, the three Asolani, carried on the Aldine press, while Paolo prosecuted his early studies with unremitting industry at Venice. Excessive application hurt his health, which remained weak during the rest of his life. At the age of twenty-one he had acquired a solid reputation for scholarship and learning. In 1533 Paolo undertook the conduct of his father's business, which had latterly been much neglected by his uncles. In the interregnum between Aldo's death and Paolo's succession (1514–33) the Asolani continued to issue books, the best of which were Latin classics. But, though their publications count a large number of first editions, and some are works of considerable magnitude, they were not brought out with the scholarly perfection at which Aldo aimed. The Asolani attempted to perform the whole duties of editing, and to reserve all its honours for themselves, dispensing with the service of competent collaborators. The result was that some of their editions, especially their Æschylus of 1518, are singularly bad. Paolo determined to restore the glories of the house, and in 1540 he separated from his uncles. The field of Greek literature having been well-nigh exhausted, he devoted himself principally to the Latin classics. He was a passionate Ciceronian, and perhaps his chief contributions to scholarship are the corrected editions of Cicero's letters and orations, his own epistles in a Ciceronian style, and his Latin version of Demosthenes. Throughout his life he combined the occupations of a student and a printer, winning an even higher celebrity in the former field than his father had done. Four treatises from his pen on Roman antiquities deserve to be commemorated for their erudition no less than for the elegance of their Latinity. Several Italian cities contended for the possession of so rare a man; and he received tempting offers from the Spanish court. Yet his life was a long struggle with pecuniary difficulties. To prepare correct editions of the classics, and to print them in a splendid style, has always been a costly undertaking. And, though Paolo's publications were highly esteemed, their sale was slow. In 1556 he received for a time external support from the Venetian Academy, founded by Federigo Badoaro. But Badoaro failed disgracefully in 1559, and the academy was extinct in 1562. Meanwhile Paolo had established his brother, Antonio, a man of good parts but indifferent conduct, in a printing office and book shop at Bologna. Antonio died in 1559, having been a source of trouble and expense to Paolo during the last four years of his life. Other pecuniary embarrassments arose from a contract for supplying fish to Venice, into which Paolo had somewhat strangely entered with the Government. In 1561 Pope Pius IV. invited him to Rome, offering him a yearly stipend of 500 ducats, and undertaking to establish and maintain his press there. The profits on publications were to be divided between Paolo Manuzio and the apostolic camera. Paolo accepted the invitation, and spent the larger portion of his life, under three papacies, with varying fortunes, in the city of Rome. Ill health, the commercial interests he had left behind at Venice, and the coldness shown him by Pope Pius V., induced him at various times and for several reasons to leave Rome. But of these excursions it is not necessary to take particular notice. As was natural, his editions after his removal to Rome were mostly Latin works of theology and Biblical or patristic literature.

Paolo married his wife, Caterina Odoni, in 1546. She brought him three sons and one daughter. His eldest son, the younger Aldus, succeeded him in the management of the Venetian printing house when his father settled at Rome in 1561. Paolo had never been a strong man, and his health was overtaxed with studies and commercial worries. Yet he lived into his sixty-second year, and died at Rome in 1574.

III. ALDUS MANUTIUS, JUNIOR (1547-1597). The younger Aldo, born in the year after his father Paolo's marriage, cradled in scholarship, and suckled as it were with printer's ink, proved what is called an infant prodigy. When he was nine years old, his name was placed upon the title page of the famous *Eleganze della lingua Toscana e Latina.* What his share was in that really excellent selection cannot be ascertained; but it is hardly possible that a boy of nine could have compiled it without assistance. The *Eleganze* was probably a book made for his instruction and in his company by his father. In 1561, at the age of fourteen, he produced a work upon Latin spelling, called *Orthographiæ Ratio.* During a visit to his father at Rome in the next year, he was able to improve this treatise by the study of inscriptions, and in 1575 he completed his labours in the same field by the publication of an *Epitome Orthographiæ.* Whether Aldo was the sole composer of the work on spelling, in its first edition, may be doubted; but he appropriated the subject and made it his own. Probably his greatest service to scholarship is this analysis of the principles of orthography in Latin.

Aldo remained at Venice, prosecuting studies in literature and superintending the Aldine press. But in these days of early manhood he was not satisfied with the career of scholarship and business. At one time he hankered after the more worldly honours of the law, at another he built a country house at Asola, perplexing his father, who had given him too easy independence, with the humours of his age. A marriage came to make these matters straight. The Giunta family had been steadily rising in the world as printers, in proportion as the Aldi declined through want of concentration upon commerce. In 1572 Aldo took for his wife Francesca Lucrezia, daughter of Bartolommeo Giunta, and great-grandchild of the first Giunta, who founded the famous printing house in Venice. This was an alliance which augured well for the future of the Aldines, especially as the young husband, in the midst of distractions, had recently found time to publish a new revised edition of Velleius Paterculus. Two years later the death of his father at Rome placed Aldo at the head of the firm. In concert with his new relatives, the Giunta, he now edited an extensive collection of Italian letters, and in 1576 he appeared again before the public as a critic with his commentary upon the *Ars Poetica* of Horace. Printing, in this case, as in the case of his father, went hand in hand with original authorship. About the same time, that is to say, about the year 1576, he was appointed professor of literature to the Cancelleria at Venice. The Aldine press continued through this period to issue books, but none of signal merit; and in 1585 Aldo determined to quit his native city for Bologna, where he occupied the chair of eloquence for a few months. In 1587 he left Bologna for Pisa, and there, in his quality of professor, he made the curious mistake of printing Alberti's comedy *Philodoxius* as a work of the classic Lepidus. Sixtus V. drew him in 1588 from Tuscany to Rome; and at Rome he hoped to make a permanent settlement as lecturer. But his public lessons were ill attended, and he soon fell back upon his old vocation of publisher under the patronage of a new pope, Clement VIII. In the tenth year of his residence at Rome, that is, in 1597, he died, leaving children, but none who cared or had capacity to carry on the Aldine press. Aldo himself, though a precocious student, a scholar of no mean ability, and a publisher of some distinction, was the least remarkable of the three men who gave books to the public under the old Aldine ensign. Times had changed in Italy since Aldo the elder conceived the great idea of reaping for the press the harvest of Greek literature. And his posterity had changed with the times for the worse. This does not of necessity mean that we should adopt Scaliger's critique of the younger Aldo without reservation. Scaliger called him "a poverty-stricken talent, slow in operation; his work is very commonplace; he aped his father." What is true in this remark lies partly in the fact that scholarship in Aldo's days had flown beyond the Alps, where a new growth of erudition, on a basis different from that of the Italian Renaissance, had begun.

Renouard's *Annales de l'Imprimerie des Aldes*, Paris, 1834, and Didot's *Alde Manuce*, Paris, 1873, contain all necessary information regarding the lives of the Manutii and their publications. (J. A. S.)

MANZONI, ALESSANDRO FRANCESCO TOMMASO ANTONIO (1785-1873), founder of the romantic school in Italian literature, was born at Milan, March 7, 1785. Don Pietro, his father, then about fifty, represented an old family settled near Lecco, but originally feudal lords of Barzio, in the Valsassina, where the memory of their violence is still perpetuated in a local proverb, comparing it to that of the mountain torrent. The poet's maternal grandfather, Cesare Beccaria, was a well-known author, and his mother Giulia a woman of some literary ability. Manzoni's intellect was slow in maturing, and at the various colleges where his school days were passed he ranked among the dunces. At fifteen, however, he developed a passion for poetry, and wrote two sonnets of considerable merit. On the death of his father in 1805, he joined his mother at Auteuil, and spent two years there, mixing in the literary set of the so-called "idealogues," philosophers of the 18th century school, among whom he made many friends, notably Claude Fauriel. There too he imbibed the negative creed of Voltairianism, and only after his marriage, and under the influence of his wife, did he exchange it for that fervent Catholicism which coloured his later life. In 1806-7, while at Auteuil, he first appeared before the public as a poet with two pieces, one entitled *Urania*, in the classical style, of which he became later the most conspicuous adversary, the other an elegy in blank verse, on the death of Count Carlo Imbonati, from whom, through his mother, he inherited considerable property, including the villa of Brusuglio, thenceforward his principal residence.

Manzoni's marriage in 1808 to Henriette Blondel, daughter of a Genevese banker, proved a most happy one, and he led for many years a retired domestic life, divided between literature and the picturesque husbandry of Lombardy. His intellectual energy at this period was devoted to the composition of the *Inni Sacri*, a series of sacred lyrics, and a treatise on Catholic morality, forming a task undertaken under religious guidance, in reparation for his early lapse from faith. In 1818 he had to sell his paternal inheritance, as his affairs had gone to ruin in the hands of a dishonest agent. The beautiful villa Il Galeotto, where he had spent his childish years amid the scenery he afterwards immortalized, then passed from his hands, to his great regret. His characteristic generosity was shown on this occasion in his dealings with his peasants, who on settling their accounts were found heavily indebted to him. He not only cancelled on the spot the record of all sums owing to him, but bade them keep for themselves the whole of the coming maize harvest.

In 1819 Manzoni published his first tragedy, *Il Conte di Carmagnola*, which, boldly violating all classical conventionalisms, excited a lively controversy. It was severely criticized in the *Quarterly Review*, in an article to which Goethe replied in its defence, "one genius," as Count de Gubernatis remarks, "having divined the other." The death of Napoleon in 1821 inspired Manzoni's powerful stanzas *Il Cinque Maggio*, the most popular lyric in the Italian language.

The political events of that year, and the imprisonment of many of his friends, weighed much on Manzoni's mind, and the historical studies in which he sought distraction during his subsequent retirement at Brusuglio, suggested his great work. Round the episode of the *Innominato*, historically identified with Bernardino Visconti, *I Promessi Sposi* began to grow into shape, and was completed in September 1822. The work when published, after revision by friends in 1825-27, at the rate of a volume a year, at once raised its author to the first rank of literary fame. In the interim of its composition in 1822, Manzoni published his second tragedy *Adelchi*, turning on the overthrow by Charlemagne of the Lombard domination in Italy, and containing many veiled allusions to the existing Austrian rule.

With these works Manzoni's literary career was practically closed. The end of the poet's long life was saddened by domestic sorrows. The loss of his wife in 1833 was followed by that of several of his children, and of his mother, to whom he was fondly attached. In 1837 he married his second wife, Teresa Borri, widow of Count Stampa, whom he also survived, while of nine children born to him in his two marriages, all but two preceded him to the grave. The death of his eldest son, Pier Luigi, on April 28, 1873, was the final blow which hastened his end; he fell ill immediately, and died of cerebral meningitis, May 22, aged eighty-eight. His country mourned him with almost royal pomp, and his remains, after lying in state for some days, were followed to the cemetery of Milan by a vast cortége, including the royal princes and all the great officers of state. But his noblest monument was Verdi's *Requiem*, specially written to honour his memory.

Manzoni's position in literature is unique; for, while the romantic Renaissance produced in other countries a galaxy of genius, in Italy it remained embodied in him alone, since none of his disciples came near enough to be classed with him. Scott declared *I Promessi Sposi* the finest novel ever written; and, if we take as our standard loftiness of aim combined with ingenuous simplicity of style, and Titianesque power of character painting relieved by an undercurrent of subtle irony giving point to every trivial incident, we need scarcely dispute his verdict. It occupies the same place in Italian as *Don Quixote* in Spanish literature, overshadowing in similar fashion the whole field of subsequent fiction. Manzoni's poetry cannot be classed so high, and, despite its nervous diction and epigrammatic intensity of thought, it is as a great master of Italian prose that he will go down to posterity.

Of exalted private character, Manzoni furnishes an almost solitary instance of a poet whose life contains no note of discord with the loftiest standard presented by his works. The highest genius, disciplined by still higher moral self-control, produced in him the rare spectacle of a perfect equilibrium of forces in a powerful mind. His presence was impressive, and his speech, though retarded by a slight impediment, so full of wisdom that Tommaseo declared he had learned more from his conversation than from all the books he had ever read. At the same time he had that exquisite courtesy in listening which gave to those who addressed him the sense of having spoken well. No man ever attained to greater honour from his contemporaries, or sought it less, and few have joined such rare intellectual gifts to so much gracious humility of mind and manners. His warmth of affection, tenderness of sympathy, and universal benevolence endeared him to his friends and fellow-citizens, while by his countrymen at large he was revered as the sage and patriarch of Italian letters.

In addition to the works already named, he wrote *La Storia della Colonna Infame*, and a small treatise on the Italian language. *I Promessi Sposi*, laboriously revised by the author in accordance with the Tuscan idiom, has gone through 118 Italian, 19 French, 17 German, and 10 English editions.

Biographical sketches of Manzoni have been recently published by Cesare Cantù (1882), Benedetto Prina, Giulio Carcano, Angelo de Gubernatis, Antonio Stoppani (his early years), and others. Some of his letters have been published by Giovanni Sforza, and a work entitled, *Commento Storico su I Promessi Sposi*, by Cesare Cantù. See also the essay on "Fauriel" in Sainte-Beuve's *Portraits Contemporains*, vol. iv.

MAORIES. See NEW ZEALAND.

MAP. 1. *First Essays in Map-making.*—As each man stands in the centre of his horizon and the portion of the earth's surface which lies within his range of vision has the appearance of a disk, the whole world was in ancient times conceived as a disk surrounded by the sea. It was consequently not uncommon for a people to imagine—as was the case we know with the Chinese, the Hindus, the Chaldæans, the Jews, the Arabs, and even the ancient Peruvians—that it occupied the middle part of the world. The wider a people's range of vision, the wider was the disk of the world represented. A circular surface is thus the simplest form for a *mappa mundi* or map of the world; and it is met with both in antiquity and in the Middle Ages. The extent of the circle of vision depends among uncivilized peoples on their way of life. Wandering tribes have seen more of the world than settled tribes; and hunters, fishers, and seamen make the widest excursions. Among them consequently we find the beginnings of map-making; and Eskimo, Indians, and Polynesians, for example, show in this matter astonishing quickness of apprehension, while among the settled Negro tribes, on the other hand, there are no maps. A map drawn by an Eskimo woman enabled Sir Edward Parry to discover Fury and Hecla Strait; M'Clintock during his endeavours to clear up the fate of the Franklin expedition repeatedly got the Eskimo to draw coast-maps of the Arctic lands; and many similar instances are given by Andree, "Beginnings of Cartography," *Globus*, xxxi. pp. 24-27, 37-43.

Turning to civilized peoples, it is among the Egyptians that we find the earliest recorded examples of cartographic representation. Apollonius of Rhodes (born 230 B.C.) reports in his *Argonautica* (iv. 279) that the Egyptians of Colchis, a colony dating from the time of Ramses II. (?), had preserved as heirlooms certain wooden tablets (κύρβεις) on which land and sea, roads and highways, were accurately indicated; Eustathius, in his commentary on Dionysius Periegetes, mentions that Sesostris the Egyptian king caused route-maps to be prepared; and Strabo also refers to certain old maps in the library of Eratosthenes in which Meroe and the south end of the peninsula of India were placed on the same parallel of latitude. These statements have been confirmed by the actual discovery of such maps and plans on old Egyptian papyrus-rolls. Birch has, for instance, identified a drawing on a papyrus in the Turin Museum as the topographical map of a gold-mining district in Nubia. The perspective in this case is very childish: in order to show that the road leads between two mountain-chains, the mountains on one side of the road are inverted (comp. Lepsius, *Urkundenbuch*, pl. xxii.). This map is one thousand years older than that of Anaximander, who was considered by the Greeks as the inventor of cartography. On another sheet appears a representation of the victorious return of Sethos I. (1443–1392 B.C.) from Asia, showing the road from Pelusium by Leontopolis to Heroopolis, Lake Timsah with fish in it, the canal from the Nile with crocodiles, and at Heroopolis a bridge over the canal. Similar picture-maps were discovered by Layard in Assyria (*Nineveh and Babylon*, p. 231 *sq.*, 1867). The ancient Babylonians have also the high distinction of having divided space and time in a way that allowed scientific measurements to be made after the still customary method. It was they who originated the division of the ecliptic into twelve signs and later into 360 degrees; and the division of the circle into 360 degrees with 60 minutes to the degree and 60 seconds to the minute, as well as the corresponding division of the hour, was the outcome of their sexagesimal system of numeration. This method of division was introduced among the Greeks by Hipparchus (150 B.C.), and obtained general currency through the geographer Ptolemy (150 A.D.). By this means were provided the elements necessary for the astronomical determination of geographical position. Among the Egyptians and Babylonians map-making remained in its first infantile stage; its scientific development was received at the hands of the Greeks.

2. *Development of Map-making among the Greeks.*—In Homer the "circumfluent ocean" represents the horizon which bounds the disk of the world; the scientific treatment of geography and map-making has its origin among the Ionic Greeks of Asia Minor. Anaximander, a pupil of Thales (about 560 B.C.), sketched the first map (γεωγραφικὸς πίναξ), and was the first who sought to determine the compass of the earth (the world-disk) and the sea. As the Greeks gradually extended their journeys as far as India in the East and the Atlantic in the West, the conviction gained ground that the world-disk could not be bounded by a regular circular outline. About one hundred years after Anaximander, Democritus of Abdera ventured to draw a new map on the basis of his own observations (for in his extensive wanderings he had been as far as Persia and perhaps even India); and in opposition to the circular form of the Ionians he gave the world an oblong shape, and taught that from east to west it was half as long again as from north to south. Although after the time of Aristotle the tabular or flat-surface theory of the figure of the earth was expelled by the spherical or globe theory, the portion of the earth's surface which was really known retained the same oblong shape which it had with Democritus; and hence we still speak of longitude and latitude, that is, length and breadth. It was on this basis also that the far-travelled Hecatæus of Miletus, who wrote his Γῆς περίοδος between 520 and 500 B.C., drew up his map; for the representation of the world on a brazen tablet, which was shown by Aristagoras, tyrant of Miletus, to King Cleomenes of Sparta, was probably nothing else than the world-map of Hecatæus. The first application of astronomy to geography was made by the famous Arctic navigator Pytheas of Marseilles, about 326 B.C.; it is from him that we obtain the first observation of latitude, and, what is of some importance, this is for Marseilles. His voyage to the extreme North (Thule) was undertaken partly for the purpose of satisfying himself in regard to the figure and size of the earth. Dicæarchus of Messana in Sicily, a pupil of Aristotle's (310 B.C.), made the first approach to a projection. He divided the inhabited (*i.e.*, the known) world, which he reckoned to be one and a half times as long as it was broad, into a northern and a southern half by means of what he considered a straight line drawn from the pillars of Hercules, through Sicily, the Peloponnesus, Caria, Lycia, Pamphylia, Cilicia, and across the Taurus to the Imaus (Himalaya). He thus drew the first parallel of latitude, and upon this basis he prepared maps which were to be publicly exhibited in a hall (Agathem., § 5; Strabo, p. 105). The name διάφραγμα τῆς οἰκουμένης, *i.e.*, partition of the inhabited world, was given to the base-line. For the next material improvement we are indebted to the famous astronomer and geographer Eratosthenes of Cyrene, the keeper of the Alexandrian library (276–196 B.C.). He was the first to make a rational geodetic measurement for the purpose of determining the size of the earth, and he collected in his Γεωγραφικά the whole geographical learning of his time. This work has unfortunately been lost, but from the numerous fragments that have been preserved, especially by Strabo, it is possible to form an idea of this the first systematic geography. Starting with the spherical form and the size of the world, it gave a description of the οἰκουμένη, discussed the space relations of the world-island, and estimated its extent in longitude and latitude. On the basis of the diaphragm of Dicæarchus, the course of which was more precisely indicated, a series of seven parallels and as many meridians cutting the diaphragm at right angles were drawn, and by this means the inhabited world was divided to the north and the south of the diaphragm into a certain number of regular divisions to which the name of sphragidia or seals was given. Then follows a description of the countries in the several "seals," beginning with India. In this arrangement we may recognize the first attempt to construct a network or system of degrees. As numerous data in regard to distances were already at his command, Eratosthenes greatly improved on the old maps in the matter of correctness; but, as the number of astronomical determinations of latitude was still small, and the intervals between the parallels and the meridians were unequal and conditioned by the available data in regard to distance, his network of lines was far from being an exact mathematical system. Hipparchus of Nicæa in Bithynia, the greatest astronomer of the ancient world (about 150 B.C.), consequently rejected the geography of Eratosthenes because it only partially utilized the abundant resources provided by the high development of contemporary mathematics and astronomy. Instead of the uncertain estimates of distance and direction furnished by travellers, only astronomical determinations of latitude and longitude should, he maintained, have been employed. He does not appear, however, to have himself written a geography or constructed a map. About the same time Crates of Mallus made the first globe. On this he extended the Atlantic Ocean southward to the south pole, placed a corresponding ocean on the other hemisphere, and, in the belief that the torrid zone could be occupied by nothing but water, ran an Oceanic belt along the line of the equator (fig. 1). In the four segments thus produced he set four semicircular land-areas, only one of which was known to the ancient world. This systematic figure maintained its place down into the Middle Ages, as

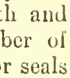


Fig. 1.

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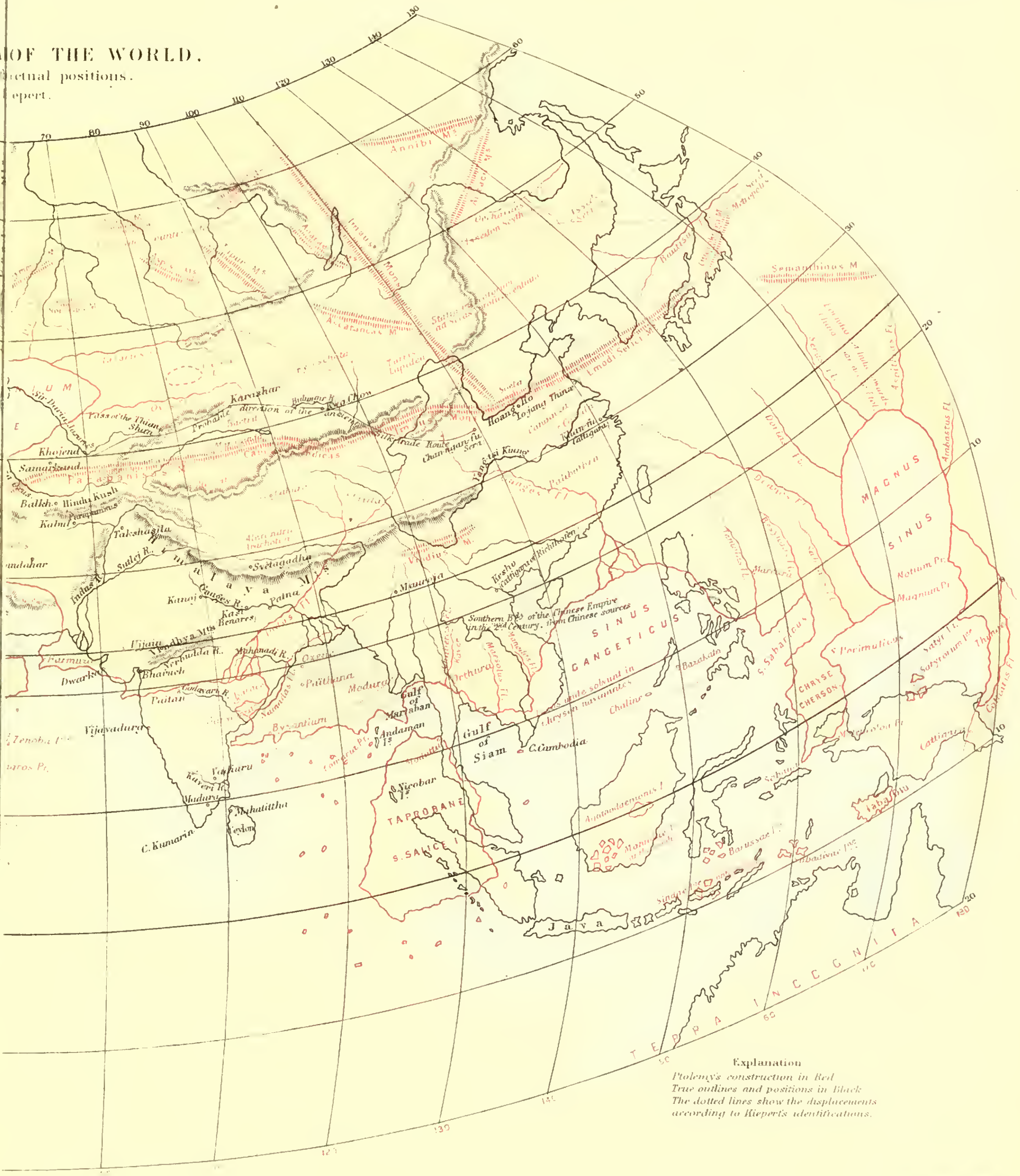


appears from the ornamentation of the globe that forms part of the insignia of royalty.

Marinus of Tyre (about 150 A.D.) was the first who sought to give effect to the demand made by Hipparchus for a trustworthy representation of the countries of the world. His work unfortunately has been lost; and we know of its existence only from his successor Claudius Ptolemy. Without Marinus, however, Ptolemy's work would have been impossible; and neither of them was able really to carry out Hipparchus's idea of determining the latitude and longitude for every place; for observations of latitude were known only for Marseilles, Syene, Alexandria, Rhodes, and perhaps a few other places, and all other positions were obtained by reducing distances to degrees. The determination of longitudes was even more difficult. Ptolemy possessed only the contemporary observation of the lunar eclipse in Arbela and Carthage of the year 331 B.C., from which he calculated a difference of meridian of 45° 10′ instead of 34° 2′. The longer axis of the Mediterranean was consequently a third too great, 62 degrees of the meridian being assumed instead of $41\frac{2}{3}$, and from this there resulted an exaggeration of all the Mediterranean countries, which was corrected only by the compass-maps of the later Middle Ages. Ptolemy, however (availing himself of the stereographic projection devised by Hipparchus), corrected an important blunder which Marinus had committed through neglecting to take account of the sphericity of the earth and constructing a rectangular system of degrees. Like Marinus, he counted his meridians from the Canaries (the Fortunate Islands). No maps appear to have been drawn by Ptolemy himself; those to be found in the oldest editions of his work are by Agathodæmon (a mathematician of the 5th (?) century after Christ), though accurately based, it is true, on Ptolemy's data. The oldest MS. of Ptolemy is that found in the Vatopedi monastery of Mount Athos, and published by Victor Langlois in 1867 along with careful reproductions of the maps. It dates from the 12th or 13th century. Besides the exaggeration of the Mediterranean, the greatest blunders of Ptolemy are the following:—the European continent between the Black Sea and the Baltic is too narrow; India is not represented as a peninsula; Ceylon (Taprobane) is made much too large; and the Indian Ocean is bounded by lands towards the south (Plate VII.). But in spite of all this the scientific method pursued in the representation was perfectly correct. It was not till the Renaissance that a return was made to the rational treatment of cartography inaugurated by Ptolemy; and he then became the teacher of the modern world.

3. *Map-making among the Romans.*—The Romans contributed nothing to the development of the scientific method of the Greeks, and did not apply astronomy to the purposes of cartography. They valued maps according to their practical utility as implements of political administration; and they accordingly attached most importance to the route-map, from which they could learn the roads, the stations, and the distances. If we may judge by the few examples which have been preserved, these sketches may, distortions apart, be compared with our railway maps. Cicero and Seneca mention general and topographical maps. In their time the military routes were already divided into stages, furnished with milestones, and consequently measured. During the reign of Augustus a survey of the whole Roman empire was carried out. The routes were marked on parchment rolls for the purposes of military and civil administration. A map of the world was painted in a portico at Rome; a map of Italy was to be seen in the temple of Tellus. Particularly celebrated was Agrippa's map. Pliny must plainly have been in possession of maps to keep himself right in regard to the great number of names which he records. A map of the Roman empire was drawn up under Domitian. The emperors of the 2d, 3d, and 4th centuries caused maps to be constructed and painted on the walls of public buildings in the cities of Gaul, as for example in Augustodunum (Autun); but of this class unfortunately none has been preserved. The only Roman map, indeed, of the imperial epoch which has come down to us is the *Tabula Peutingeriana*, which takes its modern name from Conrad Peutinger of Augsburg, who possessed it in the 16th century. It is now preserved in the Imperial Library of Vienna. Its origin as a map goes back at least to the 3d century of the Christian era,—to the time, that is, of Alexander Severus; but the actual copy is not older than the 13th century. It consists of twelve folio sheets of parchment, which originally formed one long strip. It has been published by Scheyb (1753) and Mannert (1834), and in excellent facsimile by Desjardins (1869, &c.). That the original of this remarkable map was of a circular shape has been satisfactorily proved, the pattern followed being that of the map of the world in the portico of the Campus Agrippæ, which for centuries retained the rank of a model. Probably, however, such an *orbis pictus* was not exactly round, but rather oval. In its construction effect was also given to the opinion current from the time of Herodotus that the extent of the inhabited world was greater from east to west than from north to south. From this it is clear that the Romans had not advanced beyond the earlier Greek conception, and were ignorant of the astronomico-mathematical method inaugurated by Hipparchus.

4. *Map-making in the Middle Ages.*—The scholastic Middle Ages confined themselves to imitation of the Roman *orbes.* Fulness of detail, moreover, was gradually lost, meagreness and crudity appearing in its place. Cartography in fact fell back to a second childhood. Fanatical exponents of the orthodox faith, like Lactantius, looked with disdain on all scientific culture. Geographical questions were of no interest to him because he regarded them as mere matters of opinion. Astronomy was a piece of fantastic folly, the knowledge of distant lands mere learned lumber. "Quæ beatitudo," he exclaims, "erit mihi proposita si sciero unde Nilus oriatur vel quicquid de cœlo physici delirant?" As this narrow conception of things became on the whole the dominant one, geography and map-making practically ceased to exist. The doctrine of the sphericity of the earth was placed under the ban of the church, and people went back to the Homeric idea of a disk surrounded by the ocean. Isidore of Seville (*ob.* 636) taught: "Orbis a rotunditate circuli dictus quia sicut rota est. Undique enim Oceanus circumfluens ejus in circulo ambit fines. Divisus est autem trifarie; e quibus una pars Asia, altera Europa, tertia Africa, quæ et Libya nuncupatur." Isidore is a master of false etymological inferences. Deriving *rotunditas* from *rota*, a wheel, he declares that consequently the earth has the appearance of a wheel. Hence the name wheel-maps has been given to all those maps of the earlier Middle Ages. The three-fold division which he gives of the world-disk kept its ground for centuries, and the figure of the earth put on the miserable guise shown in fig. 2. It was only by the Greek fathers that the doctrine of the earth's sphericity continued to be taught; and, as the knowledge of Greek rapidly died out in western Europe, the fountain was dried up from which a better science might have been derived. Many minor modifications were introduced into the map of the world, but the fundamental type remained as given in fig. 2. Jerusalem lay in the centre, Paradise in the extreme east. Clever artists gave life to the disk of the world by turreted pictures of towns—Jerusalem, Troy, Babylon, Rome, &c., and drew Adam and Eve in the midst of a Paradise which

was defended by a fence of thorns or of flames, and, being considered the highest place in the world, was always introduced at the top of the map! The positions of Jerusalem and Paradise served to fix the other points. How long this conception remained in vogue appears from

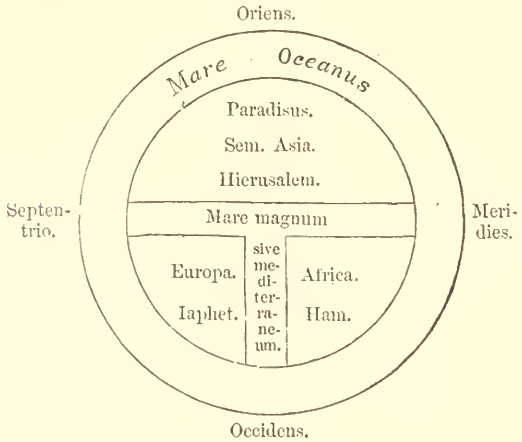


Fig. 2.

the fact that in 1422 Leonardo Dati, in a poem on the sphere (*Della Spera*), wrote, "A T within an O shows the design" (*Un T dentre a uno O mostra il disegno*), thus ⊖. In this way the whole science of cartography sank back below the level attained by the Ionian Greeks.

5. *Map-making among the Arabians.*—The first development of geographical science among the Arabs took place at Baghdad about 772 A.D., in the reign of the caliph Mansúr, and under the influence of an Indian astronomer and mathematician; and, not long after the works of Euclid, Archimedes, Aristotle, and Ptolemy were translated into Arabic, by orders of the caliph Mamún (813–833), a degree was measured in Mesopotamia in the plain of Sinjar, and a system of the world (Rasm el-ard) was constructed by his librarian Mohammed ben Musa of Khiva (Alcharesmius), in which every place was to be determined by longitude and latitude in the style of Ptolemy. But the science split up only too soon into a practical and a theoretical (astronomical) section—the one treating geography (ja'rafíyá) as the doctrine of routes and provinces, the other as the doctrine of latitudes and longitudes. Astronomy contented itself with the astronomical determination of the position of places without drawing maps or exerting any influence on their projection; travellers and topographers on the other hand did not trouble themselves about astronomy, but like Istakhri (*c.* 750) or Ibn Haukal (*c.* 750) added maps to their descriptions which were destitute of any system of degrees, and betrayed by the roughness of their outlines the clumsiness of the draughtsman. Ultimately, like Dimishkí (1327), they left mathematical geography completely out of their works, Ibn Haukal having already declared that mathematical division only brought confusion into geography. Only Edrísí's map, engraved for King Roger II. of Sicily upon a silver plate (1164), forms an exception; but, as it was not drawn according to the Ptolemaic projection, but simply indicated the seven climates, it was after all but an unsuccessful copy of Ptolemy.

6. *Nautical Maps.*—The nautical (loxodromic or compass) maps, which make their first appearance in Italy in the 13th century, indicate a gratifying improvement in cartography after a long period of stagnation. These maps were constructed with the aid of the compass, and took the name of compass-maps because they are covered with the figure of a compass from which numerous straight lines radiate out in all directions over the sheet. The fact that the magnet turns towards the north is first mentioned in 1187. Flavio Gioja of Amalfi was perhaps the first to make a mariner's compass and to teach seamen the use of that important instrument. The Italians divided the compass into eight parts (venti), assigning 45° to each—Tramontane (N.), Greco (N.E.), Levante (E.), Sirocco (S.E.), Ostro (S.), Libeccio or Garbino (S.W.), Ponente (W.), Maestro (N.W.). Every division had four quarters (quarte di vento), each of $11\frac{1}{4}$ degrees. The maps were produced as follows. The courses of individual ships were first of all inserted as straight lines, calculated according to the distances traversed, from particular ports, as Genoa or Venice, to other ports, and when a good supply of such material had been collected and a series of diagonals drawn in accordance therewith, the most important points on the coast and in the islands were fixed. The lines by which the meridians were cut at the same angle were called loxodromes; they gave a correct indication when they cut the true astronomical meridian, a false one when they cut the magnetic meridian. On the Italian charts the loxodromes were drawn as straight lines. The numerous radii of the compass shown on the maps enabled the seaman to find the direction which he had to take to reach his goal. Hence the title loxodromic maps.

Charts on which the degrees were marked became necessary only when navigation extended to the ocean; they were introduced by the Portuguese, probably at the suggestion of Prince Henry the Navigator. They are "plane charts" with lines of longitude and latitude.

The oldest loxodromic charts which have been preserved come from Pisa, Genoa, and Venice. The earliest, the so-called Pisan chart, belongs probably to the middle of the 13th century, and already comprises the whole Mediterranean. As this representation of the whole must of necessity have been preceded by surveys of the several portions, the beginning of the chart may be placed at least as far back as the first part of the 13th century. Next in point of age comes (2) the Luxoro Atlas in Genoa about the year 1300, in the possession of the Cavaliere Tomas Luxoro. Then follow (3) Petrus Vesconte, 1311, in the national archives at Florence, including the eastern Mediterranean (*Petrus Vesconte de Janua fecit ista carta ann dñi M°CCCXI°*), see fig. 3; (4) Marino Sanudo, a map of the world representing the Mediterranean and the Atlantic coasts as far as Flanders, probably drawn between 1312 and 1321—several copies in Rome (the Vatican), Venice, and Brussels; (5) an atlas of Petrus Vesconte's about 1318 (in Venice, in eight sheets; in Milan, ten sheets); (6) Perrinus Vesconte, 1327, in the Laurentian Library at Florence; (7) Joannes da Carignano, between 1306 and 1333, in the archives of Florence (*Presbiter Joannes rector sancti Marci de portu Januæ me fecit*); (8) a map of 1346 in the Castilian tongue, in the National Library at Paris; (9) the Medicean atlas of 1351 in the Laurentian Library at Florence, eight sheets, which represents also the Caspian Sea, and, remarkable enough, the whole of Africa; (10) Pizigani, 1367, in the National Library at Parma, a map of the world which extends as far as Persia, with numerous entries not only on the coasts but also in the interior; (11) an atlas of Pizigani, of date 1363, nine sheets in folio, in the Ambrosian Library in Milan, comprising the Mediterranean and the Ocean as far as Jutland (*M.CCCLXXIII a die VIII di zugno franzescho piziganij veniziano in veniexia me fecit*); (12) the famous Catalonian map of the world of 1375, in four sheets, in the National Library at Paris; (13) a map by Guill. Solerio of Majorca, 1385, in the public archives in Florence; and (14) atlas by some unknown hand, four sheets folio, in the Biblioteca Marciana at Venice.

Several of these Italian maps give indubitable evidence that as early as the 14th century the Azores and Canaries had been discovered, as well as the coast of Africa as far as beyond Cape Bojador. With the middle of the century the coast maps developed into maps of countries with trade routes, pictorial figures, and numerous inscriptions. Maps preserved from the 15th century are still more numerous:—(15) a map by the Venetian Nicolao, of date 1408, in Vienna; (16) Mecia de Villa destes, 1413, in the National Gallery at Paris; (17) a map of the world of 1417, in the National Library at Florence; (18) Francesco de Cesanis, 1421, in the Museo Correr at Venice; (19) a map of 1424 at Weimar; (20) atlases by Giacomo de Giraldi, 1426–43, in Venice and Milan; (21) Gabriel de Valsecqua, 1434, from Majorca; (22) Francesco Beccario, three maps, in the British Museum; (23) two maps by Battista Beccario in Munich (1426) and Parma (1435); (24) Andrea Bianco, 1436, an atlas of ten sheets, where for the first time the mediæval circular maps are accompanied by the Ptolemaic maps, in the Biblioteca

Marciana at Venice; also a map of 1448, drawn at London, now in the Ambrosian Library at Milan (*Andrea Bianco veneccian comito di galia me fexe a londra*, 1448); (25) an elliptical map of the world in the Pitti Palace at Florence, of Genoese origin, and of date 1447; (26) Hannibal de Madiis, 1449, in the Ambrosian Library; (27) a Catalonian map of the world, of 1450 (?), in the National Library at Florence; (28) Giovanni Leardo, two maps of the world, of date 1448 (in the museum at Vicenza) and 1452 (the property of Consul-general von Pilat at Venice); (29) Fra Mauro, a famous map of the world from 1457–59 in the Biblioteca Marciana at Venice; (30) Gratioso Benincasa of Ancona, a diligent cartographer, twenty-five very carefully executed works dating from between 1460 and 1482; most of them are in Italy, chiefly at Venice, two in Paris, one at Munich, and one without date in the British Museum; (31) Andrea Benincasa, son of the preceding, three maps of 1476 (Geneva) and 1490 (Ancona and Rome); (32) Bartolomeo Pareto, a map of the world, of 1455, at Rome; (33) Giorgio Giovanni, 1484 (Parma); (34) Count Hortomanus Fredutius of Ancona, 1497 (Wolfenbüttel).

In the beginning of the 16th century, (35) Alberto Cantino, about 1501–3, was the first in Italy to draw a map representing portions of America, *Carta da navigare per le Isole nuovamente trovate in la parte delle Indie*, in the library at Modena. (36) The Maggiolo family, famous for its cartography, flourished in Genoa between 1511 and 1648. Visconte Maggiolo, the founder of the family, is known to have produced nineteen atlases between 1511 and 1587. A map by Giacomo Maggiolo, of date 1562, is in the British Museum. (37) Battista Agnese laboured between 1527 and 1554 in Venice, and the thirteen atlases he has left behind him are pieces of fine artistic work adorned with charming miniatures. Two of these atlases, of date 1527 and 1536, are in the British Museum.

In the 15th century and the beginning of the 16th Spanish, Portuguese, Greek, and French cartographers appear as competitors with the Italian, Catalonian, and Balearic artists. We name only the most important. Juan de la Casa, a Basque, and a companion of Columbus, drew in 1500 a map of the world in which for the first time the hitherto discovered coasts and islands of

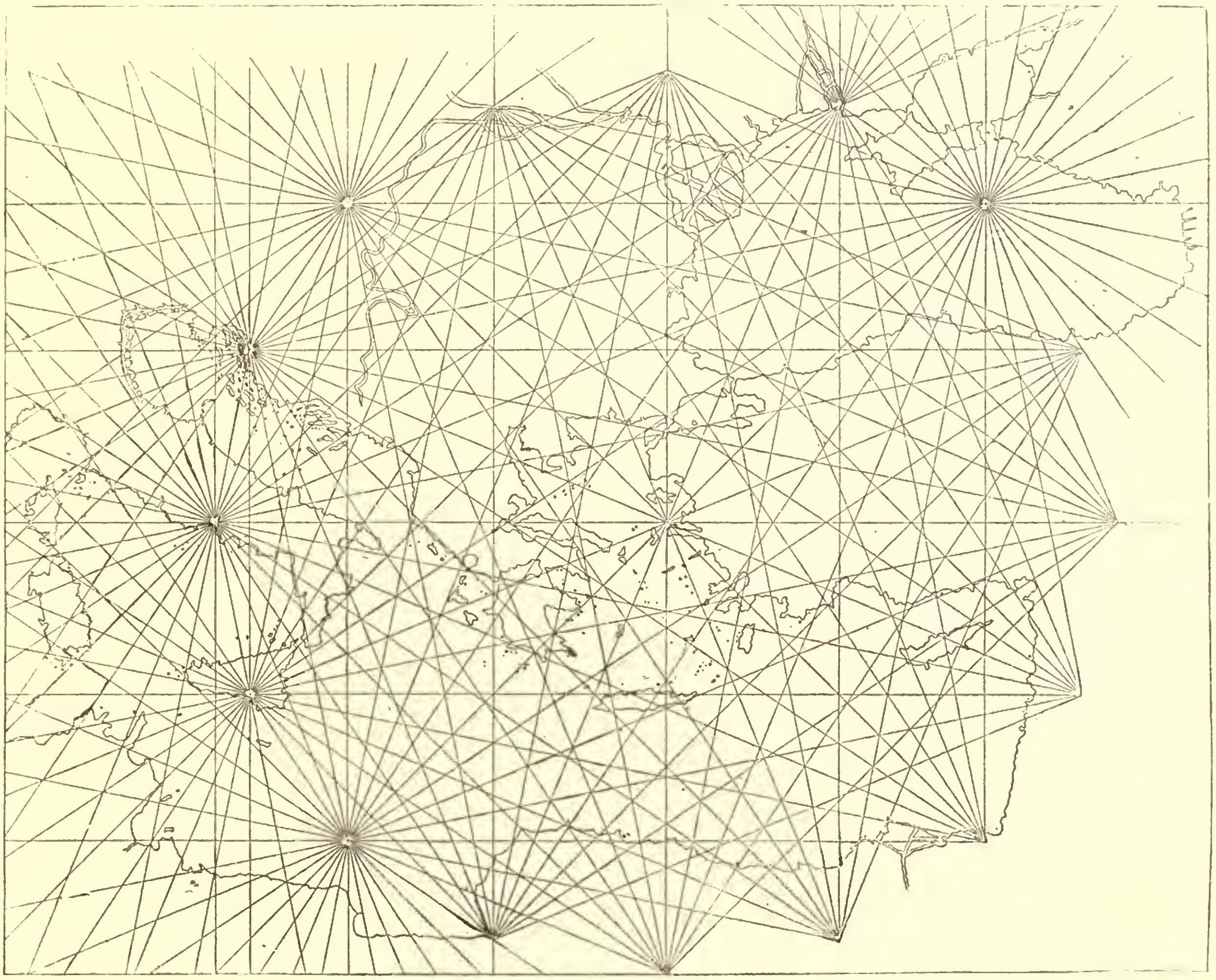


FIG. 3.—Chart of the Mediterranean (P. Vesconte, 1311).

America were introduced. A map of the world by Garcia de Torero, 1522, is preserved at Turin; and two general maps, the one dating 1527 (probably by Fernando Colon, son of Columbus) and the other 1529 (by Diego Ribero), exist at Weimar. Between 1558 and 1569 Diego Homem produced several beautiful atlases; of these four are in Italy, and one, of date 1568, at Dresden. Among the French world-maps a special place is due to that drawn up by order of King Henry II. It is published by Jomard in his *Monumens de la géographie.*

As far as Italian navigation extended, and especially within the limits of the Mediterranean, a very correct representation of the coasts and of the contours of the several countries was secured at an early date. The interior of the countries, on the other hand, remained confused and inexact. These defects were first supplied in the 15th century, when recourse was again had to the contributions of the Greeks, and especially of Ptolemy.

Before proceeding to discuss this new development, it may be as well to mention the various names by which the representations of the earth's surface have been designated. The Greeks employed the expression πίναξ (picture), the Romans in like manner said *tabula.* The word map came into use in the Middle Ages, the name *mappamundi*, *mappemonde* ("world-napkin"), proving that maps were originally painted on cloth. In English map is applied only to a land-map, the sea-map being known as a chart. The Romance languages had the expressions *disegno*, *figura*, *pintura*, *padron.* When the loxodromic maps came into existence, hand-books with sailing directions were written to accompany them, hence the titles "sailing directions," "sea-books," portulani (by which word actual maps were afterwards meant), or cartas da marear. The Latin word *charta* signifies originally a letter, a written document; and in like manner the Portuguese and Spanish form *carta.* But as early as the 14th century this expression was (as appears from the inscription quoted under No. 3 above) used to distinguish a sea-map. In the same sense Paolo Toscanelli speaks of his *carta*, which he sent to the king of Portugal. But the expression did not become general till the 16th century; in 1513 we find it in Germany in a Strasburg edition of Ptolemy (Carta Marina Portugalensium), in 1524 in Spain (in the Junta of Badajoz), in 1582 in England (Michael Lock).

7. *The Revival of Ptolemy.*—This produced in the 15th century a revolution in the construction of maps, and laid the foundations of modern cartography. Ptolemy's great work again became generally well known in western Europe only after it was translated into Latin by Jacobus Angelus de Scarparia in 1409; and this version was first printed in 1475 at Vicenza without maps. The first edition with maps (to wit, a map of the world, ten maps of Europe, four of Africa, and twelve of Asia) appeared at Rome in 1478. Afterwards there were editions at Bologna (1482), Ulm (1482, by Nicolaus Donis with five modern maps), Ulm (1486), Rome (1490, 1507, and 1508, the last with seven modern maps, among which the famous map of the world by Joh. Ruysch), Strasburg (1513, with forty-seven maps); and in the course of the same century twenty-five other editions might be mentioned at Strasburg, Basel, Lyons, Cologne, Venice, and Paris. From this long series, which if prolonged to the beginning of the Thirty Years' War would be further increased by five, it is evident that Ptolemy was the great master of the modern time. At first maps were drawn according to Ptolemy's determinations of geographical position; but, in proportion as the study of mathematics, astronomy, and cosmography excited the interest of men of culture, opportunities were afforded of correcting Ptolemy's astronomical positions, especially in the case of central and northern Europe, where the range of the great cosmographer's knowledge had hardly enabled him to collect original material. The new arts of wood and copper engraving supplied the means for a rapid diffusion of *printed* maps. The oldest map printed from a wooden block (in the National Library at Paris), dating from 1460, and thus belonging to the earliest period of wood engraving, was produced in Germany, and represents Germany and western Europe. It is considered to be a copy from an old Roman map.

After the foundations of trigonometry had been laid by Purbach, Regiomontanus, and others, attempts of a rather rude kind were made in the beginning of the 16th century to execute geographical triangulations and delineations. The towns formed the central points of the system, their direction and position from the post of observation being fixed as precisely as possible, and their distance estimated in miles according to the best available data without being accurately measured. It was considered sufficient to assign in this way the relative positions of inhabited places, and the representation of the physical relations was very superficial; the course of rivers, for instance, was not measured, but carried past the towns on their banks in conventional lines.

In the Ptolemy of 1513 we already find three topographical maps, viz., one of Switzerland, one of the district of the upper Rhine from Basel to Mainz and Lorraine, and a large one of Crete, which it has been conjectured was taken from a Venetian original. The number of maps of smaller districts rapidly increased. In 1528 Aventinus drew the duchy of Bavaria, in 1533 Sebastian of Rotenhamm produced a map of East Franconia. Map drawing became a favourite occupation with the Germans. The best geographical survey of this period was the *Chorographia Bavariæ*, by the famous Philip Apianus (twenty-four sheets, at Ingolstadt, 1568). The number of cartographers increased so rapidly that Abraham Ortelius, in the first edition of his collection of maps (*Theatrum Mundi*, 1570), was able to give the names of ninety-three. The first attempts to improve and to increase the methods of projection known to the Greeks were made by Germans,—namely, Johann Stöffler (1452–1536), Johann Werner of Nuremberg (1468–1528), Peter Apianus (1495–1552). The last-mentioned introduced the favourite method of representing both hemispheres together in an elliptical form with lines of latitude. Maps of the world were compiled by Peter Apianus, Oronce Finé (1494–1555), Sebastian Cabot (1544), Giacomo Gastaldo (1546–48), Giov. Batt. Guicciardini (1549), Giov. Domin. Methoni at Venice, Heinrich Pontanus of Arnhem (1556, a map of the world in the shape of an imperial eagle), Guill. Postel at Paris (1581), &c.

8. *Mercator and his Successors.*—Gerhard Kramer, usually called Mercator (born of German parents at Rupelmonde in Flanders in 1512), has the honourable place of a reformer of cartography. We possess his map of Palestine (1537), a map of Flanders (Louvain, 1540) in nine sheets, phototyped in 1882, a globe (1541), and the first critical map of Europe (1554), by which he laid the foundation of his fame as the first cartographer of his age. The exclusive use of Latin letters for maps in Germany was due to his example. Especially famous is his map of the world (fig. 4) dating from 1569: "Nova et aucta orbis terræ descriptio ad usum navigantium emendate accommodata" (one copy in the National Library at Paris). This map is drawn in the projection of increasing latitudes with lines of latitude and parallel meridians, the basis of which was furnished by Edward Wright in 1599 in *Certain Errors in Navigation.* It is the first chart on which true rhumb lines could be drawn as straight lines. By 1601 Mercator's projection was in use for all sea charts. In 1578 Mercator drew up maps for Ptolemy exactly in accordance with his determinations; and these were followed by maps of Germany, the Low Countries, and France (1585), and of Italy (1590). It was his purpose to produce a complete collection of new maps, to which he gave the name *Atlas*; but he died in 1594, and the publication of this first atlas (1595) was left to his son. The title took the place of the designations previously in fashion—*Theatrum Orbis*, *Speculum Mundi*, &c. The second edition of the *Atlas* appeared in 1602. The later editions were issued by Jodocus Hondius in Amsterdam.

Before Mercator collections of maps, including various countries, and independent of Ptolemy, had begun to be published. Thus Christoffel Froschover in Zurich issued various "Landtaflen" in 1562—a map of the world (Universalis Cosmographia, in the shape of a heart, dated MD.XL.VI.), Europe, Germania, Gallia, "die gantze Eydgnoschafft," and eight topographical maps of Swiss districts. Of much greater importance and influence was the collection published by Abraham Ortelius of Antwerp (1527–98), *Theatrum Orbis Terrarum* (1570), in which the best maps from all countries were re-engraved. The first edition with a Latin text contained fifty-three sheets; the seventh (1573) had sixty-nine maps, the twelfth (1579) ninety-two. Editions appeared with the text in German, French, Dutch, and after 1600 in English and Italian, and obtained the widest diffusion. Through this work the centre of cartographic activity was transferred to Holland. There too laboured the successors of Mercator, Jodocus Hondius (1563–1611) and his son Henricus Hondius (1580–1644). Their maps, in several folio volumes, were numbered by hundreds. To the school of Mercator belonged also Petrus Plancius and Lucas Janszoon Waghenaer of Enkhuyzen (Aurigarius), who by his *Spieghel der Zeevaerdt* (Leyden, 1583) became the founder of nautical map-collections. In 1588 a reproduction of this atlas appeared in London as the first "Waggoner." In the beginning of the 17th century the town of Dieppe also produced excellent charts,—Guill. Levasseur (1601), Jean Dupont (1625), and Jean Guerard (1631) being at work there. About the same time another famous cartographic family arose in Holland. William Jansz. Blaeu (1571–1638) and his sons Jan and Cornelis turned out about four hundred maps previous to 1655. William Blaeu was in 1633 appointed by public decree cartographer to the States-General; and it was his duty to examine the ships' logs and so amend the maps. He had a rival in the person of Jan Janszoon (Jansonius), who, working with the material inherited by him from his father-in-law Jodocus Hondius, produced a Dutch atlas in six volumes, a French in six folios, a German in nine folios, and a Latin in two. Cartography became a lucrative business, but the scientific value of the work grew less and less in the hands of Nicolaus Visscher (Piscator) from 1621 to 1670 and his son of the same name (*ob.* 1709), of Friedrich de Witt and his sons, and of Peter Schenck. The influence of the Dutch school, which had previously been so great, disappeared with the close of the 17th century.

In the 16th century the Italians were still active competitors with the Germans and Dutch. In engraved maps Venice held a specially high rank up to 1570, the Piedmontese Giacomo Gastaldo and Paolo Forlani of Verona being settled there. Their publications comprised well-nigh all parts of the earth. The progress of discovery can be followed on their general (*universale*) and topographical maps. Gastaldo's period of activity lay between 1546 and 1569, Forlani's between 1560 and 1570. They had a successor in Antonio

Magini (1555-1617) of Padua, who in his *Novæ geogr. tabulæ*, published in 1596, gave greater precision to the determinations of position. Giovanni Battista Nicolosi (1610-70) of Sicily issued at Rome a series of huge maps of the hemispheres and continents. Among the French map-makers of this period must be mentioned Oronce Finé (Finæus) from Dauphiné (1494-1555), who published in 1531 his *Planisphærium geographicum* in the shape of a heart according to the projection of Apianus; Jolivet (about 1560); Guillaume Postel (1505-81), who in 1570 drew a new map of France; the Franciscan André Thevet (1502-90), who in 1575 edited a *Cosmographie universelle* (2 vols. in folio), and finally Melchior Tavernier, a pupil of Ortelius (*ob.* 1641), who published many maps of European countries. In England there appeared in 1544 the great map of the world by Sebastian Cabot. The first modern map of England was produced by Humphrey Lhuyd in 1569 (*Angliæ regni tabula* and *Corographia Cambriæ*). He was succeeded by Christopher Saxton, who travelled through different parts of the country with several engineers, and in 1575 gave to the world his British atlas of thirty-six sheets, which Philip Lea afterwards reduced to twelve sheets. John Speed's atlas (*Theatrum*) of Great Britain was published at Amsterdam in 1610 by Jodocus Hondius. The first map of Scandinavia (*Regnorum Aquiloniorum Descriptio*) was produced in 1539 by Olaus Magnus, archbishop of Upsala. Much more accurate was the map drawn by Adrian Veno in 1613, and engraved by Jodocus Hondius, but the real reformer of northern cartography was Anders Buré (Buræus, 1571-1646), who surveyed the several parts of the country. His maps were afterwards published in the atlas of the brothers Blaeu between 1650 and 1660.

The first new map of Spain and the first of Portugal both appeared in the same year, 1560, the former being due to Pedro de Medina, the latter to Fernando Alvarez Secco.

During all this period there prevailed a remarkable variety in the determination of the first meridian. Whilst the Spaniards and Portuguese reckoned from the line of demarcation (370 leagues west of the Cape Verds) sanctioned by the pope, the Protestant Dutch, Germans, and English at first went back to Ptolemy, who began at the Canaries. Mercator, on his globe of the year 1541, chose the island Forteventura in the Canaries as his starting-point, but he afterwards adopted Corvo in the Azores, because he there approached the true indication of the magnetic needle. For the same reason Ortelius, the younger Mercator, Jansonius, and at first also William Blaeu fixed on the Isla del Fuego in the Cape Verd group. Blaeu afterwards proposed the Peak of Teneriffe, and in this he was followed by all Dutchmen. In the year 1634 Richelieu consulted the astronomers Gassendi (1592-1655) and Morin (1583-1656), and in accordance with their decision Louis XIII. commanded, under penalty, that all French ships should calculate their longitudes from the meridian of Ferro, though it was not till the close of the 17th century that a French expedition determined with accuracy the relation of the position of Ferro to that of the observatory of Paris. It was in this way that the Ferro meridian obtained almost universal currency down to the 19th century. As in this period it was still practically impossible to secure precise determinations of longitude, all cartographic representations were naturally subject to considerable distortions, especially in countries outside of Europe.

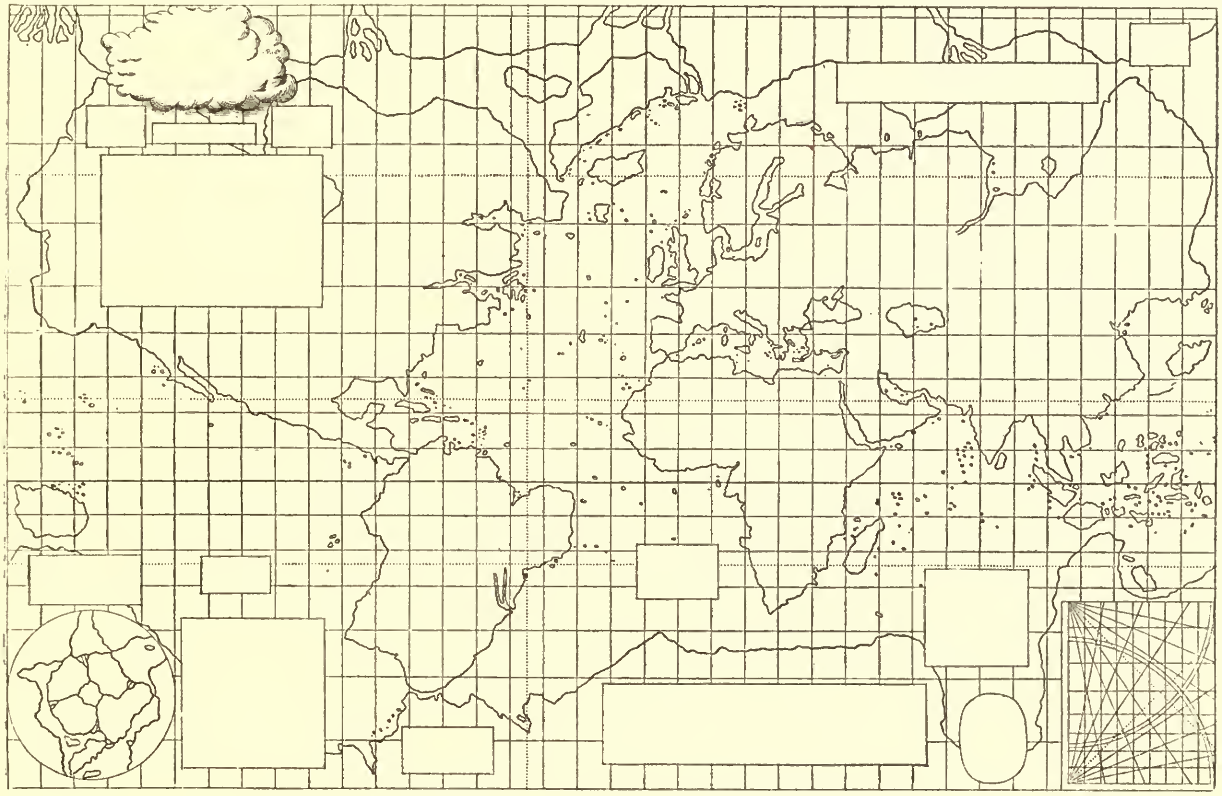


FIG. 4.—Outline of Mercator's *Nova et Aucta Orbis Descriptio*, 1569.

9. *Period of Transition.*—A series of important discoveries and inventions in mathematics, physics, and astronomy having provided the means of making much more accurate observations and calculations, there followed as a matter of course a substantial improvement in cartography. Of chief moment were the invention of the telescope (1606), Galileo's discovery of Jupiter's moons (1610) and Cassini's calculation of their periods of rotation, so important for determinations of longitude (1666), the first application of trigonometry to geodesy by Snellius (1615), Picard's measurement of a degree between Paris and Amiens (1669 and 1670), the French measurement of a degree between Dunkirk and Perpignan by Cassini and Lahire (1683-1718), Hadley's mirror-sextant (1731; according to Newton's idea, 1699), the improvements made on the lunar tables by Tobias Mayer (1753), and John Harrison's chronometer (1761). In this way there set in a period of transition in cartography which lasted till somewhere about 1750; the results of new investigations and measurements were gradually turned to account, but, while here and there traditional blunders were corrected and expunged, nothing essentially new was as yet created.

To this epoch in Germany belong Johann Baptist Homann, (1664-1724), whose elegantly engraved maps, published in Nuremberg, continued to have a wide sale after his death, Johann Matthias Hase in Nuremberg (*ob.* 1743), and the famous Tobias Mayer (1723-86), who published in Nuremberg a critical map of Germany. In France eminence was obtained by Nicolas Sanson (1600-67) of Abbeville, who from 1627 worked at Paris as royal geographer, and issued more than three hundred maps; and the reputation of the house was maintained by his sons Nicolas, Adrien, and

Guill. Sanson, who worked along with Hubert Jaillot (1681–1717), Pierre du Val (1619–83), and Jean Baptiste Nolin (1692) at the French book of charts, *Neptune françois*, 1693, in which for the first time the new astronomical determinations were turned to account. Greater critical acumen was shown by the royal geographer Guill. de l'Isle (1675–1726), and especially by the talented Jean Baptiste Bourgignon d'Anville (1697–1782) and his younger contemporary Philippe Buache (1700–1773). In this period France was *facile princeps* in cartographic achievements, and led the way to the next and latest epoch. In England Dowet's *Atlas* was published at the cost of the duke of Argyll, and in the same year Aaron Arrowsmith was born (*ob.* 1828). A beginning of geodetic labour was at this time made in Sweden under Charles XI.,—the proceedings being carried on first under the Baron Karl Griepenhielm (*ob.* 1684) and afterwards under Count Dahlberg. For political reasons, however, the king did not allow the publication of the map of Sweden; but, the French ambassador D'Avaux having in 1704 got possession of copies, it was engraved at Paris by De l'Isle. In Italy P. Vincent Coronelli (*ob.* 1718) deserves to be mentioned.

10. *The Period of Triangulations and Geodetic Surveys.*—Up to this point the whole art of map-making had been treated as a matter of private speculation. It was France that gave the first example of carrying out the cartographic survey of the country at the cost of the state. Such surveys had a double object, one military, to provide the army with satisfactory maps, and the other administrative, to furnish a cadastre for the land tax. The military interest predominated; consequently the surveys have in almost all countries been carried out by officers of the general staff, and the maps are briefly designated as general staff or ordnance maps. For such a survey the whole country is covered with a network of triangles, and, in order to secure the most trustworthy basis for the representation, numerous points are astronomically fixed. In comparison with those of earlier date the maps thus produced are distinguished by correctness of detail. In the century between 1750 and 1850 attention was mainly directed to the accurate rendering of the horizontal development of the face of the country; but during the last thirty years the vertical configuration has also been faithfully represented on topographical maps of large scale by the introduction of contour lines. The first example of this also was given by France, when at Laplace's suggestion (1816) it was determined to publish a new map of France with curves of altitude. But owing to the great extent of the country, and the consequent difficulty and slowness of the undertaking, only four sheets of this kind were published by 1833. Hanover, however, followed suit in 1829, Baden in 1833, Hesse in 1840, and so on. Since the middle of last century nearly all the states of Europe have been active in map-making; and prolonged effort has produced rich results. Surveying and mapping have been followed by the publication of topographic maps. The states of the Balkan peninsula alone lag behind; there no comprehensive survey has been undertaken at public expense. As a summary of these great achievements in the larger part of Europe, we append a chronological[1] table of the most important surveys, with the date of the publication of the first sheet, the name of the country, the title of the map, the scale, and the number of sheets. Outside of Europe there are but few countries in which a survey based on exact triangulation has been carried out. The largest areas thus measured are the United States of North America and British India, where great activity has been shown; and to these may be added Asiatic Russia, portions of Australia, portions of the Dutch possessions in the East Indies, and Algeria. In the whole of South America there is only one country, Chili, of which we possess a map based upon a careful survey. In the second portion of the table consequently some maps are included which are merely the work of private cartographers, and the list must be regarded as tentative.

List of Topographic Maps.

Year.	Country.	Title of Map.	Scale.	No. of Sheets.
1750	France.	Carte géometrique de la France.	1:86,400	134
1766	Denmark.	Maps of Denmark, published by the Academy of Sciences.	Various.	19
1780	Mecklenburg-Strelitz.	Chorograph. und Militair-Karte.	1:33,900	9
1788	Mecklenburg-Schwerin.	,, ,, ,, ,,	,,	16
1855	England.	25-inch maps (400,400 shts. published).	1:2500	3625
1846	,,	6-inch maps.	1:10,560	110
1801	,,	1-inch map (old series). }	1:63,360	355
1874	,,	1-inch map (new series). }		
1856	Scotland.	25-inch maps.	1:2500	14315
1847	,,	6-inch maps.	1:10,560	2025
1856	,,	1-inch maps.	1:63,360	131
1871	Ireland.	25-inch maps (Dublin county only).	1:2500	665
1833	,,	6-inch maps ,,	1:10,560	1908
1853	,,	1-inch maps ,,	1:63,360	205
1803	Prussia.	Karte von Altpreussen, enthaltend Ostpreussen nebst Preuss. Lithauen und Westpreussen nebst dem Netze-district.	1:150,000	25
1805	Salzburg.	Karte des Herzogthums Salzburg.	1:144,000	15
1812	Bavaria.	Topograph. Atlas vom Königr. Bayern.	1:50,000	112
1813	Austria.	Karte d. Erzherzogth. Oesterreich.	1:144,000	31
1815	,,	Karte der gefürsteten Grafsch. Tyrol nebst Vorarlberg.	1:144,000	24
1826	Norway.	Official maps published since 1845 by the Government.	1:200,000	...
1828	Parma.	Carta topografica dei ducati Parma, Piacenza, e Guastalla.	1:86,400	9
1829	Würtemberg.	Karte vom Königr. Württemberg.	1:50,000	57
1832	Hanover and Brunswick.	Topogr. Atlas des Königr. Hannover und Herzogth. Braunschweig.	1:100,000	69
1832	Hesse.	Karte von dem Gressherz. Hessen.	1:50,000	31
1833	France.	Carte topographique de la France.	1:80,000	274
1833	Lombardy and Venice.	Carte topogr. del Regno Lombardo-Veneto.	1:86,400	42
1837	Saxony.	Topogr. Atlas des Königr. Sachsen.	1:57,600	20
1838	Baden.	Topogr. Karte über das Grossherz. Baden.	1:50,000	56
1840	Hesse.	Topogr. Karte von dem Kurfürstenth. Hessen.	1:50,000	40
1842	Modena.	Carta topogr. del ducato di Modena.	1:86,400	8
1842	Switzerland.	Topogr. Karte der Schweiz.	1:100,000	25
1844	Moravia and Silesia.	Specialkarte d. Markgr. Mähren mit d. Antheilen des Hrzgth. Schlesien.	1:144,000	20
1849	Bohemia.	Specialkarte des Königr. Böhmen.	,,	38
1849	Belgium.	Grande Carte topogr. de Belgique par P. v. d. Maelen.	1:20,000	250
1850	Sardinia.	Carta degli stati di sua maesta Sarda, in terra firma.	1:50,000	91
1850	Netherlands.	Topogr. en Milit. Kaart van het Koningrijk der Nederlande.	1:50,000	62
1851	Tuscany and Papal States.	Carta topogr. dello stato Pontificio e del gran ducato di Toscana.	1:86,400	52
1852	Denmark.	Topographisk Kart over Kongeriget Danmark met hertogt. Slesvig	1:80,000	81
1852	Prussia, E.	Topogr. Karte vom östliche Theile der Monarchie.	1:100,000	249
1852	Prussia, W.	Topogr. Karte der Provinz Westphalen und der Rheinprovinz.	1:80,000	70
1852	Greece.	Map of Greece (Paris, 1852).	1:200,000	20
1854	Hungary.	Komitäts-Karten des Königr. Ungarn.	1:288,000	...
1854	Galicia.	Generalkarte von Galizien und Lodomerien.	1:288,000	33
1856	Oldenburg.	Topogr. Karte des Grossherz. Oldenburg.	1:50,000	16
1856	Portugal.	Carta corografica dos reinos de Portugal e Algarve.	1:100,000	37
1857	Russia.	Military Topogr. Map of Russia.	1:126,000	751
1860	Sweden.	Topogr. Corpsens Karta öfver Sverige.	1:100,000	233
1863	Saxony.	Topogr. Karte vom Königr. Sachsen.	1:100,000	28
1867	Belgium.	Carte topographique.	1:40,000	76
1868	Sinai Penins.		1:63,360	1
1868	,,		1:126,720	2
1869	Norway.	Topogr. Kart. over Kongeriget Norge.	1:100,000	216
1869	Hungary.	Specialkarte von Ungarn, Croatien, und Slavonien.	1:144,000	198
1869	Switzerland.	Topographischer Atlas — higher mountain regions. }	1:50,000	546
		Do. —hill regions. }	1:25,000	
1871	Portugal.	Carta geogr. de Portugal poblicada por ordera de Sua Magestade.	1:500,000	1
1874	Spain.	Mapa topogr. de España.	1:50,000	...
1875	Austria.	Specialkarte der Oesterr.-ungar. Monarchie.	1:75,000	718
1875	Saxony.	Topogr. Karte von Sachsen.	1:25,000	156
1878	Germany	Karte des deutschen Reiches.	1:100,000	674
1878	Italy.	Carta delle provincle meridionali.	1:50,000	230
1879	,,	Gran Carta topografica d'Italia.	1:500,000	...
1879	Palestine.	1-inch map.	1:63,360	26
1825	United States.	Virginia (Hermann Boije).	5 ml.=1 in.	9
		South Carolina (Rob. Mills).	2 ml.=1 in.	
1827	East Indies.	The Indian Atlas (J. Horsburgh).	1:266,000	177
1834	Australia.	Map of the Colony of New South Wales (T. L. Mitchell).	1:540,000	3
1838	United States.	Map of Alabama and West Florida (John la Tourrette).	6 ml.=1 in.	
1839	,,	Map of Mississippi with a large portion of Louisiana and Alabama (La Tourrette).	6 ml.=1 in.	
1847	Caucasia.	Map of the Caucasian Countries (General Staff).	1:420,000	25

[1] For convenience of comparison the different series for the British Isles are grouped together in the table in the place of the earliest date.

Year	Country.	Title of Map.	Scale.	No. of Sheets.
1853	United States.	Map of the Eastern Provinces of Australia (J. Arrowsmith)	1:1,700,000	6
1851	Australia.	Reference Map of Louisiana (La Tourrette).	6 ml.=1 in	
1854	United States.	Map of Arkansas (Langtree).	8 ml.=1 in.	
,,	India.	North-West Himalaya (surveyed 1848–54 by A. S. Waugh).	4 ml.=1 in.	15
1856	United States.	Map of Kentucky (Edmund Fr. Lee).	6 ml.=1 in.	
1857	India.	Kashmir (surveyed 1850-57 by T. G. Montgomerie).	1 ml.=1 in.	4
1858	United States.	Map of Texas (C. W. Pressler).	13 m.=1 in.	8
,,	Palestine.	Map of the Holy Land (Van der Velde).	1: 315,000	
1859	Australia.	County Maps of New South Wales.	1: 126,720	
,,	United States.	Map of Georgia (J. R. Butts).	6 ml.=1 in.	
1860	,,	Map of Missouri (Fiela).	6 ml.=1 in.	
1863	South Africa.	Natal (Capt. Grantham).	1: 250,000	
1865	United States.	Territory of the U.S. from the Mississippi River to the Pacific Ocean (Edward Freyhold).	1:3,000,000	4
1866	,,	U.S. North-West Boundary Survey.	1:1,060,000	2
,,	,,	Map of parts of California, Nevada, and Idaho Territory.	1: 760,320	1
,,	,,	Post Route Maps of the States (W. L. Nicholson).	Various.	36
1867	Siberia.	General Map of Transbaikal country.	1: 840,000	10
1867	Java.	Residency Maps.	1: 100,000	
1869	Caucasia.	Map of the Caucasian countries.	1: 420,000	22
1870	Siberia.	Special Map of West Siberia.	1: 420,000	125
1871	Australia.	Plan of the southern portion of the province of South Australia.	1: 550,000	10
1872	Turkestan.	Military Map of Turkestan.	1:1,168,000	4
1873	Chili.	Plano topografico y geologico de la Republ. de Chile (A. Pissis).	1: 250,000	13
,,	United States.	Atlas of the United States to the W. of 100° W. long. (Wheeler).	1: 506,880	95
1874	,,	Map of Central California.	1: 380,160	2
1876	Algeria.	Carte d'Algérie (Dépôt de la guerre).	1: 800,000	4
1877	Turkestan.	Map of Turkestan, Military District.	1: 168,000	12
1878	Australia.	Western Australia, Northern District (J. Forrest).	1: 770,000	1
1879	South Africa.	Eastern portion of South Africa (Capt. C. E. Grover).	8·6m.=1in.	
,,	Algeria.	Carte de la province d'Alger.	1: 200,000 1: 800,000	2 2
1881	Australia.	Map of Queensland (Bailey and Lawson).	1:1,000,000	6

(S. R.)

MAP, MAPES, or MAPUS, WALTER, an ecclesiastical statesman and renowned wit of the 12th century, must be ranked among the greatest of English writers, though French was the language that he used, and his personal fame has long been lost in the splendour of his creations. He was the cosmogonist and one of the principal creators of the Round Table legends, which supplied the ideal of chivalrous life to so many succeeding centuries. Most of the facts that are known about his position in the world have been gathered from a gossipy anecdotical work of his in Latin, *De Nugis Curialium.* He was probably a native of Herefordshire or Gloucestershire. He tells us that his parents rendered services to Henry II. both before and after his accession. He was acquainted with the household of Thomas Becket before this famous ecclesiastic became archbishop of Canterbury, which was in 1162. He studied in the university of Paris, attending the lectures of Girard la Pucelle, who began lecturing in 1160. Map seems to have risen rapidly in favour at the court of Henry II., combining ecclesiastical with civil and political functions. In 1173 he was an itinerant justice at the assize of Gloucester, and in the same year was with the court at Limoges, where the duty fell to him of entertaining the archbishop of Tarentaise, about whom he tells some marvellous stories. He was sent on a diplomatic mission to Louis le Jeune, king of France, and sat as a delegate in a council called by Pope Alexander III. (probably 1179), enjoying such repute that he was deputed to argue with the Waldenses. He accompanied Henry II. on all his progresses, and in return for his services received several ecclesiastical preferments. Apparently he maintained his position at court under Richard and John. In 1196 he was appointed archdeacon of Oxford, and in 1207–8 the custodes of the abbey of Eynsham were ordered to pay him his accustomed rent of five marks per annum. In the 12th century the abuses of the church were assailed with great freedom and abundance of humorous wit in rhymed Latin verse, and a century or two later rubrics appear in the MSS. of these satirical poems ascribing them to Walter Map. "Golias Episcopus" is the nominal author and hero of a great many of these effusions; that is to say, they represent the sayings and doings of Golias, the revelation made to him, the confession made by him, his creed, his reasons for not marrying, and so forth. The fact that Map's friend Giraldus Cambrensis denounces Golias as a foul-mouthed scoffer is rather against Map's alleged authorship, and they have probably been attributed to him in consequence of his great reputation as a wit, and a tradition that he had such a hatred of the White Monks that he exempted them from his oath as king's deputy to render even justice to all men. If these coarse and witty poems were really Map's, they are a proof of astonishing versatility, for they offer as great a contrast as possible to the high imaginative qualities, gracious tenderness, pure and lofty idealism, of his contributions to the Round Table legends. This is not the place for an exposition of the origin of these legends, but the *Quest du Saint Graal* was undoubtedly written by Map, being assigned to him in the earliest MSS. M. Paulin Paris ascribes to him also, upon grounds which commend themselves as being at least highly probable, the *Saint Graal*, and the noble prologue and the concluding parts of *Lancelot du Lac.* The effect of these contributions to the cycle was to completely transform its character, making out of it a lofty spiritual allegory, and forcing the paganism of the earlier legends into the service of the morality of the church. With such consummate skill did Map insinuate his story of the Graal into the cycle that the separate legends of Lancelot, Gawain, Percival, and Tristan seem to grow out of it; the whole luxuriant and irregular growth acquires a unity from its connexion with this root and stem. This reorganizing achievement alone, apart from the high romantic value of Map's independent additions, entitles him to a high place in literature.

The *De Nugis Curialium* and the Latin poems commonly attributed to Walter Mapes were edited by Mr Thomas Wright for the Camden Society; and the *Quest du Saint Graal*, by Mr Furnivall, for the Roxburghe Club.

MAPLE. Maples and the sycamore are species of *Acer*, suborder *Acerineæ*, order *Sapindaceæ*. The genus includes about fifty species, natives of Europe, North America, North Asia, especially the Himalayas and Japan (Benth. and Hook., *Gen. Pl.*, i. 409). Maples are for the most part trees with palmately-lobed leaves. The flowers are in corymbs or racemes,—the lowermost mostly male, the terminal bisexual. The fruit is a two-winged "samara."

The earliest known maples occur in the Miocene strata of Oeningen, where nineteen species have been discovered, —a greater number than occurs in any one district at the present day (Lyell's *El. of Geol.*, 6th ed. p. 250). A typical species appears to have been *Acer trilobatum*, Heer (*Flora Tert. Helv.*, pl. 114). This had many marked varieties, of which leaves, flowers, and fruit have all been discovered. The foliage was even attacked by a fungus, *Rhytisma induratum*, Heer, just as the sycamore is now by *R. acerinum*, which forms black spots on the leaves.

The common maple, *A. campestre*, L., is the only species indigenous to Great Britain. This and the sycamore were described by Gerard in 1597 (*Herball*, p. 1299), the latter being "a stranger to England." Many species have been introduced, especially from Japan, for ornamental purposes. The following are more especially worthy of notice.

European Species.—*Acer campestre*, L., the common maple, is common in hedgerows, but not often seen as a tree (see, however, Loudon, *Arboretum*, vol. i. p. 430). Loudon gives four varieties,—the downy-fruited, the variegated, the hill-inhabiting, and the

Austrian. It occurs in northern Europe, the Caucasus, and northern Asia. The wood is excellent fuel, and makes the best charcoal. It is compact, of a fine grain, sometimes beautifully veined, and takes a high polish. Hence it has been celebrated from antiquity for tables, &c. The wood of the roots is frequently knotted, and valuable for small objects of cabinet work. The young shoots, being flexible and tough, are employed in France as whips. *A. pseudo-Platanus*, L., the sycamore, or great maple, is a handsome tree of quick growth, with a smooth bark. The leaves are large, with finely acute and serrated lobes, affording abundant shade. Its longevity is from one hundred and forty to two hundred years. It is found in various parts of Europe in wooded mountainous situations. The wood when young is white, but old heart-wood is yellow or brownish. Like the common maple it is hard and takes a high polish. It is much prized by wheelwrights, cabinetmakers, sculptors, &c., on the Continent, while knotted roots are used for inlaying. Sugar has been obtained from the sap of this as from other species, the most being one ounce from a quart of sap. The latter has also been made into wine in the Highlands of Scotland. There are many varieties, the variegated and cut-leaved being the most noticeable (see *Gard. Chron.*, 1881, p. 229). For remarkable variations in the number of cotyledons arising from fusion, see a paper by the late Prof. J. S. Henslow in *Mag. Nat. Hist.*, vol. v. p. 346. *A. Platanoides*, L., the Norway maple (Loudon, *l.c.*, p. 408; *Gard. Chron.*, 1881, p. 564), is met with from Norway to Italy, Greece, central and south Russia. It was introduced into Britain in 1683. It is a lofty tree (from 40 to 70 feet), resembling the sycamore, but with yellow flowers, and more spreading wings to the fruit. There are several varieties. The wood is used for the same purposes as that of the sycamore. Sugar has been made from the sap in Norway and Sweden. The leaves of this species, in common with those of the sycamore especially, and perhaps all others, are liable to produce honeydew, which appears to be extravasated cell-sap. The present writer suggests that the starch formed in the leaves may be rapidly converted into sugar, which is then condensed on the surface of the leaf under excessive transpiration.

Asiatic Species.—Thirteen species are described by Hiern, chiefly in the temperate Himalayas (*Flor. of Brit. India*, p. 692; see also Brandis, *For. Fl.*, 110). The wood of some species is used, as that of *A. lævigatum*, Wall., for building; that of *A. cæsium*, Wall., being soft, inferior drinking cups are made of it; while that of *A. pictum*, Thunb., is white, light, and fine-grained.

Japanese Species.—Species, and many varieties, especially of *A. palmatum*, Thunb., generally known as *polymorphum*, with variously laciniated and more or less coloured foliage, have lately been introduced as ornamental shrubs. The original species was introduced in 1832. The branches and corolla are purple, the fruit woolly. The foliage of the typical form is bright green with very pointed lobes. It occurs in the central mountains of Nippon and near Nagasaki. Beautiful varieties have been introduced under the names *A. P. ampelopsifolium*, *atropurpureum*, *dissectum*, &c. They are remarkable for the coppery purple tint that pervades the leaves and young growths of some of the varieties (for figs., see *Catalogue of Hardy Trees*, &c., by Messrs Veitch). Of other Japanese species, *A. rufinerve*, Sieb. and Zucc., with the habit of the sycamore, from Nippon; *A. distylum*, Sieb. and Zucc., bearing leaves without lobes; *A. diabolicum*, Bl., with large plane-like leaves, from Nippon; and *A. carpinifolium*, Sieb. and Zucc., with foliage resembling that of the hornbeams, are especially worthy of note.

North American Species.—*A. saccharinum*, L., the sugar, rock, or bird's-eye maple, was introduced in 1735. It sometimes attains to 70 or even over 100 feet, more commonly 50 to 60 feet. It is remarkable for the whiteness of the bark. The wood is white, but acquires a rosy tinge after exposure to light. The grain is fine and close, and when polished has a silky lustre. The timber is used instead of oak where the latter is scarce, and is employed for axle-trees and spokes, as well as for Windsor chairs, &c. It exhibits two accidental forms in the arrangement of the fibres, an undulated one like those of the curled maple (*A. rubrum*), and one of spots which gives the name bird's-eye to the wood of this species. Like the curled maple, it is used for inlaying mahogany. It is much prized for bedsteads, writing desks, shoe lasts, &c. The wood forms excellent fuel and charcoal, while the ashes are rich in alkaline principles, furnishing a large proportion of the potash exported from Boston and New York. Sugar is principally extracted from this species, the sap being boiled and the syrup when reduced to a proper consistence run into moulds to form cakes. Trees growing in low and moist situations afford the most sap but least sugar. A cold north-west wind, with frosty nights and sunny days in alternation, tends to incite the flow, which is more abundant during the day than the night. A thawing night is said to promote the flow, and it ceases during a south-west wind and at the approach of a storm; and so sensitive are the trees to aspect and climatic variations that the flow of sap on the south and east side has been noticed to be earlier than on the north and west side of the same tree. The average quantity of sap per tree is from 12 to 24 gallons in a season. For full details of the preparation, &c., see Loudon, *l.c.*, p. 413; and *Gard. Chron.* 1878, p. 137.

A. rubrum, L., the red-flowering or scarlet maple, is a middle-sized tree, and was introduced in 1656. It is the first tree to blossom in spring in North America. The wood, like that of other species, is applicable to many purposes, as for the seats of Windsor chairs, turnery, &c. The grain in very old trees is sometimes undulated, which suggested the name of curled maple, and gives beautiful effects of light and shade on polished surfaces. The most constant use of curled maple is for the stocks of fowling pieces and rifles, as it affords toughness and strength combined with lightness and elegance. The inner bark is dusky red. On boiling, it yields a purple colour which with sulphate of iron affords a black dye. The wood is inferior to that of the preceding species in strength and as fuel. Sugar was made from the sap by the French Canadians, but the production is only half as great as that from the sugar maple (Michaux). In Britain it is cultivated as an ornamental tree, as being conspicuous for its flowers in spring, and for its red fruit and foliage in autumn. *A. macrophyllum*, Pursch., furnishes material for hats, baskets, mats, &c., from its inner bark, and the sap gives sugar. *A. circinatum*, Pursch., of California, has a fine, white, tough wood, which takes a good polish.

For description of other species of North America, see *Gard. Chron.*, 1881, index. *s.v.* "Acer"; Sargent's *Cat. of For. Trees of N. Amer.*; Loudon, *l.c.*, p. 405 *sq.*; Gray's *Manual of Bot.*, p. 84. (G. H.)

MAR, Earldom of. Mar, one of the ancient divisions or provinces of Scotland, comprised the larger portion of Aberdeenshire, extending from north of the Don southwards to the Mounth. It is remarkable for its association with the oldest historical dignity of Scotland, or perhaps of any country, which has been perpetuated to our own time. Donald MacEnun MacCainech, mormaer (hereditary ruler or steward) of Mar, fought, according to nearly contemporary testimony, at the battle of Clontarf in Ireland in 1014. Under Anglo-Saxon influences mormaers or great stewards became earls; and Ruadri, mormaer of Mar, whose name appears in the Book of Deer, is designed "Rothri comes" in a charter of Alexander I. of 1114 or 1115. His representative in the latter part of the 12th century was Gratney, earl of Mar, who married Christian Bruce, sister of King Robert, a lady famed for her defence of the chief stronghold of the earldom, Kildrummy Castle, against David of Strathbogie, earl of Athole, then (1335) in alliance with the English. Their son, Earl Donald, in his youth a captive in England, was restored to his country after Bannockburn. On the landing of Edward Balliol in 1332, and death of Thomas Randolph, earl of Moray, he was invested with the regency, and the troops hastily assembled by him to meet the invader suffered a disastrous defeat at Dupplin, the earl of Mar being himself among the slain. Earl Thomas, the regent's son, dying without issue in 1377, his successor was his sister Margaret, countess of Douglas by marriage. From her the earldom of Mar passed to her daughter, Isabel Douglas, countess of Mar, whose second marriage forms a notable episode in Scottish history. Alexander Stewart, natural son of Alexander, earl of Buchan, and, according to common belief, the instigator of a murderous attack on that lady's first husband, stormed the widowed countess of Mar in Kildrummy Castle in 1404, compelled her to marry him, and extorted from her a charter which, had the king been prevailed on to confirm it, would have made over the earldom to him and his heirs, in exclusion of the heirs of his wife. But, weak as was the law north of the Mounth in the reign of Robert III., this outrage was too flagrant to be condoned. The indispensable confirmation was refused by the king; but a compromise was effected, by which Isabel voluntarily accepted Stewart as her husband, and, by a charter which Robert duly confirmed, gave him a right to the earldom for life, with remainder, however, to her own heirs. *Qua* earl of Mar, the quondam leader of freebooters became a supporter of law and order; and in 1411, when Donald, lord of the Isles, was leading his marauding host southwards, it was under Alexander, earl of Mar, that the lowland gentry and the burghers of Aberdeen mustered to oppose his advances. The sanguinary battle of Harlaw arrested the progress of the highlanders, and left Mar master of the field.

Earl Alexander died in 1435, when the right to the earldom passed to Isabel's nearest heir, Robert Lord Erskine (descended from a daughter of Earl Gratney), who established his right by retour in 1438, and became earl of Mar. The crown, however, had seized on the valuable territories of the earldom, of which he could only obtain partial possession; and James II. and his advisers, after temporizing for a length of time, in 1457 reduced Earl Robert's retour by a collusive "service negative," based on the plea that, either by the bastardy of Alexander or in virtue of a resignation by him to James I., the earldom had lapsed to the crown, two *ex facie* worthless pretexts, inasmuch as Alexander had only been a liferenter. The wrongful possession of the crown lasted more than a century, in the course of which time the earldom was twice temporarily in possession of younger members of the royal house, and portions of it were given away to favourites; while its lawful owners, the Erskines, continued loyally to serve the sovereigns who had usurped their inheritance.

At length, on 23d May 1565, Queen Mary, made aware of the wrongs inflicted by her predecessors, and "moved by conscience" to make the fullest reparation, granted to John Lord Erskine a charter restoring the earldom of which he and his ancestors had been unjustly deprived. The earl of Mar, thus replaced in his rights, was regent of Scotland during the last two years of his life; and his son, who succeeded him in 1572, and was treasurer to James VI., recovered by process of law those portions of his inheritance which had been alienated by the crown during the period of illegal possession. In the next two generations the attachment of the family to the Stewarts brought with it fines and impaired fortunes. John, earl of Mar, fourth in descent from the treasurer, headed the rebellion of 1715, and suffered attainder, but escaped abroad and survived till 1732. His daughter Lady Frances (who married an Erskine, the younger son of her uncle, Lord Grange) would, but for the attainder, have inherited his title; and what remained of the lands was preserved to her by arrangement with the commissioners of forfeited estates. In 1824 her son, John Francis Erskine of Mar, was, as "grandson and lineal heir" of the attainted earl, restored by Act of Parliament from the effects of the forfeiture.

At the death in 1866 of John Francis Miller Erskine, earl of Mar, grandson of the restored earl, there seemed no room for doubt that the earldom devolved, in accordance with the rule of succession which it had always followed, on his sister's son John Francis Erskine Goodeve, in preference to his cousin and heir male, the earl of Kellie. The latter, however, claimed, not indeed the ancient dignity, but a separate titular earldom, supposed to have been bestowed by Queen Mary, not by her charter above alluded to, but by a lost and till then unheard-of patent a few weeks later in date, and with a different remainder, namely, to heirs male of the body. The resolution of the committee of privileges of the House of Lords in 1875, finding Lord Kellie entitled to the earldom thus claimed by him, has caused great surprise; and Scotch lawyers generally, while disbelieving as a question of fact in this creation of 1565, seem also to hold in point of law that the resolution alluded to leaves untouched the right of the heir general to the ancient historical honour. The same view has been expressed by way of protest by a large number of the Scottish peers, and enforced by the late earl of Crawford in his ably written posthumous work *The Earldom of Mar in Sunshine and Shade.*

MARABOUT is a corruption of the Arabic *Morábit*, a Moslem name for a hermit or a devotee. Primarily the word is derived from *ribát*, a fortified frontier station. To such stations pious men betook them to win religious merit in war against the infidel; their leisure was spent in devotion, and the habits of the convent superseded those of the camp (see De Slane in *Jour. As.*, 1842, i. 168; Dozy, *Suppl.*, i. 502). Thus *ribát* came to mean a religious house or hospice (*záwiya*). The great sphere of the marabouts is North Africa. There it was that the community formed by King Yaḥya and the doctor Abdalla developed into the conquering empire of the Morábiṭs, or, as Christian writers call them, the ALMORAVIDES (*q.v.*), and there still, among the Berbers, the marabouts enjoy extraordinary influence, being esteemed as living saints and mediators. They are liberally supported by alms, direct all popular assemblies, and have a decisive voice in intertribal quarrels and all matters of consequence. On their death their sanctity is transferred to their tombs, where chapels are erected and gifts and prayers offered. The prominent part which the marabouts took in the resistance offered to the French by the Algerian Moslems is well known; and they have been similarly active in recent politico-religious movements in Tunis and Tripoli.

MARACAIBO, a city and seaport of Venezuela, the capital of the state of Zulia (formerly Maracaibo), lies about 25 miles from the sea on the west bank of Lake Maracaibo, the suburbs presenting, with their cocoa-nut groves, a fine contrast to the background of barren-looking hills sloping up from the shore to a height of about 200 feet. The streets are laid out at right angles; the houses are poor structures of a crude concrete or rubble, strengthened by wooden beams; and even the public buildings—such as the churches, the government house, the court-house, and the theatre—owe their pretentious appearance to plaster and paint. The water of the lake being brackish, and the sinking of Artesian wells as yet in the experimental stage, Maracaibo is dependent on the rains for its drinking water. The markets are well supplied with provisions (especially game), and the lower classes, with whom the plantain forms the staff of life, are able to subsist in a state of comparative idleness. The prosperity of the place is due to the fact that it forms the outlet for the produce of a wide region; and if the bar at the mouth of the lake, preventing the entrance of vessels drawing more than 10 or 11 feet, were removed Maracaibo would bid fair to become the chief mercantile centre of the north coast of South America. Coffee, not of prime quality, cocoa, and hides are the principal exports at present, $4,029,852 out of the $4,188,617 at which the whole exports were valued in 1880 being drawn from those items. Steamers ascend the Catatumbo as far as San Buenaventura and Villarnizar and the Escalente to Santa Cruz, thus tapping the border provinces of both Venezuela and Colombia. Bricks and tiles, leather and admirable saddlery, cocoa-nut oil, sugar, rum, and chocolate are manufactured in the town. Though the Jesuit College, which formerly made Maracaibo one of the few real seats of learning in this part of the world, no longer exists, means of education are fairly abundant (a national college, a nautical school, &c.); and, although they devote themselves mainly to political agitation, the upper classes are not without culture. Maracaibo was founded by Alonso Pacheco in 1571. The population, returned in 1873 as 21,954, is estimated at 30,000 in 1881.

See Engel, "Maracaibo," in *Zeit. d. Ges. Erdk.*, Berlin, 1870; and *U. S. Consular Reports*, 1882.

MARÁGHA, a town of Persia, province Azerbijan, 37° 20′ N., 46° 25′ E., 68 miles from Tabríz, 232 north-west of Tehrán, pleasantly situated in a long narrow valley opening towards Lake Urmiah, which lies 10 miles to the north-west. The town consists mostly of mud houses enclosed by a high dilapidated wall, and containing no conspicuous buildings except a large bazaar and fine public bath. Náṣir-ed-dín's observatory formerly stood on a hill to the west, where there are some old tombs covered with Cufic inscriptions. The surrounding gardens and plantations are watered by canals from a small river crossed here by two good bridges built in 1809. At the village of Dash-Kesen, 6 miles from Deh Kurgán in this district, are the famous Marágha marble pits, occupying a space half a mile in circumference, and sunk to a depth of about 12 feet. Here a multitude of springs charged with carbonic acid gas bubble up in all directions, precipitating large quantities of carbonate of lime. The marble in the semi-crystallized formation of this deposit forms horizontal layers, which when cut in thin slabs are nearly transparent, and serve as windows in the Tabríz baths and elsewhere. Larger blocks are also used as pavements in bazaars and palaces, and the famous throne in the Díwán Khána at Tehrán is made of the same material. Marágha was formerly the capital of Húlakú, grandson of Jenghis Khán, and its fifteen thousand inhabitants still belong mostly to the Mukadam Turki tribe.

MARANHÃO, or Maranham (Latinized as *Maragnanum*), in full form Sao Luiz de Maranhão, the chief town of the province of Maranhão in Brazil, is situated in 2° 30′ S. lat. and 44° 17′ W. long., on the west side of an island of the same name 28 miles long and 15 broad. Though built on so hilly a surface that carriages cannot be used, it is laid out with regularity, and has straight, wide, and clean-looking streets. The public institutions comprise a naval arsenal, a high court of appeal, a tribunal of commerce, a military hospital, several general hospitals, a theatre, a museum, a public library, and a botanic garden, as well as a cathedral and an episcopal palace, both built by the Jesuits. Maranhão has some commercial importance, exporting cotton, sugar, hides, &c., from a wide region of the interior, and receiving manufactured goods from Europe, and especially from England. Though somewhat difficult of access to large sailing vessels, the port affords good anchorage to all drawing less than 20 feet. Steamers ply to Rio de Janeiro and Pará, as well as up the rivers Itapicuru, Guajahu, and Pindare; and direct steam communication is maintained with Lisbon and Liverpool. The population of the island Maranhão was 34,023 in 1872, about 30,000 belonging to the city.

French colonists settled at St Luiz in 1612, but they were expelled by Jeronimo d'Albuquerque in 1614. The Dutch were in possession from 1641 to 1653. The bishopric was created in 1676. The city was captured in 1823 by Lord Cochrane, who was afterwards created marquis of Maranham.

MARAT, Jean Paul (1743–1793), a famous revolutionary leader, was the eldest child of Jean Paul Mara of Cagliari and Louise Cabrol of Geneva, and was born at Boudry, in the principality of Neuchâtel, on May 24, 1743. His father was a doctor of some learning, who had abandoned his country and his religion, and had married a Swiss Protestant. It was he that laid the basis of the young Jean Paul's scientific learning, and the son at the same time imbibed the doctrines of Rousseau. On his mother's death in 1759 he set out on his travels, and spent two years at Bordeaux in the study of medicine, whence he moved to Paris, where he made use of his knowledge of his two favourite sciences, optics and electricity, to subdue an obstinate disease of the eyes. After some years in Paris he went to Holland, the retreat of philosophers, where all the works of the Encyclopédists were printed for the French market, and then on to London, where he settled in Church Street, Soho, a fashionable district, and practised his profession. In 1773, at the age of thirty, he made his first appearance as an author with a *Philosophical Essay on Man, being an Attempt to Investigate the Principles and Laws of the Reciprocal Influence of the Soul on the Body*, of which only two volumes are extant, though at the end of the second volume he speaks of a third. The book shows a wonderful knowledge of English, French, German, Italian, and Spanish philosophers, and directly attacks Helvetius, who had in his *L'Esprit* declared a knowledge of science unnecessary for a philosopher. Marat, as he now began to call himself, declares that physiology alone can solve the problems of the connexion between soul and body, and proposes the existence of a nervous fluid as the true solution. In 1774 he published a political work, *The Chains of Slavery*, which appeared without his name, and was intended to influence constituencies to return popular members, and reject the king's friends, with innumerable examples from classical and modern history of the ways in which kings enslaved their peoples. The book was too late to have any influence on the general election, and was got up in a style too costly for a wide circulation, but its author declared later that it procured him an honorary membership of the patriotic societies of Carlisle, Berwick, and Newcastle. He remained devoted to his profession, and in 1775 published in London a little *Essay on Gleets*, price 1s. 6d., of which no copy is to be found, and in Amsterdam a French translation of the first two volumes of his *Essay on Man*. In this year, 1775, he visited Edinburgh, and on the recommendation of certain Edinburgh physicians, was, on June 30, made an M.D. of St Andrews University. On his return to London he published an *Enquiry into the Nature, Cause, and Cure of a Singular Disease of the Eyes*, with a dedication to the Royal Society. In the same year there appeared the third volume of the French edition of the *Essay on Man*, which reached Ferney, and exasperated Voltaire, by its onslaught on Helvetius, into a sharp attack, that only made the young author more conspicuous. His fame as a clever doctor was now great, and on June 24, 1777, the Comte d'Artois, afterwards Charles X. of France, "owing to the report he had heard of the good and moral life, and of the knowledge and experience in the art of medicine, of J. P. Marat," made him by brevet physician to his guards, with 2000 livres a year and allowances.

Marat was soon in great request as a court doctor among the aristocracy; and even Brissot, in his *Mémoires*, admits his influence in the scientific world of Paris. The next years were much occupied with scientific work, especially the study of heat, light, and electricity, on which he presented memoirs to the Académie des Sciences, but the Academicians were horrified at his temerity in differing from Newton, and, though acknowledging his industry, would not receive him among them. His experiments greatly interested Benjamin Franklin, who used to visit him; and Goethe always regarded his rejection by the Academy as a glaring instance of scientific despotism. In 1780 he had published at Neuchâtel without his name a *Plan de Législation Criminelle*, founded on the humane principles established by Beccaria. In April 1786 he resigned his court appointment. The results of his leisure were in 1787 a new translation of Newton's *Optics*, and in 1788 his *Mémoires Académiques, ou Nouvelles Découvertes sur la Lumière*.

His scientific life was now over, his political life was to begin; in the notoriety of that political life his great scientific and philosophical knowledge was to be forgotten, the high position he had given up denied, and he himself to be scoffed at as an ignorant charlatan, who had sold quack medicines about the streets of Paris, and been glad to earn a few sous in the stables of the Comte d'Artois. In 1788 the notables had met, and advised the assembling of the states-general. The elections were the cause of a flood of pamphlets, of which one, *Offrande à la Patrie*, was by Marat, and, though now forgotten, dwelt on much the same points as the famous brochure of the Abbé Siéyès. When the states-general met, Marat's interest was as great as ever, and in June 1789 he published a supplement to his *Offrande*, followed in July by *La Constitution*, in which he embodies his idea of a constitution for France, and in September by his *Tableau des Vices de la Constitution d'Angleterre*, which he presented to the assembly. The latter alone deserves remark. The assembly was at this time full of Anglomaniacs, who desired to establish in France a constitution exactly similar to that of England. Marat, who had lived in England, had seen that England was at this time being ruled by an oligarchy using the forms of liberty, which, while pretending to represent the country, was really being gradually mastered by the royal power. His heart was now all in politics; and, feeling that his energies needed a larger scope than occasional tracts afforded, he decided to start a paper. At first appeared a single number of the *Moniteur patriote*, followed on September 12 by the first number of the *Publiciste parisien*, which on September 16 took the title of *L'Ami du Peuple*, and was to absorb his future life.

The life of Marat now becomes part of the history of the French Revolution. From the beginning to the end he stood alone. He was never attached to any party; the tone of his mind was to suspect whoever was in power; and therefore no historian has tried to defend him, and all state the facts about him with a strong colouring. About his paper, the incarnation of himself, the first thing to be said is that the man always meant what he said; no poverty, no misery or persecution, could keep him quiet; he was perpetually crying—"nous sommes trahis."

Further, the suspicious tone of his mind extended to his paper, and he made it play the part of the lion's mouth at Venice: whoever suspected any one had only to denounce him to the *Ami du Peuple*, and the denounced was never let alone till he was proved innocent or guilty. He began by attacking the most powerful bodies in Paris,—the corps municipal, with Bailly at their head, and the court of the Châtelet,—and after a struggle found them too strong for him, and fled to London (January 1790). There he wrote his *Denonciation contre Necker*, and in May dared to return to Paris and continue the *Ami du Peuple*. He was embittered by persecution, and continued his vehement attacks against all in power—against Bailly, against La Fayette, and at last, after the day of the Champs du Mars, against the king himself. All this time he was hiding in cellars and sewers, where he was attacked by a horrible skin disease, tended only by the woman Simonne Evrard, who remained true to him. The end of the constituent assembly he heard of with joy, and with bright hopes (soon dashed by the behaviour of the legislative) for the future, when almost despairing in December 1791 he fled once more to London, where he wrote his *École du Citoyen*. In April 1792, summoned again by the Cordeliers, he returned to Paris, and published No. 627 of the *Ami*. The war was now the question, and Marat saw clearly enough that it was not sought for the sake of France, that it was to serve the purposes of the royalists and the Girondins, who thought of themselves alone. The early days of the war being unsuccessful, the proclamation of the duke of Brunswick excited all hearts; who could go to save France on the frontiers and leave Paris in the hands of his enemies? Marat, like Danton, foresaw the massacres of September. After the events of August 10th he took his seat at the commune, and demanded a tribunal to try the royalists in prison. No tribunal was formed, and the massacres in the prisons were the inevitable result. In the elections to the convention, Marat was elected seventh out of the twenty-four deputies for Paris, and for the first time took his seat in an assembly of the nation. At the declaration of the republic, he closed his *Ami du Peuple*, and commenced a new paper, the *Journal de la République Française*, which was to contain his sentiments as its predecessor had done, and to be always on the watch. In the assembly Marat had no party; he would always suspect and oppose the powerful, refuse power for himself. After the battle of Valmy, Dumouriez was the greatest man in France; he could almost have restored the monarchy, yet Marat did not fear to go uninvited to the tragedian Talma's, and there accuse Dumouriez in the presence of his friends of want of patriotism. His unpopularity in the assembly was extreme, yet he insisted on speaking on the question of the king's trial, declared it unfair to accuse Louis for anything anterior to his acceptance of the constitution, and, though implacable towards the king, as *the* one man who must die for the people's good, he would not allow Malesherbes, the king's counsel, to be attacked in his paper, and speaks of him as a "sage et respectable vieillard." The king dead, the months from January to May were spent in an unrelenting struggle between Marat and the Girondins. Marat despised the ruling party because they had suffered nothing for the republic, because they talked too much of their feelings and their antique virtue, because they had for their own purposes plunged the country into war; while the Girondins hated Marat as representative of that rough red republicanism which would not yield itself to a Roman republic, with themselves for tribunes, orators, and generals. The Girondins conquered at first in the convention, and ordered that Marat should be tried before the Tribunal Revolutionnaire. But their victory ruined them, for Marat was acquitted on April 24, and returned to the convention with the people at his back. Their fall was a veritable victory for Marat. But it was his last. The skin disease he had contracted in the subterranean haunts was rapidly closing his life; he could only ease his pain by sitting in a warm bath, where he wrote his journal, and accused the Girondins, who were trying to raise France against Paris. Sitting thus on the 13th July he heard in the evening a young woman begging to be admitted to see him, saying that she brought news from Caen, where the escaped Girondins were trying to rouse Normandy. He ordered her to be admitted, asked her the names of the deputies then at Caen, and, after writing their names, said, "They shall be soon guillotined," when the young girl, whose name was Charlotte Corday, stabbed him to the heart. Grand was the funeral given to the man who had suffered so much for the republic. Whatever his political ideas, two things shine clearly out of the mass of prejudice which has shrouded the name of Marat—that he was a man of great attainments and acknowledged position, who sacrificed fortune, health, life itself, to his convictions, and that he was no *bête feroce*, no factious demagogue, but a man, and a humane man too, who could not keep his head cool in stirring times, who was rendered suspicious by constant persecution, and who has been regarded as a personification of murder, because he published every thought in his mind, while others only vented their anger and displayed their suspicions in spoken words.

The only works of Marat not mentioned in the text are *Les aventures du Comte Potowski*, a poor novel, which must have been written in his early days, and which was discovered in MS. and published by Bibliophile Jacob; two brochures on a balloon accident, 1785; *Les Charlatans Modernes, ou Lettres sur le Charlatanisme académique*, 1791; *Le Junius Français, journal politique*, June 2 to June 24, 1790; translation of *Chains of Slavery*, with fifty pages on French history prefixed, year 1.

On Marat's life should be read *L'ami du peuple, Skizzen aus Marat's journalistichen Leben*, Hamburg, 1846; A. Bougeart, *Marat, l'ami du peuple*, 2 vols., 1864; G. Piazzoli, *Marat, l'amico del Popolo e la Rivoluzione*, Milan, 1874; A. Vermorel, *Œuvres de J. P. Marat, l'ami du peuple, recueillies et annotées*, 1869; F. Chevremont, *Marat, Index du Bibliophile*, &c., 1876; Id., *Placards de Marat*, 1877; and particularly his *Jean Paul Marat, esprit politique, accompagné de sa vie scientifique, politique, et privée*, 2 vols., 1881.

(H. M. S.)

MARATHON was a plain on the north-east coast of Attica, containing four villages—Marathon, Probalinthos, Tricorythos, and Oinoe, which formed a tetrapolis. It was divided from the plain of Athens by Mount Pentelicus and the hilly district of Diacria, and was in the early period an autonomous state. After it became incorporated in the Attic state, it retained something of its original distinctive character. The worship of Apollo had its first home in Attica here, and it was carried hence to Athens when the tetrapolis was made part of the Athenian commonwealth. The district was one of the chief seats of the worship of Hercules, and boasted that it was the first place where he had been worshipped as a god. Hence legend localized here several events in the story of the Heraclidæ, and especially the self-sacrifice of Macaria, daughter of Hercules. The legend of Theseus was also known in the district; here the hero slew the Marathonian bull. The plain derived its fame chiefly from the battle in which the Athenians and Platæans under Miltiades defeated the Persians, 490 B.C. The one hundred and ninety-two Athenians that were slain were buried on the field of battle, contrary to the usual Attic custom, and a mound, which is still called Soro, was erected over them. Another tumulus covered the bodies of the slain Platæans and slaves, and a special monument was raised to Miltiades.

MARBLE is a term applied to any limestone which is sufficiently close in texture to admit of being polished. Many other ornamental stones—such as serpentine, alabaster, and even granite—are sometimes loosely designated as marbles, but by accurate writers the term is invariably restricted to those crystalline and compact varieties of carbonate of lime which, when polished, are applicable to purposes of decoration. The crystalline structure is typically shown in statuary marble. A fractured surface of this stone displays a multitude of sparkling facets, which are the rhombohedral cleavage-planes of the component grains. On placing a thin section of Carrara marble under the microscope, it is seen that each grain is an imperfect crystal, or crystalloid, of calc-spar, having an irregular boundary, and being itself made up of a number of crystalline plates twinned together (see fig. 5, article GEOLOGY, vol. x. p. 231). It is said that a somewhat similar polysynthetic structure may be artificially induced in calc-spar by means of pressure. As marble appears to be, in many cases, a metamorphic rock, it is probable that pressure and heat have been the principal natural agents concerned in the alteration of compact into crystalline limestones. It was shown many years ago by Sir James Hall that even an earthy limestone, like chalk, when strongly heated in a closed vessel, might assume a saccharoidal texture; and it is a fact familiar to the field-geologist that a crystalline structure is often locally developed in limestone where it happens to have been invaded by an eruptive rock. Prof. Geikie proposes to distinguish this kind of metamorphism by the term *marmarosis* (*Text-Book of Geology*, 1882).

Among statuary marbles the first place may be assigned to the famous Pentelic marble, the material in which Phidias, Praxiteles, and other Greek sculptors executed their principal works. The characteristics of this stone are well seen in the Elgin marbles, which were removed from the Parthenon at Athens, and are now in the British Museum. The marble was derived from the quarries of Mount Pentelicus in Attica. The neighbouring mountain of Hymettus likewise yielded marbles, but these were neither so pure in colour nor so fine in texture as those of Pentelicus. Parian marble, another stone much used by Greek sculptors and architects, was quarried in the isle of Paros, chiefly at Mount Marpessa. It is called by ancient writers *lychnites*, in allusion to the fact that the quarries were worked by the light of lamps. The Venus de' Medici is a notable example of work in this material. Carrara marble is better known than any of the Greek marbles, inasmuch as it constitutes the stone invariably employed by the best sculptors of the present day. This marble occurs abundantly in the Apuan Alps, an offshoot of the Apennines, and is largely worked in the neighbourhood of Carrara, Massa, and Serravezza. Stone from this district was employed in Rome for architectural purposes in the time of Augustus, but the finer varieties, adapted to the needs of the sculptor, were not discovered until some time later. It is in Carrara marble that the finest works of Michelangelo and of Canova are executed. The purest varieties of this stone are of snow-white colour and of fine saccharoidal texture. Silica is disseminated through some of the marble, becoming a source of annoyance to the workman; while occasionally it separates as beautifully pellucid crystals of quartz known as Carrara diamonds. The geological age of the marbles of the Apuan Alps has been a subject of much dispute, some geologists regarding them as metamorphosed Triassic or even Liassic rocks, while others are disposed to refer them to the Carboniferous system. Much of the common marble is of a bluish colour, and therefore unfit for statuary purposes; when streaked with blue and grey veins, the stone is known as *bardiglio*. Curiously enough, the common white marble of Tuscany comes to England as Sicilian marble—a name probably due to its having been formerly re-shipped from some port in Sicily.

Although crystalline marbles fit for statuary work are not found to any extent in Great Britain, the limestones of the Palæozoic formations yet yield a great variety of marbles well suited for architectural purposes. The Devonian rocks of South Devon are rich in handsome marbles, presenting great diversity of tint and pattern. Plymouth, Torquay, Ipplepen, Babbacombe, and Chudleigh may be named as the principal localities. Many of these limestones owe their beauty to the fossil corals which they contain, and are hence known as madrepore marbles.

Of far greater importance than the marbles of the Devonian system are those of Carboniferous age. It is from the Carboniferous or Mountain Limestone that British marbles are mainly derived. Marbles of this age are worked in Derbyshire and Yorkshire, in the neighbourhood of Bristol, in North Wales, in the Isle of Man, and in various parts of Ireland. One of the most beautiful of these stones is the encrinital marble, a material which owes its peculiarities to the presence of numerous encrinites, or stone-lilies. These fossils, when cut in various directions, give a characteristic pattern to the stone. The joints of the stems and arms are known from their shape as "wheel-stones," and the rock itself is sometimes called entrochal marble. The most beautiful varieties are those in which the calcareous fossils appear as white markings on a ground of grey limestone. On the Continent a black marble with small sections of crinoid stems is known as *petit granit*, while in Derbyshire a similar rock, crowded with fragments of minute encrinites, is termed bird's-eye marble.

Perhaps the most generally useful marbles yielded by the Carboniferous system are the black varieties, which are largely employed for chimney-pieces, vases, and other ornamental objects. The colour of most black limestone is due to the presence of bituminous matter, whence the mineralogical name anthraconite. Such limestone commonly emits a fetid odour when struck; and the colour, being of organic origin, is discharged on calcination. Black marbles, more or less dense in colour, are quarried in various parts of Ireland, especially at Kilkenny and near Galway; but the finest kind is obtained from near Ashford in Derbyshire. From Ashford is also derived a very beautiful stone known as rosewood marble. This is a dense brown laminated limestone, displaying when polished a handsome pattern somewhat resembling the grain of rosewood; it occurs in very limited quantity, and is used chiefly for inlaid work.

With the rosewood marble may be compared the well-known landscape marble or Cotham stone, an argillaceous limestone with peculiar dendritic markings, due probably to the infiltration of water containing oxide of manganese. This limestone occurs in irregular masses near the base of the White Lias, or uppermost division of the Rhætic series. It is found principally in the neighbourhood of Bristol. The arborescent forms depicted in bluish-grey upon this landscape marble form a marked contrast to the angular markings of warm brown colour which are seen on slabs of ruin marble from Florence—a stone occasionally known also as landscape stone, or *pietra paesina*.

British limestones of Secondary and Tertiary age are not generally compact enough to be used as marbles, but some of the shelly beds are employed to a limited extent for decorative purposes. Ammonite marble is a dark brown limestone from the Lower Lias of Somersetshire, crowded with ammonites, principally *A. planicostata*. Under the name of Forest marble, geologists recognize a local division of the Lower Oolitic series, so named by W. Smith from Wychwood Forest in Oxfordshire, where shelly limestones occur; and these, though of little economic value, are capable of being used as rough marbles. But the most important marbles of the Secondary series are the shelly limestones of the Purbeck formation. Purbeck marble was a favourite material with mediæval architects, who used it freely for slender clustered columns and for sepulchral monuments. It consists of a mass of the shells of a fresh-water snail, *Paludina carinifera*, embedded in a blue or grey limestone, and is found in the Upper Purbeck beds of Swanage in Dorsetshire. Excellent examples of its use may be seen in Westminster Abbey and in the Temple Church, as well as in the cathedrals of Salisbury, Winchester, Worcester, and Lincoln. Sussex marble is a very similar stone, occurring in thin beds in the Weald clay, and consisting largely of the shells of *Paludina*, principally *P. sussexiensis* and *P. fluviorum*. The altar stones and the episcopal chair in Canterbury cathedral are of this material.

Mixtures of limestone and serpentine frequently form rocks which are sufficiently beautiful to be used as ornamental stones, and are generally classed as marbles. Such serpentinous limestones are included by petrologists under the term ophicalcite. The famous *verde antico* is a rock of this character. Mona marble is an ophicalcite from the metamorphic series of the Isle of Anglesey, while the "Irish green" of architects is a similar rock from Connemara in western Galway. It is notable that some of the "white marble" of Connemara has been found by Messrs King and Rowney to consist almost wholly of malacolite, a silicate of calcium and magnesium.

A beautiful marble has been worked to a limited extent in the island of Tiree, one of the Hebrides, but the quarry appears to be now exhausted. This Tiree marble is a limestone having a delicate carnelian colour diffused through it in irregular patches, and containing rounded crystalloids of sahlite, a green augitic mineral resembling malacolite in composition. When dissolved in acid the marble leaves a brick-red powder, which has been studied by Dr Heddle, who has also analysed the sahlite.

Many marbles which are prized for the variegated patterns they display owe these patterns to their formation in concentric zones,—such marbles being in fact stalagmitic deposits of carbonate of lime, and probably consisting in many cases of aragonite. One of the most beautiful stalagmitic rocks is the so-called onyx marble of Algeria. This stone was largely used in the buildings of Carthage and Rome, but the quarries which yielded it were not known to modern sculptors until 1849, when M. Delamonte rediscovered the marble near Oued-Abdallah. The stone is a beautifully translucent material, delicately clouded with yellow and brown, and is greatly prized by French workmen. Large deposits of a very fine onyx-like marble, similar to the Algerian stone, have been worked of late years at Técali, about 35 miles from the city of Mexico. Among other stalagmitic marbles, mention may be made of the well-known Gibraltar stone, which is often worked into models of cannon and other ornamental objects. This stalagmite is much deeper in colour and less translucent than the onyx marbles of Algeria and Mexico. A richly tinted stalagmitic stone worked in California is known as Californian marble. It is worth noting that the "alabaster" of the ancients was stalagmitic carbonate of lime, and that this stone is therefore called by mineralogists "Oriental alabaster" in order to distinguish it from our modern "alabaster," which is a sulphate, and not a carbonate, of lime.

The brown and yellow colours which stalagmitic marbles usually present are due to the presence of oxide of iron. This colouring matter gives special characters to certain stones, such as the *giallo antico*, or antique yellow marble of the Italian antiquaries. Siena marble is a reddish mottled stone obtained from the neighbourhood of Siena in Tuscany; and a somewhat similar stone is found in King's County, Ireland. True red marble is by no means common, but it does occur, of bright and uniform colour, though in very small quantity, in the Carboniferous limestone of Derbyshire and north-east Staffordshire. It may be noted that the red marble called *rosso antico* is often confounded with the *porfido rosso antico*, which is really a red porphyritic felstone.

Fire marble is the name given to a brown shelly limestone containing ammonites and other fossil shells, which present a brilliant display of iridescent colours, like those of precious opal. It occurs in rocks of Liassic age at the lead-mines of Bleiberg in Carinthia, and is worked into snuff-boxes and other small objects. By mineralogists it is often termed *lumachella*, an Italian name which may, however, be appropriately applied to any marble which contains small shells.

It would unnecessarily extend this article to enumerate the local names by which marble-workers in different countries distinguish the various stones which pass under their hands. The quarries of France, Belgium, and Italy, not to mention less important localities, yield a great diversity of marbles, and almost each stone bears a distinctive name, often of trivial meaning.

America possesses some valuable deposits of marble, which in the eastern States have been extensively worked. The crystalline limestones of western New England furnish an abundance of white and grey marble, while a beautiful material fit for statuary work has been quarried near Rutland in Vermont. A grey bird's-eye marble is obtained from central New York, and the greyish clouded limestones of Thomaston in Maine have been extensively quarried. Of the variegated and coloured marbles, perhaps the most beautiful are those from the northern part of Vermont, in the neighbourhood of Lake Champlain. A fine brecciated marble is found on the Maryland side of the Potomac, below Point of Rocks. Among the principal localities for black marble may be mentioned Shoreham in Vermont and Glen Falls in New York. In Canada the crystalline limestones of the Laurentian series yield beautiful marbles.

Turning to India, we find important quarries at Makrana in Rajputana—a locality which is said to have yielded the marble for the famous Taj Mahal at Agra. In the valley of the Nerbudda, near Jabalpur, there is a large development of marble. The white marble which is used for the delicately-pierced screens called *jalee* work is obtained from near Raialo, in Ulwar. See Ball's *Economic Geology of India*, 1882.

For descriptions of ancient marbles see F. Corsi's treatise *Delle Pietre antiche*; and for marbles in general consult Professor Hull's *Building and Ornamental Stones*, 1872. (F. W. R.*)

MARBLEHEAD, a town and port of entry of the United States, in Essex county, Massachusetts, situated on the coast, 17 miles by rail north-east of Boston, and 4 miles south-east of Salem, and communicates by two branch lines with the main line of the Eastern Railway. It is built on a rocky peninsula of about 3700 acres in extent, which juts out into Massachusetts Bay, and has a deep, roomy, and nearly land-locked harbour. The fisheries in which Marblehead was once largely engaged have declined; but shoemaking has become an important industry, and the town is rising into favour as a summer resort. Many of the houses date from the "colonial" period, and one of the churches was built in 1714, but in the summer of 1877 nearly the whole business part of the town was burnt to the ground. The population was 7703 in 1870, and 7467 in 1880.

Marblehead was incorporated in 1649. Of the original settlers, a considerable number were from the Channel Islands, and their peculiarities of speech continued for a long time to affect the local dialect. As at that period the second town of Massachusetts in wealth and size, Marblehead sent one thousand men to the War of Independence, and its privateers rendered excellent service; but its trading prosperity never recovered from the effects of the contest. Elbridge Gerry, vice-president of the United States in 1812, was born at Marblehead; and the town is the scene of the grim revenge celebrated, with considerable poetical licence, in Whittier's *Skipper Ireson's Ride*.

MARBURG, an ancient university town of Prussia, in the province of Hesse-Nassau and district of Cassel, is very picturesquely situated on the slope of a hill on the right bank of the Lahn, 50 miles to the north of Frankfort-on-the-Main, and about the same distance to the south-west of Cassel. On the opposite bank of the river, which is here spanned by two bridges, lie the suburb of Weidenhausen and the station of the Main-Weser Railway. The streets of the town proper are steep and narrow, and the general character of the architecture is quaint and mediæval. The hill on which the town lies is crowned by the extensive old schloss, a fine Gothic building, the most noteworthy parts of which are the rittersaal (see below), dating from 1277–1320, and the beautiful little chapel. This chateau was formerly the residence of the landgraves of Hesse, afterwards served as a prison, and is now the repository of the historically interesting and valuable archives of Hesse. The chief architectural ornament of Marburg is, however, the Elisabethenkirche, a veritable gem of the purest Early Gothic style, erected by the grand master of the Teutonic Order in 1235–83, to contain the tomb of St Elizabeth of Hungary. The remains of the saint were deposited in a rich silver-gilt sarcophagus, which is still extant, and were afterwards visited by myriads of pilgrims, until the Protestant zeal of Landgrave Philip the Generous caused him to remove the body to some unknown spot in the church. The church also contains the tombs of numerous Hessian landgraves and knights of the Teutonic Order. The Lutheran church is another good Gothic edifice, dating mainly from the 15th century. The town-house, built in 1512, and several fine houses in the Renaissance style, also deserve mention. The university of Marburg, founded by Philip the Generous in 1527, was the first university established without papal privileges, and speedily acquired a great reputation throughout Protestant Europe. It has a library of 140,000 volumes, and is admirably equipped with medical and other institutes, which form some of the finest modern buildings in the town. The number of students is now about seven hundred. Marburg also possesses a gymnasium, a "realschule," an agricultural school, a society of naturalists, a hospital, a poorhouse, and an extensive lunatic asylum. It is the seat of a district court, and of superintendents of the Lutheran and Reformed churches. Marburg pottery is renowned; and leather, iron wares, and surgical instruments are also manufactured there. The population in 1880 amounted to 11,225. The environs are very picturesque.

Marburg is first historically mentioned in a document of the beginning of the 13th century, and received its municipal charter from Landgrave Louis of Thuringia in 1227. On his death it became the residence of his wife, Elizabeth of Hungary, who built a hospital there and died in 1231, at the age of twenty-four, worn out with works of religion and charity. She was canonized soon after her death. By 1247 Marburg had already become the second town of Hesse, and in the 15th and 16th centuries it alternated with Cassel as the seat of the landgraves. In 1529 the famous conference between Luther and Zwingli on the subject of transubstantiation took place there in the rittersaal of the schloss. During the Thirty Years' and Seven Years' Wars Marburg suffered considerably from sieges and famine. In 1806, and again in 1810, it was the centre of an abortive rising against the French, in consequence of which the fortifications of the castle were destroyed.

Several monographs have been published on the conference and university of Marburg. A general account of the town, with references to the most important of these, is given in Bücking's *Wegweiser durch Marburg*, 1875.

MARBURG, the second town of the Austrian duchy of Styria, is very picturesquely situated on both banks of the river Drave, in a plain called the Pettauer-Feld, at the base of the well-wooded Bachergebirge. It is the seat of the bishop of Lavant, and of the judicial and administrative authorities of the district, and contains a gymnasium, a "realschule," an episcopal seminary, a normal school, a pomological school, a theatre, and three hospitals. The principal buildings are the cathedral, the tower of which commands a beautiful view, and the old castle. Its situation in the midst of a fertile vine-growing district, connected by the navigable Drave with Hungary, and by railway with Vienna, Trieste, the Tyrol, and Carinthia, makes it the centre of a considerable traffic in wine and grain. Its industrial products are leather, iron and tin wares, liqueurs, and sparkling wine, and it also contains several large cooperages. The extensive workshops of the South Austrian Railway are situated in the suburb of Magdalena, on the right bank of the Drave, and give employment to nearly three thousand hands. With the exception of a successful resistance to Matthias Corvinus in 1480–81, the history of the town presents no notable event. In 1880 Marburg contained 17,628 inhabitants, including a garrison of 1600 men. The environs abound in interesting and picturesque points.

See Puff's *Handbook to Marburg*, Gratz, 1847.

MARCANTONIO, or, to give him his full name, MARCANTONIO RAIMONDI, is celebrated as the chief Italian master of the art of engraving in the age of the Renaissance. The date of his birth is uncertain, nor is there any good authority for assigning it, as is commonly done, approximately to the year 1488. He was probably born some years at least earlier than this, inasmuch as he is mentioned by a contemporary writer, Achillini, as being an artist of repute in 1504. His earliest dated plate, illustrating the story of Pyramus and Thisbe, belongs to the following year, 1505. Marcantonio received his training in the workshop of the famous goldsmith and painter of Bologna, Francesco Raibolini, usually called Francia. "Having more aptitude in design," says Vasari, "than his master, and managing the graver with facility and grace, he made waist-buckles and many other things in niello, such being then greatly in fashion, and made them most beautifully, as being in truth most excellent in that craft." The real fame, however, of Marcantonio was destined to be founded on his attainments, not in the goldsmith's art generally, but in that particular development of it which consists of engraving designs on metal plates for the purpose of reproduction by the printing press. This art was not new in Italy in the days of Marcantonio's apprenticeship. It had been practised, in a more or less elementary form, for not less than forty or fifty years in the workshops of both Tuscany and Lombardy. A school of engravers had formed itself at Florence under the inspiration, as it appears, chiefly of Sandro Botticelli; in Lombardy the prevailing influence upon the nascent art had been that of Andrea Mantegna. But hitherto neither the engravers of Florence nor those of the Lombard cities had produced anything comparable for richness of effect and technical accomplishment to the work done during the same period on the other side of the Alps. The aim of the Italian engravers had not hitherto been directed, like that of Schongauer or Dürer, towards securing such freedom and precision in the use of the burin as should impart to the impressions taken from their engraved plates both a striking decorative effect and a power of suggesting to the eye a complex variety of natural objects and surfaces in light and shade. The Italian masters had been satisfied with a much more primitive order of effects. They had been content to omit all accessories and details except the simplest. They had merely drawn with the needle, or dry-point, upon the copper, in just the same way as they were accustomed to draw on paper with the pen or silver point,—taking great pains to get the outlines true and pure, and indicating shadows only by means of straight lines rapidly drawn in, or very simple hatchings.

By the beginning of the 16th century, however, when Marcantonio began to work at engraving along with the other pupils of Francia, a desire for a more complicated kind of effects was already arising among the followers of the art in Italy. Both backgrounds and passages of foreground detail were often imitated, inartificially enough, from the works of the northern masters. Marcantonio himself was among the foremost in carrying out this movement. There exist about eighty engravings which can be referred to the first five or six years of his career (1505–11). Their subjects are very various, including many of pagan mythology, and some of obscure allegory, along with those of Christian devotion. The types of figures and drapery, and the general character of the compositions, bespeak for the most part the inspiration, and sometimes the direct authorship, of that artist as graceful as he was grave, Francia. But the influence of German example is very perceptible also in the work of the young Marcantonio, particularly in the landscape backgrounds, and in the endeavour shown by him to express form by means of light and shadow with greater freedom than had been hitherto the practice of the southern schools. In a few subjects also the figures themselves correspond to a coarse Teutonic, instead of to the refined Italian, ideal. But so far we find Marcantonio only indirectly leaning on the north for the sake of self-improvement. It must have been for the sake of commercial profit that he by and by produced a series of direct counterfeits of northern work. We allude to the celebrated facsimiles engraved by Marcantonio on copper from Albert Dürer's woodcuts. These facsimiles are sixty-nine in number, including seventeen of Dürer's *Life of the Virgin,* thirty-seven of his *Little Passion* on wood, and a number of single pieces. According to Vasari, Dürer's indignation over those counterfeits was the cause of his journey to Venice, where he is said to have lodged a complaint against Marcantonio, and induced the signoria to prohibit the counterfeiting of his monogram, at any rate, upon any future imitations of the kind. Vasari's account must certainly be mistaken, inasmuch as Dürer's journey to Venice took place in 1506, and neither of the two series of woodcuts imitated by Marcantonio was published until 1511. The greater part of the designs for the *Life of the Virgin* had, it is true, been made and engraved seven years earlier than the date of their publication; and it is to be remarked that, whereas Marcantonio's copies of the *Little Passion* leave out the monogram of Dürer, it is inserted in his copies of the *Life of the Virgin*; whence it would after all seem possible that he had seen and counterfeited a set of impressions of this series at the time when they were originally executed, and before their publication. But the real nature of the transaction, if transaction there was, which took place between Dürer and Marcantonio, we cannot now hope to recover. Enough that the Bolognese engraver evidently profited, both in money and in education of the hand, by his work in imitating in a finer material the energetic characters of these northern woodcuts. He was soon to come under a totally different influence, and to turn the experience he had gained to account in interpreting the work of a master of a quite other stamp. Up till the year 1510 Marcantonio had lived entirely at Bologna, with the exception, it would appear, of a visit or visits to Venice. Very soon afterwards he was attracted for good and all into the circle which surrounded Raphael at Rome. Where or when he had first made Raphael's acquaintance is uncertain. His passage to Rome by way of Florence has been supposed to be marked by an engraving, dated 1510, and known as the Climbers, *Les Grimpeurs* (Bartsch 487), in which he has reproduced a portion of the design of Michelangelo's cartoon of the Battle of Anghiari, and has added behind the figures a landscape imitated from the then young Dutch engraver Lucas of Leyden. The piece in which he is recorded to have first tried his hand after Raphael himself is the Lucretia (Bartsch 192). From that time until he disappears in the catastrophe of 1527, Marcantonio was almost exclusively engaged in reproducing, by means of engraving, the designs of Raphael or of his immediate pupils. Raphael, the story goes, was so delighted with the print of the Lucretia that he personally trained and helped Marcantonio afterwards, adding, as some think, a touch of his own here and there to the engraver's work. A printing establishment was set up under the charge of Raphael's colour grinder, Il Baviera, and the profits, in the early stage of the business, were shared between the engraver and the printer. The sale soon became very great; pupils gathered round about Marcantonio, of whom the two most distinguished were Marco Dente, known as Marco da Ravenna, and Agostino de' Musi, known as Agostino Veneziano; and he and they, during the last ten years of Raphael's life, and for several years following his death, gave forth a great profusion of engravings after the master's work,—not copying, in most instances, his finished paintings, but working up, with the addition of simple backgrounds and accessories, his first sketches and trials, which often give the composition in a different form from the finished work, and are all the more interesting on that account.

The best of these engravings produced in the workshop of Marcantonio—those, namely, done by his own hand, and especially those done during the first few years after he had attached himself to Raphael—justly count among the most prized and coveted examples of the art. In them he enters into the genius of his master, the genius of choice, of balance, of rhythmical purity and charm; he loses little of the chastened science and subtle grace of

Raphael's contours, or of the inspired and winning sentiment of his faces; while in the parts where he is left to himself—the rounding and shading, the background and landscape—he manages his burin with all the skill and freedom which he had gained by the imitation of northern models, but puts away the northern emphasis and redundance of detail. His work, however, does not long remain at the height marked by pieces like the Lucretia, the Dido, the Judgment of Paris, the Poetry, the Philosophy, or the first Massacre of the Innocents. Marcantonio's engravings after the works of Raphael's later years are cold, ostentatious, and soulless by comparison. Still more so, as is natural, were those which he and his pupils produced after the designs of the degenerate scholars of Raphael and Michelangelo, of a Giulio Romano, a Polidoro, or a Bandinelli. Marcantonio's association with Giulio Romano was the cause of his first great disaster in life. He engraved a series of obscene designs by that painter in illustration of the *Sonnetti lussuriosi* of Pietro Aretino, and thereby incurred the anger of Pope Clement VII., at whose order he was thrown into prison. Marcantonio's ruin was completed by the calamities attendant on the sack of Rome in 1527. He had to pay a heavy ransom in order to escape from the hands of the Spaniards, and fled from Rome, in the words of Vasari, "all but a beggar." It is said that he took refuge in his native city, Bologna; but he never again emerges from obscurity, and all we know with certainty is that in 1534 he was dead. (S. C.)

MARCASITE. Modern mineralogists, following Haidinger, have restricted this name to those forms of native bisulphide of iron which crystallize in the orthorhombic system, and are sometimes known as "prismatic iron-pyrites." By the older mineralogists the word was used with less definite meaning, being applied to all crystallized and radiated pyrites, whether rhombic or cubic. In the last century both minerals were extensively used as ornamental stones. The marcasites were generally of small size, faceted like rose diamonds, and brilliantly polished, in which form they were mounted in pins, brooches, shoe-buckles, watch-cases, and other ornamental objects. The lustre of the polished surface was so brilliant that the stone, although opaque, formed a rough substitute for diamond; and this lustre was not readily impaired by atmospheric influences. Much of the old marcasite jewellery is of so pale a colour as almost to resemble burnished steel; such kinds generally belong to the true modern marcasite, sometimes called "white pyrites"; while the specimens which possess a brassy yellow colour are mostly referable to the cubic species, which is distinctively termed pyrite. Some of the finest pyrites suitable for the jeweller is found in Elba and in Brazil; but the mineral enjoys a very wide geographical distribution, and is common in England, especially in Cornwall, where it is known to the miners as "mundic." By the ancient Peruvians the mineral was extensively used for amulets, while the larger pieces were polished as mirrors; hence marcasite is sometimes called *pierre des Incas.* The word marcasite, variously written *marchasite, marchesite, marquesite,* &c., appears to have been introduced from Spain, and is supposed to be of Arabic origin. It is notable that the word was applied by early writers on chemistry to the metal now called bismuth.

MARCELLINUS, St, according to the Liberian catalogue, became bishop of Rome on June 30, 296; his predecessor was Caius or Gaius. Of his pontificate virtually nothing is known. In the *Concilia* of Mansi and Hardouin there is an account of a synod alleged to have been held in 303 at Sinuessa (between Rome and Capua), at which Marcellinus was accused by three of his priests and two of his deacons of having accompanied Diocletian into the temple of Vesta and Isis, and there burnt incense. The narrative goes on to say that ultimately he confessed his guilt in the presence of the three hundred assembled bishops, but that his condemnation was left to himself, for "prima sedes non judicatur a quoquam." It is further stated in the same account that he and many of the other bishops were put to death by Diocletian on August 23, 303. The story of the synod of Sinuessa was current at an early date, but was condemned by Augustine and Theodoret as a mere invention of the Donatists. Its fabulous character is maintained by Döllinger (*Papstfabeln*) and by Hefele (*Conciliengeschichte*), even against the weighty authority of the *Breviary*, where it constitutes a lesson in one of the nocturns for April 26, the commemoration day of Marcellinus. Marcellinus died, according to the Liberian catalogue, in 304, after a pontificate of eight years three months and twenty-five days; after a considerable interval he was succeeded by Marcellus, who has sometimes been identified with him.

MARCELLUS, Marcus Claudius, Roman warrior, was born about 268 B.C., and served first in Sicily against Hamilcar. In his first consulship (222) he was engaged in the war against the Insubres, and won the *spolia opima* by slaying their chief Viridomarus. In 216 he was to have gone as prætor to Sicily with a fleet, but was detained on the news of the defeat at Cannæ. He went to Canusium and took command of the fragments of the army. He tried without success to prevent Capua going over to Hannibal, but saved Nola. In 214 he was in Sicily as consul at the time of the revolt of Syracuse; he stormed Leontini and besieged Syracuse, but the engineering skill of Archimedes repelled his attacks and compelled him to content himself with a blockade. Himilco landed with a Carthaginian army, and Marcellus failed to prevent their occupying Agrigentum. Taking the opportunity of a feast of Artemis, Marcellus stormed Epipolæ; but the old town and the island remained untaken, as also the fort of Euryalus, which was, however, cut off and soon fell. Meanwhile pestilence raged among the Carthaginian army encamped outside. After several months, during which disorder reigned in the town, he gained a lodgment by the aid of a Spanish officer, and Syracuse was surrendered (212). Marcellus spared the lives of the Syracusans, but carried off their art treasures to Rome. Consul again in 210, he took Salapia by help of the Roman party there, and put to death the Numidian garrison. Proconsul in 209, he attacked Hannibal near Venusia, and after a desperate battle retired to that town; he was accused of bad generalship, and had to leave the army to defend himself in Rome. In his last consulship (208), while both consuls were reconnoitring near Venusia, they were unexpectedly attacked, and Marcellus was killed. His successes have probably been exaggerated, but he was a brave soldier, and the name often given to him, the "sword of Rome," was well deserved. Though plebeians, the Marcelli henceforth took a high position; they were hereditary patrons of Sicily.

MARCELLUS, M. Claudius, was curule ædile in 56 B.C. with P. Clodius. In 52 he spoke on behalf of Milo at his trial. In 51 he was consul with Ser. Sulpicius. During his consulship he proposed to remove Cæsar from his army from March 49. The decision was, however, delayed by Pompeius's irresolution till February 50, and then the tribune C. Curio insisted that Pompeius also should vacate his command; and the senate voted this by a large majority. But at last C. Marcellus, cousin of Marcus, and then consul, went to Pompeius with the two consuls elect, and offered him the command of the army against Cæsar. In January 49 M. Marcellus tried to put off declaring war till an army could be got ready; but when Pompeius left Italy Marcus and his brother Caius followed, while his cousin withdrew to Liternum. After Pharsalus M. Marcellus retired to Mytilene. He long made no attempt to return, till in 46 the senate appealed to Cæsar. Marcellus accepted this favour reluctantly. Pressed by Cicero, he left Mytilene for Italy, but was murdered in May by Magius Cilo in the Piræus. Marcellus was a thorough aristocrat, but free from the violence which disgraced many of his party.

MARCELLUS, M. CLAUDIUS, son of C. Marcellus and Octavia, sister to Octavianus, was born about 43 B.C. Octavianus adopted him and made him pontifex and senator with prætorian rank. In 25 he married Julia, daughter of Octavianus, and was looked on as his future successor. Yet in a dangerous illness Augustus gave his signet to Agrippa. Differences arising, Agrippa was made proconsul of Syria to separate the rivals. In 23 Marcellus, while curule ædile, fell ill and died at Baiæ. Livia was suspected of having poisoned him to get the empire for her son Tiberius. Great hopes had been built on the youth, and he was celebrated by many writers, especially by Virgil, in a famous passage in *Æn.* vi.

MARCELLUS I., pope, succeeded Marcellinus, after a considerable interval, most probably in May 307; under Maxentius he was banished from Rome in 309 on account of the tumult caused by the severity of the penances he had imposed on Christians who had lapsed under the recent persecution. He died the same year, being succeeded by Eusebius.

MARCELLUS II., Marcellus Cervini, cardinal of Santa Croce, a native of the Mark of Ancona, was elected pope in the room of Julius III. on April 9, 1555, but his feeble constitution succumbed to the fatigues of the conclave, the exhausting ceremonies connected with his accession, and the anxieties arising from his high office, on the twenty-first day after his election. He had a high reputation for integrity, tact, and ability. His successor was Paul IV.

MARCH, the third month of our modern year, contains thirty-one days. As in the Roman year so in the English ecclesiastical calendar used till 1752 this was the first month, and the legal year commenced on the 25th of March. The Romans called this month *Martius*, from the god Mars; and it received the name *Illyd Monath, i.e.*, loud or stormy month, from the Anglo-Saxons. In France March was also generally reckoned the first month of the year until 1564, when, by an edict of Charles IX., January was decreed to be thenceforth the first month. Scotland followed the example of France in 1599; but in England the change did not take place before 1752. There is an old saying, common to both England and Scotland, which represents March as borrowing three days from April; thus the last three days of March are called the "borrowing" or the "borrowed days." In the *Complaynt of Scotland* we find "the borial blastis of the thre borouing dais of Marche hed chaisset the fragrant flureise of evyrie fruit-tree far athourt the feildis." An ancient popular rhyme says:—

> "March borrowit from Averill
> Three days, and they were ill;"

and then there is another rhyme which graphically characterizes those three "ill" days in detail:—

> "The first, it sall be wind and weet,
> The next, it sall be snaw and sleet;
> The third, it sall be sic a freeze,
> Sall gar the birds stick to the trees."

There is an old proverb, "A bushel of March dust is worth a king's ransom." Dry weather in March is generally favourable to the production of grain on clay lands; and hence a "dusty March" portended a plenteous season; while, on the contrary, a "wet March" frequently proved destructive of both wheat and rye.

The principal fixed days now observed and noted in the course of this month are the following:—March 1st, St David; March 12th, St Gregory; March 17th, St Patrick; and March 25th, Lady Day, one of the established quarter-days in England.

MARCHE, a former province of central France, was bounded on the N. by Berri, on the N. E. by Bourbonnais, on the E. by Auvergne, on the S. by Limousin, and on the W. by Angoumois and Poitou, embracing the greater part of the modern department of Creuse, a considerable portion of Haute-Vienne, and fragments of Charente and Indre. It derived its name from the circumstance of its being the "mark" or boundary between Poitou and Berri; it is sometimes referred to as Marche Limousine. It is first mentioned in history as a separate fief about the middle of the 10th century, when the countship of Marche was committed by Duke William III. of Aquitania to Boso I., count of Limoges and Charroux.

MARCHENA, a town of Spain, in the province of Seville, lies in a sandy valley, not far from the Corbones, a tributary of the Guadalquivir, about 30 miles east-south-east from Seville. It is a station on the line by which Seville and Utrera are connected with Osuna and the Cordova-Malaga line. Formerly it was surrounded with walls and towers, of which some traces still remain. Among the principal buildings is the palace of the dukes of Arcos (descendants of Ponce de Leon), within the enclosure of which is an ancient Moorish building, now the church of Santa Maria de la Mota, with a tower of considerable architectural merit. The ancient parish church of San Juan, rebuilt in 1490, has five naves. At the eastern end of the town is a sulphur spring which is a place of considerable resort for the cure of cutaneous diseases. The manufactures of the place are unimportant; there is some trade in the wheat, barley, olives, oil, and wine produced in the neighbourhood. The population in 1877 was 13,768. Marchena (the *Castra Gemina* of Pliny?) was taken from the Moors by St Ferdinand in 1240, and was presented to Ponce de Leon by Ferdinand IV. in 1309.

MARCIAN (MARCIANUS), emperor of the East from 450 to 457, was born in a private station of life in Illyria or Thrace, about the year 391, and at an early age entered the army, where after a considerable term of obscurity he attracted the attention of Ardaburius and subsequently of Aspar, being made military secretary and a captain in the guards. He accompanied Aspar in the ill-fated expedition against Genseric, by whom he was taken prisoner, but soon released. In 450, having in the meantime become tribune and senator, he went through the form of marriage with Pulcheria, the sister and successor of Theodosius II., and was crowned on August 25. In 451 he assembled the œcumenical council of Chalcedon, at which the proceedings of the "robber-synod" of Ephesus were annulled, and the Eutychian heresy condemned, a service to orthodoxy which has greatly endeared his memory to the minds of Catholic historians. In 452 his generals Ardaburius and Maximin respectively gained victories of some importance over the Arabs near Damascus and over the Blemmyes who had invaded the Thebaid; and after the death of Attila (453) he set about the task of repopulating the extensive tracts which had been devastated by the Huns. He maintained the peace of his dominions during the troubles which convulsed the Western empire in 455; and in 456 his arms were free to repress disturbances in Lazica which had been fomented by the Armenians and Persians. He died in 457, and was succeeded by Leo I.

MARCION AND THE MARCIONITE CHURCHES. In the period between 130 and 180 A.D. the varied and complicated Christian fellowships in the Roman empire crystallized into close and mutually exclusive societies[1]—churches with fixed constitutions and creeds, schools with distinctive esoteric doctrines, associations for worship with peculiar mysteries, and ascetic sects with special rules of conduct. Of churchly organizations the most important, next to catholicism, was the Marcionite community. Like the catholic church, this body professed to comprehend everything belonging to Christianity. It admitted all believers without distinction of age, sex, rank, or culture. It was no mere school for the learned, disclosed no mysteries for the privileged, but sought to lay the foundation of the Christian community on the pure gospel, the authentic institutes of Christ. The pure gospel, however, Marcion found to be everywhere more or less corrupted and mutilated in the Christian circles of his time. His undertaking thus resolved itself into a reformation of Christendom. This reformation was to deliver Christendom from false Jewish doctrines by restoring the Pauline conception of the gospel,—Paul being, according to Marcion, the only apostle who had rightly understood the new message of salvation as delivered by Christ. In Marcion's own view, therefore, the founding of his church—to which he was first driven by opposition—amounts to a reformation of Christendom through a return to the gospel of Christ and to Paul; nothing was to be accepted beyond that. This of itself shows that it is a mistake to reckon Marcion among the Gnostics. A dualist, we shall see, he certainly was, but he was not a Gnostic. For he ascribed salvation, not to "knowledge" but to "faith"; he appealed openly to the whole Christian world; and he nowhere consciously added foreign elements to the revelation given through Christ. It is true that in many features his Christian system—if we may use the expression—resembles the so-called Gnostic systems; but the first duty of the historian is to point out what Marcion plainly aimed at; only in the second place have we to inquire how far the result corresponded with those purposes.

The doctrines of Marcion and the history of his churches from the 2d to the 7th century are known to us from the controversial works of the catholic fathers. From Justin downwards, almost every eminent church teacher takes some notice of Marcion, while very many write extensive treatises against him. The most important of those which have come down to us are the controversial pieces of Irenæus (in his great work against heretics), Tertullian (*Adv. Marc.*, i.–v.), Hippolytus, Pseudo-Origen Adamantius, Epiphanius, and the Armenian Esnik. From these works the contents of the Marcionite Gospel, and also the text of Paul's epistles in Marcion's recension, can be settled with tolerable accuracy. His opponents, moreover, have preserved some expressions of his, with extracts from his principal work; so that our knowledge of Marcion's views is in part derived from the best sources.

Marcion was a wealthy shipowner, belonging to Sinope in Pontus. He appears to have been a convert from paganism to Christianity, although it was asserted in later times that his father had been a bishop. That report is probably as untrustworthy as another, that he was excommunicated from the church for seducing a virgin. What we know for certain is that after the death of Hyginus (or *c.* 139 A.D.) he arrived, in the course of his travels, at Rome, and made a handsome donation of money to the local church. Even then, however, the leading features of his peculiar system must have been already thought out. At Rome he tried to gain acceptance for them in the college of presbyters and in the church; indeed he had previously made similar attempts in Asia Minor. But he now encountered such determined opposition from the majority of the congregation that he found it necessary to withdraw from the great church and establish in Rome a community of his own. This was about the year 144. The new society increased in the two following decades; and very soon numerous sister-churches were flourishing in the east and west of the empire. Marcion took up his residence permanently in Rome, but still undertook journeys for the propagation of his opinions. In Rome he became acquainted with the Syrian Gnostic Cerdo, whose speculations influenced the development of the Marcionite theology. Still Marcion seems never to have abandoned his design of gaining over the whole church to his gospel. The proof of this is found, partly in the fact that he tried to establish relations with Polycarp of Smyrna,—from whom, to be sure, he got a sharp rebuff,—partly in a legend to the effect that towards the end of his life he sought re-admission to the church. Such, presumably, was the construction put in after times on his earnest endeavour to unite Christians on the footing of the "pure gospel." When he died is not known; but his death can scarcely have been much later than the year 165.

The distinctive teaching of Marcion originated in a comparison of the Old Testament with the gospel of Christ and the theology of the apostle Paul. Its motive was not cosmological or metaphysical, but religious and historical. In the gospel he found a God revealed who is goodness and love, and who desires faith and love from men. This God he could not discover in the Old Testament; on the contrary, he saw there the revelations of a just, stern, jealous, wrathful, and variable god, who requires from his servants blind obedience, fear and outward righteousness. Overpowered by the majesty and novelty of the Christian message of salvation, too conscientious to rest satisfied with the ordinary attempts at the solution of difficulties, while yet he was in no position to reach an historical insight into the relation of Christianity to the Old Testament and to Judaism—who indeed was so in those days?—he believed that he expressed Paul's view by the hypothesis of two Gods: the just God of the law (the God of the Jews, who is also the Creator of the world), and the good God, the Father of Jesus Christ. Paradoxes in the history of religion and revelation which Paul draws out, and which Marcion's contemporaries passed by as utterly incomprehensible, are here made the foundation of an ethico-dualistic conception of history and of religion. It may be said that in the 2d century only one Christian—Marcion—took the trouble to understand Paul; but it must be added that he misunderstood him. The profound reflexions of the apostle on the radical antithesis of law and gospel, works and faith, were not appreciated in the 2d century. Marcion alone perceived their decisive religious importance, and with them confronted the legalizing, and in this sense Judaizing, tendencies of his Christian contemporaries. But the Pauline ideas lost their truth under his treatment; for, when it is denied that the God of redemption is at the same time the almighty Lord of heaven and earth, the gospel is turned upside down.

The assumption of two gods necessarily led to cosmological speculations. Under the influence of Cerdo, Marcion carried out his ethical dualism in the sphere of cosmology; but the fact that his system is not free from contradictions is the best proof that all along religious knowledge, and not philosophical, had the chief value in his eyes. The main outlines of his teaching are as follows. Man is, in spirit, soul, and body, a creature of the just and wrathful god. This god created man from Hyle (matter),[1] and imposed on him a strict law. Since no one could keep this law, the whole human race fell under the curse, temporal and eternal, of the Demiurge. Then a higher God, hitherto unknown, and concealed even from the

[1] On the relation of matter to the Creator Marcion himself seems not to have speculated, though his followers may have done so.

Demiurge, took pity on the wretched, condemned race of men. He sent His Son (whom Marcion probably regarded as a manifestation of the supreme God Himself) down to this earth in order to redeem men. Clothed in a visionary body, in the likeness of a man of thirty years old, the Son made His appearance in the fifteenth year of Tiberius, and preached in the synagogue at Capernaum. But none of the Jewish people understood Him. Even the disciples whom He chose did not recognize His true nature, but mistook Him for the Messiah promised by the Demiurge through the prophets, who as warrior and king was to come and set up the Jewish empire. The Demiurge himself did not suspect who the stranger was; nevertheless he became angry with Him, and, although Jesus had punctually fulfilled his law, caused Him to be nailed to the cross. By that act, however, he pronounced his own doom. For the risen Christ appeared before him in His glory, and charged him with having acted contrary to his own law. To make amends for this crime, the Demiurge had now to deliver up to the good God the souls of those who were to be redeemed; they are, as it were, purchased from him by the death of Christ. Christ then proceeded to the underworld to deliver the spirits of the departed. It was not the Old Testament saints, however, but only sinners and malefactors who obeyed His summons. Then, to gain the living, Christ raised up Paul as His apostle. He alone understood the gospel, and recognized the difference between the just God and the good. Accordingly, he opposed the original apostles with their Judaistic doctrines, and founded small congregations of true Christians. But the preaching of the false Jewish Christians gained the upper hand; nay, they even falsified the evangelical oracles and the letters of Paul. Marcion himself was the next raised up by the good God, to proclaim once more the true gospel. This he did by setting aside the spurious gospels, purging the real Gospel (the Gospel of Luke) from supposed Judaizing interpolations, and restoring the true text of the Pauline epistles. He likewise composed a book, called the *Antitheses*, in which he proved the disparity of the two gods, from a comparison of the Old Testament with the evangelical writings.

On the basis of these writings Marcion proclaimed the true Christianity, and founded churches. He taught that all who put their trust in the good God, and His crucified Son, renounce their allegiance to the Demiurge, and approve themselves by good works of love, shall be saved. But he taught further—and here we trace the influence of the current Gnosticism on Marcion—that only the spirit of man is saved by the good God; the body, because material, perishes. Accordingly his ethics also were thoroughly dualistic. By the "works of the Demiurge," which the Christian is to flee, he meant the whole "service of the perishable." The Christian must shun everything sensual, and especially marriage, and free himself from the body by strict asceticism. The original ethical contrast of "good" and "just" is thus transformed into the cosmological contrast of "spirit" and "matter." The good God appears as the god of spirit, the Old Testament god as the god of matter. That is Gnosticism; but it is at the same time illogical. For, since, according to Marcion, the spirit of man is derived, not from the good, but from the just God, it is impossible to see why the spiritual should yet be more closely related to the good God, than the material. There is yet another direction in which the system ends with a contradiction. According to Marcion, the good God never judges, but everywhere manifests His goodness,—is, therefore, not to be feared, but simply to be loved, as a father. But here the question occurs, What becomes of the men who do not believe the gospel? Marcion answers, The good God does not judge them, but merely removes them from His presence. Then they fall under the power of the Demiurge, who—rewards them for their fidelity? No, says Marcion, but on the contrary—punishes them in his hell! The contradiction here is palpable; and at the same time the antithesis of "just" and "good" ultimately vanishes. For the Demiurge now appears as an inferior being, who in reality executes the purposes of the good God. It is plain that dualism here terminates in the idea of the sole supremacy of the good God.

It is not surprising, therefore, that even in the 2d century the disciples of Marcion diverged in several directions. Rigorous asceticism, the rejection of the Old Testament, and the recognition of the "new God" remained common to all Marcionites, who, moreover, like the catholics, lived together in close communities ruled by bishops and presbyters (although their constitution was originally very loose, and sought to avoid every appearance of "legality"). Some, however, accepted three first principles (the evil, the just, the good); others held by two, but regarded the Demiurge as the god of evil, *i.e.*, the devil; while a third party, like Apelles, the most distinguished of Marcion's pupils, saw in the Demiurge only an apostate angel of the good God,—thus returning to monotheism. The golden age of the Marcionite churches falls between the years 150 and 250. During that time they were really dangerous to the great church; for in fact they maintained certain genuine Christian ideas, which the catholic church had forgotten. From the beginning of the 4th century they began to die out in the West; or rather they fell a prey to Manichæism. In the East also many Marcionites went over to the Manichæans; but there they survived much longer. They can be traced down to the 7th century, and then they seem to vanish. But it was unquestionably from Marcionite impulses that the new sects of the Paulicians and Bogomiles arose; and in so far as the western Katharoi, and the antinomian and anticlerical sects of the 13th century are connected with these, they also may be included in the history of Marcionitism.

Literature.—Baur, *Die Gnosis*, 1835; Möller, *Geschichte der Kosmologie in der griechischen Kirche*, 1860; Lipsius, *Gnosticismus*, 1860; Harnack, *Zur Quellenkritik der Geschichte des Gnosticismus*, 1873, and in the *Zeitschrift f. hist. Theol.*, 1874; Harnack, *De Apellis gnosi monarchica*, 1874; Lipsius, *Quellen der ältesten Ketzergeschichte*, 1875; Mansel, *The Gnostic Heresies*, 1875; Harnack, *Zur Geschichte der Marcionitischen Kirchen* (Hilgenfeld's *Zeitschrift*, 1876). Of the numerous works on Marcion's Gospel and Apostolos lists will be found in any introduction to the New Testament or history of the canon. The following are the ascertained results of criticism:—(1) Marcion was the first to make a canonical collection of New Testament writings; (2) his Gospel is to be regarded as a reconstruction, and not as the basis, of our canonical Gospel of Luke. (A. HA.)

MARCO POLO. See Polo.

MARCUS, the successor of Pope Sylvester I., according to the Liberian catalogue, had a pontificate of eight months and twenty days, from January 18 to October 7, 336. Of his character or history nothing is recorded. He was succeeded by Julius I.

MÁRDÍN, a town of Turkish Kurdistan, the seat of a governor dependent on the pasha of Diarbekir, is situated in 37° 20′ N. lat. and 41° E. long., about 60 miles south-east of Diarbekir, at a height of 3900 feet above the sea. Climbing the southern side of a steep conical hill (of soft limestone) in such a way that the roofs of the lower tier of houses serve as a street for those immediately above, Márdín presents a very picturesque appearance; and on the summit of the hill, which affords an unusually wide view over the Mesopotamian plain, stand the ruins of the famous castle Kal'ah Shubbá (Maride and Marde in Latin, and similarly in Syriac), which, at least from the time of the Romans, played an important part in the history of this region. The Arabian geographers characterize it as impregnable; and, the approaches being extraordinarily steep, narrow, and well arranged for purposes of defence, it was able to offer a protracted resistance to the Mongolian conqueror Hulagu, and to the armies of Timur. The castle was for hundreds of years the residence of princes more or less independent. The town has not much commerce or industry, but the surrounding country is distinguished for its excellent water and general fertility, and more especially for its fruit trees and, melons. As regards their capacity and the honesty of their dealings, the people of Márdín do not enjoy the best reputation. They are estimated to number from 15,000 to 18,000; in 1870 Professor Socin was informed in the town that there were 600 Jacobite, 300 Catholic Armenian, 200 Catholic Syrian, 30 Chaldæan, and 57 Protestant families. Among the Jacobites are included a few remnants of the old sect called Shemsiye. See Ritter, *Erdkunde von Asien*, 2d ed., vol. vii.

MARGARET of Anjou, who became the queen of Henry VI. of England, was born at Pont à Mousson in Lorraine on the 24th[1] March 1429. Her father, "the good King René," as he was called in later years, did not at the time of her birth possess any of the pompous titles to which he afterwards laid claim, but was simply count of Guise, and younger brother of the existing duke of Anjou. He had, however, married Isabella, daughter of Charles II., duke of Lorraine, and during Margaret's infant years he succeeded to two dukedoms, first Lorraine and then Anjou, and afterwards to the crowns of Naples, Sicily, and Jerusalem. Some of these acquisitions, however, were no more than empty titles. He had a competitor for the duchy of Lorraine against whom he was unsuccessful in war, and he was actually a prisoner in the hands of the duke of Burgundy when the death of Joan II. of Naples first made him nominally a king. He deputed his wife Isabella to go to Naples and take possession of his new kingdom for him, and she took with her while on this enterprise her second son Louis and her second daughter Margaret, then in her seventh year. René himself obtained his liberty after a time, and followed his wife to Naples, but, being defeated by a rival there also, he returned to France after more than four years' absence. Before revisiting Lorraine or Anjou, he spent some time in Provence, and there received a proposal for the marriage of Margaret, who had by this time nearly completed her fourteenth year, from Charles, count of Nevers. It was accepted, and the contract was actually signed; but the marriage was delayed on account of some disputes about the settlement, and next year it was set aside for the more splendid match offered by the king of England.

This was in 1444. The earl, afterwards duke, of Suffolk, had proposed the match to Henry VI. as a means of terminating the long war with France, and securing peace upon a solid basis. Henry fully entered into the scheme, and was content for so great an object, not only to accept a bride without a dowry, but to give up to King René the provinces of Anjou and Maine. A great embassy was sent over to France, with Suffolk himself at its head, to negotiate the matter, and some months later the marriage was celebrated by proxy at Tours, Suffolk acting as Henry's representative. In April of the following year, 1445, Margaret crossed the Channel, and was received by Henry on her landing at Porchester. A few days later, 22d April, they were married in Tichfield Abbey, or, as some other authorities say, at Southwick,[2] and on Sunday the 30th of May Margaret was crowned at Westminster. Suffolk was now high in favour at court, but the policy he had pursued of giving up territory for the sake of peace was not likely to be generally acceptable in itself, and the events of the next few years completed his unpopularity. War broke out again with France in 1449, and in the course of a single year the whole of Normandy was lost to the English. Suffolk was impeached by the Commons, and the king was persuaded that the best way to protect him was to order him to quit the country. But he was taken and murdered at sea, and for some time the country was in a state of fearful anarchy. Margaret's position was now one that required great tact and delicacy. The king's marriage was already unpopular, and the fact was soon manifest that his wife possessed far higher abilities and greater power of governing than himself. This, together with the king's occasional attacks of mental imbecility, was really the great source of her misfortunes. During Henry's intervals of sanity it was she who really governed, and unfortunately she gave her whole support to the duke of Somerset, whose mismanagement abroad had been the immediate cause of the loss of Normandy. The duke of York vainly endeavoured to procure Somerset's removal, but he was so protected by the court that the complaints of his accuser were utterly unheeded, except during the king's periods of total incapacity, when the lords made York protector. Civil war at last broke out, and Somerset fell at St Alban's in 1455. Party feeling was bitterly exasperated, and Margaret, as we learn from a contemporary French historian, actually instigated an attack on Sandwich by the French out of hatred to the duke of York. At length, in 1460, that nobleman openly challenged the crown as his right and obtained from parliament, with the consent of Henry himself, a settlement of the succession in his favour. But at this time Margaret was out of the way. The king had been taken prisoner the year before by the Yorkists at the battle of Northampton, and she had sought refuge in Wales and Scotland along with her only son Edward, prince of Wales, then seven years old, who was now disinherited. Margaret's friends took up her cause in the north of England, and the duke of York, going to meet them, fell at the battle of Wakefield, 30th December 1460. Margaret naturally endeavoured to improve her victory by marching on to London. But Edward, earl of March, the duke of York's son, defeated her adherents on the borders of Wales, while the earl of Warwick with the king in his custody left London to oppose her. The ill-disciplined troops that she brought with her from the north ravaged the country as they went, and made themselves generally detested. But they overthrew Warwick's forces at St Alban's (the second battle fought there in this war), and liberated the king. The earl of March, however, soon came up and entered London, where he was proclaimed king by the name of Edward IV., amid the shouts of the citizens, who had always been devoted to his father. Margaret then thought it advisable to withdraw into the north along with Henry and her son, and Edward and Warwick pursued them into Yorkshire, where the bloody battle of Towton (29th March 1461) utterly crushed for the time the hopes of the house of Lancaster. Henry and Margaret fled to Scotland, and surrendered Berwick to the Scots as the price of their assistance. Margaret and her son soon after entered England with a body of Scots, who besieged Carlisle, but they were driven back by Lord Montague. Then King Henry accompanied another invasion into the county of Durham which was equally unsuccessful. Next year (1462) Margaret sailed from Kirkcudbright to seek aid in France, and offered the surrender of Calais to Louis XI. if Louis enabled her husband to regain his kingdom. Louis gave her two

[1] Most authorities say the 23d, but according to the MS. *Heures* of René, cited in the *Nouvelle Biographie Générale*, the day was the 24th.

[2] Southwick, according to Fabyan, who is followed by Hall and later writers; but William Wyrcestre and the anonymous author of the *English Chronicle* edited by Davies for the Camden Society, who are both strictly contemporary, say Tichfield.

thousand men under the command of Pierre de Brézé, and with these she made a descent upon Northumberland and took Bamborough and some other castles, which, however, were soon after besieged by King Edward's forces, and after a while recovered. King Edward himself, on hearing of her landing, hastened into the north, on which Margaret took ship to sail for France, but meeting with a storm was driven to land at Berwick and lost all her treasure. On the total failure of this expedition the well-known story is told by a French writer of her wandering with her son in a forest where she was attacked by robbers, and appealing successfully to the loyalty of one of them to save the son of his king.

Soon after, in April 1463,[1] she sailed to Flanders and sought the aid of Philip of Burgundy, but he declined to do more than relieve her poverty, and she retired to a castle in Lorraine, which her father gave her to occupy. Here Sir John Fortescue, who accompanied her into exile, superintended the education of her son, and composed for his benefit his celebrated treatise on the laws of England. Here also she apparently remained while her husband made further efforts and met with further defeats,—while he lay concealed, for more than a year, in Lancashire, was taken prisoner, and committed to the Tower. But in 1470, when her old enemy the earl of Warwick, having rebelled against King Edward, sought a refuge in France, Louis XI. induced her, though with great difficulty, to pardon him and concert measures along with him for her husband's restoration to the throne. The negotiation was cemented by an agreement for the marriage of her son, the prince of Wales, to the earl's daughter after the kingdom should be recovered, and so successful was the project that Edward was actually driven into exile, and for a period of six months Henry was again acknowledged as king. But the return of King Edward and the battle of Barnet once more changed the aspect of affairs before Margaret was able to rejoin her husband, and when she at length landed again in England she was defeated and taken prisoner at Tewkesbury. To add to her misery her only son Prince Edward was butchered after the battle. Four years later, in 1475, on peace being made between England and France, she was ransomed by Louis XI., and returned to her native country. She died at Dampierre near Saumur in Anjou, on the 25th of August 1482.

Principal Authorities.—Bourdigné, *Chroniques d'Anjou et du Maine*; Villeneuve Bargemont, *Histoire de René d'Anjou*; William Wyrcestre, *Annals*, edited by Hearne (with *Liber Niger Scaccarii*); *Fragment relating to Edward IV.*, ed. Hearne (with *Sprott's Chronicle*); *English Chronicle*, ed. Davies (Camden Society); *Paston Letters*; *Rolls of Parliament*; *Anchiennes Chronicques d'Engleterre, par Jehan de Wavrin*, edited by Mlle. Dupont; Lord Clermont's edition of the *Works* of Sir John Fortescue. Mrs Hookham's *Life and Times of Margaret of Anjou* (London, 8vo, 1872) is an elaborate and useful work, but not always accurate and discriminating in the use of authorities.

MARGARET OF AUSTRIA (1480-1530), duchess of Savoy, and regent of the Netherlands from 1507 to 1530, was the daughter of the emperor Maximilian and Mary of Burgundy, and was born at Brussels on January 10, 1480. In 1482 she was betrothed to Charles, the son of Louis XI. (afterwards Charles VIII. of France); and in 1497 she was actually married to the infante John of Aragon, who left her a widow a few months afterwards. In 1501 she became the wife of Philibert II. of Savoy, who only survived until 1504; and in 1507 she was entrusted by Maximilian with the regency of the Netherlands and also with the charge of his grandson Charles. She died at Mechlin in 1530.

[1] This is clearly the date intended by William Wyrcestre (p. 496); and it agrees entirely with Monstrelet (iii. 96). Yet almost all modern historians (except Lingard) and even biographers of Margaret of Anjou date her departure to Flanders after the battle of Hexham, at which she certainly was not present, as they would have her.

MARGARET OF AUSTRIA (1522-1586), duchess of Parma, and regent of the Netherlands from 1559 to 1567, was a natural daughter of Charles V. by Margaret van Gheenst, a Flemish lady, and was born at Brussels in 1522. In 1533 she was married to Alexander, duke of Florence; and, having been left a widow in 1537, she became the wife of Ottavio Farnese, duke of Parma, in 1542. The union proved an unhappy one, and she for the first time found a sphere for her somewhat masculine abilities in the Netherlands, which were entrusted to her care by her brother Philip II. of Spain on his departure for the peninsula in 1559 (see HOLLAND, vol. xii. pp. 74, 75). It was with much reluctance that she resigned the reins of power into the hands of the duke of Alva in 1567 and retired to Italy. Before her death, which occurred at Ortona in 1586, she had the satisfaction of seeing her son Alexander Farnese appointed to the government which she had occupied some twenty years before.

MARGARET, ST, queen of Scotland, born in Hungary about 1040, was a daughter of Edward the Atheling, son of Edmund Ironside; her mother was Agatha, most probably a niece of Queen Gisela of Hungary and of the emperor Henry II. She accompanied her father to England in 1057, and after the Norman Conquest she was brought (1068) to Scotland, where she became the wife of Malcolm Canmore in the spring of 1069. She survived her husband, who died in November 1093, by only a few days (see SCOTLAND). The chroniclers all agree in depicting Queen Margaret as a strong, pure, noble character, who had very great influence over her husband, and through him over Scottish history, especially in its ecclesiastical aspects. Her religion, which was genuine and intense, was of the newest Roman style; and to her are attributed a number of reforms by which the Church of Scotland was considerably modified from the insular and primitive type which down to her time it had exhibited. Among those expressly mentioned are a change in the manner of observing Lent, which thenceforward began as elsewhere on Ash Wednesday and not as previously on the following Monday, and the abolition of the old practice of observing Saturday (Sabbath), not Sunday, as the day of rest from labour (see Skene's *Celtic Scotland*, book ii. chap. 8). Her sons Edgar, Alexander, and David successively occupied the throne of Scotland; her elder daughter, Matilda, became the wife of Henry I. of England in 1101. Margaret was canonized by Innocent IV. in 1251, and by Clement X. she was made patroness of Scotland. Her festival (semi-duplex) is observed by the Roman Church on June 10.

MARGARET (1283-1290), known in Scottish history as the "Maid of Norway," was, through her mother Margaret, who had been married to Eric of Norway, the only grandchild of Alexander III. of Scotland, and was born in Norway in 1283. At the death of her grandfather (1286), while she was still an infant, Edward I. of England arranged for her betrothal to his son, but this policy was defeated by her early death, which took place, it was alleged, in Orkney, as she was on her way to Scotland, in 1290. The circumstances of her death were so obscure that doubts were entertained in some quarters whether she had not rather been spirited away. About 1300 a woman presented herself in Leipsic as the long-lost queen of Scotland; ultimately, however, she was burnt at Bergen as an impostor.

MARGARET OF VALOIS. See MARGUERITE.

MARGARITA, an island in the Caribbean Sea, about 8 miles off the coast of Venezuela, constituting along with the lesser islands Blanquilla and Hermanos the new state of Nueva Esparta. It has an area of 400 square miles, consists of two portions united by a low and narrow isthmus, is generally mountainous, and attains its greatest elevation of 4630 feet in Mont Macanao. The pearls from which Margarita takes its name, and which proved a considerable source of wealth in the 16th and 17th centuries, are no longer sought after; but the ordinary fisheries are actively prosecuted, and since the War of Independence, agriculture, trade, and industry have all greatly improved. Pompatar is the only harbour, Pueblo del Norte and Pueblo de la Mar being rather open roadsteads. Asuncion, the chief town, contains about 3000 inhabitants. The population of the island was 16,200 in 1807 (about 8000 being whites), and that of the state 30,983 in 1873.

Discovered by Columbus in 1498, Margarita was in 1524 bestowed by Charles V. on Marceto Villalobos. In 1561 it was ravaged by Lopez de Aguirre, a notorious freebooter, and in 1662 the town of Pompatar was destroyed by the Dutch. Long included in the government of Cumana, Margarita attained administrative independence only in the 18th century. In the War of Independence the inhabitants made an effective stand against Murillo; and to this they owe the honour of having their island erected into the state of New Sparta.

MARGARITA, St, virgin and martyr, is celebrated by the Church of Rome on July 20, but her feast formerly fell on the 13th, and her story is almost identical, even in the proper names, with that of the Greek St Marina (July 17). She was of Antioch (in the Greek story Antioch of Pisidia), daughter of a priest Ædesius. She lived in the country with a foster mother, scorned by her father for her Christian faith, and keeping sheep. Olybrius the "præses Orientis" sees her and offers his hand as the price of renunciation of Christianity. Her refusal leads to her being cruelly tortured, and after various miraculous incidents, in which a heavenly dove plays a prominent part, she is put to death. Women prayed to St Margarita for easy deliverance. It has been shown by H. Usener (*Legenden der heiligen Pelagia*, Bonn, 1879) that this legend belongs to a group of curious narratives which all have their root in a transformation of the Semitic Aphrodite into a Christian penitent or saint. Of these legends that of St Pelagia (*q.v.*) is perhaps the most important. Marina is a translation of Pelagia, and both are epithets of Aphrodite as she was worshipped on the coasts of the Levant. Pelagia in the legend has Margarito as her second name. The association of the marine goddess with the pearl is obvious, and the images of Aphrodite were decked with these jewels.

MARGATE, a municipal borough, market-town, and watering-place of Kent, England, is situated in the Isle of Thanet, 4 miles west of North Foreland, and by rail 90 miles east of London, with which it has also in summer daily steam communication by water. The streets of the town are regular and spacious, and there are many good villas in the suburbs. There is a marine terrace 2500 feet in length, parallel to which there is an esplanade. The pier, 900 feet long, was constructed by Rennie in 1810. A landing-place permitting the approach of vessels at all tides was constructed in 1854, and enlarged in 1876. The church of St John the Baptist, founded in 1050, contains some portions of Norman architecture, the remainder being Decorated and Late Perpendicular. It possesses several fine brasses and monuments. Among the other public buildings are the new town-hall, the market, the assembly rooms, the deaf and dumb asylum, and the royal sea-bathing infirmary, which has lately been much enlarged through the munificence of Sir Erasmus Wilson. The old name of Margate was *Meregate*, the entrance to the sea. Previous to the last century it was only a fishing village with a small coasting trade, but since then, owing principally to its fine stretch of sand, it has been steadily rising into favour as a watering-place, and is now one of the most favourite resorts of the middle classes of London. It received municipal privileges in 1857. The population of the municipal borough (384 acres) in 1871 was 11,995, and in 1881 it was 15,889.

MARGHILAN, Baber's Marghinan, 40° 28′ N. lat., 71° 45′ E. long., now the administrative centre of the Russian province of Ferghana (*q.v.*), a very old town, with high earthen walls and twelve gates, commanded by the fort of Yar Mazar, lies in a beautiful and extraordinarily fertile district of the same name, irrigated by canals from the Shahimardán river. The heat in summer is excessive. Population about 40,000, chiefly Usbeg. The principal industry is the production and manufacture of silk; camels' hair and woollen fabrics are also made. The new Russian town, planned by General Skobeleff, is 15 versts distant.

MARGUERITE de Valois. The name Marguerite was common in the Valois dynasty, and during the 16th century there were three princesses, all of whom figure in the political as well as in the literary history of the time, and who have been not unfrequently confounded. The first and last are the most important, but all deserve some account.

I. Marguerite d'Angoulême (1492–1549). This, the most celebrated of the Marguerites, bore no less than four surnames. By family she was entitled to the name of Marguerite de Valois; as the daughter of the Count d'Angoulême she is more properly and by careful writers almost invariably called Marguerite d'Angoulême. From her first husband she took during no small part of her life the appellation Marguerite d'Alençon, and from her second, Henri d'Albret, king of Navarre, that of Marguerite de Navarre. She was born at Angoulême on the 12th April 1492, and was two years older than her brother Francis I. She was betrothed early to Charles, Duke d'Alençon, and married him in 1509. She was not very fortunate in this first marriage, but her brother's accession to the throne made her, with their mother Louise of Savoy, the most powerful woman of the kingdom. She became a widow in 1525, and was sought in marriage by many persons of distinction, including, it is said, Charles V. and Henry VIII. In 1527 she married Henri d'Albret, titular king of Navarre, who was considerably younger than herself, and whose character was not faultless, but who seems on the whole, despite slander, to have both loved and valued his wife. Navarre was not reconquered for the couple as Francis had promised, but ample apanages were assigned to Marguerite, and at Nérac and Pau miniature courts were kept up, which yielded to none in Europe in the intellectual brilliancy of their frequenters. Marguerite was at once one of the chief patronesses of letters that France possessed, and the chief refuge and defender of advocates of the Reformed doctrines. Round her gathered Marot, Bonaventure Desperiers, Denisot, Peletier, Brodeau, and many other men of letters, while she protected Rabelais, Dolet, &c. For a time her influence with her brother was effectual, but latterly political rather than religious considerations made him discourage Lutheranism, and a fierce persecution was begun against both Protestants and freethinkers, a persecution which drove Desperiers to suicide and brought Dolet to the stake. Marguerite herself, however, was protected by her brother, and her personal inclinations seem to have been rather towards a mystical pietism than towards dogmatic Protestant sentiments. Nevertheless bigotry and the desire to tarnish the reputation of women of letters have led to the bringing of odious accusations against her character, for which there is not the smallest foundation. Marguerite died in 1549. By her first husband she had no children, by her second a son who died in infancy, and a daughter, Jeanne d'Albret, who became the mother of Henry IV. Although the poets of the time are unwearied in celebrating her charms, she does not, from the portraits which exist, appear to have been regularly beautiful, but as to her sweetness of disposition and strength of mind there is universal consent.

Her literary work has not yet been given entirely to the world, but the printed portion of it makes her a considerable figure in French literature. It consists of the *Heptameron*, of poems entitled *Les Marguerites de la Marguerite des Princesses*, and of *Letters*. The *Heptameron*, constructed as its name indicates on the lines of the *Decameron* of Boccaccio, consists of seventy-two short stories told to each other by a company of ladies and gentlemen who are stopped in the journey homewards from Cauterets by the swelling of a river. It was not printed till 1558, ten years after the author's death. Internal evidence is strongly in favour of its having been a joint work, in which more than one of the men of letters who composed Marguerite's household took part. It is a delightful book, and strongly characteristic of the French Renaissance. The sensuality which characterized the period appears in it, but in a less coarse form than in the great work of Rabelais; and there is a poetical spirit which, except in rare instances, is absent from *Pantagruel*. The *Letters* are interesting and good. The *Marguerites* consist of a very miscellaneous collection of poems, mysteries, farces, devotional poems of considerable length, spiritual and miscellaneous songs, &c. Other poems, said to be of equal merit, are still unprinted, or have appeared only in part.

II. The second MARGUERITE (1523–1574), daughter of Francis I., married the duke of Savoy in 1559. She is noteworthy as having given the chief impulse at the court of her brother Henry II. to the first efforts of the Pléiade.

III. The third MARGUERITE (1553–1615), called more particularly Marguerite de Valois, was great-niece of the first and niece of the second, being daughter of Henry II. by Catherine de' Medici. She was born in 1553. When very young she became famous for her beauty, her learning, and the looseness of her conduct. She was married to Henry of Navarre, afterwards Henry IV., on the eve of St Bartholomew's Day. Both husband and wife were extreme examples of the licentious manners of the time, but they not unfrequently lived together for considerable periods, and nearly always on good terms. Later, however, Marguerite was established in the castle of Usson in Auvergne, and after the accession of Henry the marriage was dissolved by the pope. But Henry and Marguerite still continued friends; she still bore the title of queen; she visited Marie de' Medici on equal terms; and the king frequently consulted her on important affairs, though his somewhat parsimonious spirit was grieved by her extravagance. Marguerite exhibited during the rest of her life, which was not a short one, the strange Valois mixture of licentiousness, pious exercises, and the cultivation of art and letters, and died in 1615. She left letters and memoirs, the latter of which are admirably written, and rank among the best of the 16th century. She is the "Reine Margot" of anecdotic history and romance.

The best editions of the works of Marguerite d'Angoulême are—of the *Heptameron*, that of Leroux de Lincy, 3 vols., Paris, 1855; of the *Letters*, that of Genin, Paris, 2 vols., 1842–43; and of the *Marguerites*, that of Frank, Paris, 4 vols., 1873; the *Heptameron* is also obtainable in several cheap editions. The *Mémoires* of Marguerite de Valois are contained in the collection of Michaud and Poujoulat, and have been published separately by Guessard, Lalanne, Caboche, &c. (G. SA.)

MARIA THERESA (1717–1780), archduchess of Austria, queen of Hungary and Bohemia, and empress of Germany, was the daughter of the emperor Charles VI. of Austria, by his wife Elizabeth Christina of Brunswick-Wolfenbüttel, and was born in Vienna on May 13, 1717. By the Pragmatic Sanction of 1713, a settlement which was guaranteed by the principal states of Europe, her father had regulated the succession in the imperial family; and in 1724 accordingly, after the death of the archduke Leopold, her only brother, she was publicly declared sole heiress of the Austrian dominions. In 1736 she married Francis Stephen of Lorraine, who in the following year became grand-duke of Tuscany; and on October 20, 1740, she came to the throne, her husband (emperor in 1745) being declared co-regent. The events of her reign have been briefly summarized under AUSTRIA (vol. iii. p. 127–129) and HUNGARY (xii. 370). She died at Vienna on November 29, 1780. Of sixteen children whom she bore to Francis, ten reached maturity. Her sons were Joseph II., who succeeded his father as Holy Roman emperor in 1765; Leopold, grand-duke of Tuscany, afterwards the emperor Leopold II.; Ferdinand, duke of Modena; and Maximilian, elector of Cologne. Of her daughters the best-known is Marie Antoinette, the wife of Louis XVI. of France.

MARIANA, JUAN DE (1536–1624), a celebrated Spanish historian, was born of obscure parentage at Talavera de la Reina in 1536. He studied at the university of Alcalá, and was admitted at the age of seventeen into the Society of Jesus, where he soon attracted notice by his brilliant talents and extensive acquirements. Called to the Collegium Romanum in 1561, he there professed theology four years, and reckoned among his pupils Robert Bellarmine, afterwards the famous cardinal. He then passed into Sicily, where he remained for about two years, and in 1569 he was sent to Paris, where his expositions of the writings of Aquinas attracted large audiences. In 1574 the decline of his health compelled him to give up teaching, and he obtained permission to return to Spain; the rest of his life was passed at the Jesuits' house in Toledo, in a vigorous literary activity which was interrupted only by the molestations to which his too great independence, liberality, and candour exposed him. He died on February 17, 1624.

His great work, *Historiæ de Rebus Hispaniæ*, first appeared in twenty books at Toledo in 1592; ten books were subsequently added (1605), bringing the work down to the accession of Charles V., and in a still later abstract of events the author completed it to the accession of Philip IV. in 1621. It was so well received that Mariana was induced to translate it into Spanish. The first part of this in some respects new work (*Historia de España*) appeared in 1601; it was completed in 1609, and much enlarged and improved in three subsequent editions which appeared during the translator's lifetime. It has been frequently reprinted since 1624, both in Latin and in Spanish; and an English translation by J. Stevens appeared in 1699. Mariana's *History* is justly esteemed for the extent of the author's researches, for the general accuracy of his acquaintance with the materials at his command, for the sagacity of his reflexions and characterizations, and above all for the merit of his style, which, in its simplicity, vividness, and directness, has deservedly been compared to that of Livy. The modern student may regret but can hardly blame the credulity with which in too many cases he has without the least attempt at historical criticism adopted the "received traditions of his country." Of the other works of Mariana, the most interesting is his treatise *De Rege et Regis Institutione*, of which the first edition, dedicated to Philip III., appeared at Toledo in 1599. In its sixth chapter the question whether it is lawful to overthrow a tyrant is freely discussed and answered in the affirmative,—a circumstance which brought much popular odium upon the Jesuits, especially after the assassination of Henry IV. of France in 1610. See Bayle's *Dictionnaire* and Hallam's *Literary History*, part ii. chap. iv. A volume entitled *Tractatus VII. Theologici et Historici*, published by Mariana at Cologne in 1609, containing in particular a tract "On Mortality and Immortality," and another "De Mutatione Monetæ," was put upon the Index Expurgatorius, and led to the confinement and punishment of its author by the Inquisition. During his confinement there was found among his papers a criticism upon the Jesuits (*De las Enfermedades de la Compañia de Jesus y de sus Remedios*), which was believed to have been written by him. It was not printed until after his death (1625).

MARIAZELL, a village in the duchy of Styria, Austria, with about 1200 inhabitants, is very picturesquely situated in the valley of the Salza, amid the Styrian Alps. Its entire claim to notice lies in the fact that it is the most frequented sanctuary in Austria, being visited annually by about 100,000 pilgrims. The object of veneration is a miracle-working image of the Virgin, carved in lime-tree wood, and about 18 inches high. This was presented to the place in 1157, and is now reverently enshrined in a chapel lavishly adorned with objects of silver and other costly materials. The large church of which the chapel forms part was erected in 1644 as an expansion of a smaller church built in 1363 by Louis I., king of Hungary, after a victory over the Turks. It possesses four lofty towers. In the immediate vicinity of Mariazell there is a very large and important iron foundry, formerly worked by Government, but now leased to a company.

MARIE ANTOINETTE, Josephe Jeanne (1755-1793), queen of France, was the fourth daughter of Maria Theresa and the emperor Francis I., and was born on the 2d November 1755, on the day of the great earthquake at Lisbon, and in the year in which the hereditary policy of enmity between the houses of France and Austria was changed to an alliance between them. From her earliest years she was destined by her mother to sustain this alliance, and was educated, with a view to a marriage with a French prince, by the Abbé de Vermond, who was to have a great influence on her future life. In 1770 Choiseul negotiated her marriage to the young dauphin, which took place on May 16 with the greatest pomp, but which was soon overshadowed by a terrible accident in Paris at the fête given in honour of the marriage. The dauphine soon found her position very difficult; she was but fourteen, and was intended by her mother to support the Austrian alliance and Choiseul at the court of France. This use of her daughters for political purposes has been recently denied by Von Arneth, the able editor of Maria Theresa's letters; but a consideration of the letters themselves confirms the idea, which was at the bottom of Marie Antoinette's unpopularity in France, that she was only an Austrian spy in a high position. She had hardly arrived at Paris, when her friend and the friend of the Austrian alliance, Choiseul, was dismissed from the ministry, and she was left alone to steer a difficult course by the advice of the Austrian minister, the Count de Mercy-Argenteau, whose reports of her daily doings to Maria Theresa have been published. In May 1774 Louis XV. died, and Marie Antoinette became queen of France. Through the first years of her reign she played a very important political part, but, except, as in the cases of Poland and the Bavarian succession, when her mother pressed her to maintain the alliance, she chiefly exerted her influence with regard to individuals, not to measures or policies. Thus she effected the dismissal of Turgot, and, by the Abbé de Vermond's advice, the summons of Loménie de Brienne to the ministry, not from political but from personal motives, and obtained enormous presents for her intimate friends without thinking that they were interested in her for selfish motives of their own. This political rôle of hers, which was more than suspected, made her intensely unpopular to the French people, and this feeling was increased by her social mistakes. Her extravagance in dress and her passion for the card-table had greatly incensed and disgusted her mother; and, when her mother's death removed her only frank and bold adviser, she became more extravagant and more frivolous than ever. Her passion for play, her love of amusement, her intimacy with the Polignacs and their wild and dissipated society, her night visits to masked balls in Paris, and her favours to many officers of her guards and young foreigners at her court were the subject of ribald conversation in every coterie of Paris. The scandal of the diamond necklace, in which the queen was not to blame, spread her name with infamy all over France as if she had been guilty; and among the people her extravagance was regarded as a potent cause of their poverty and want. Such was her unpopularity when the states-general met in May 1789; she was believed to be debauched and dissipated, when her real faults were that she was frivolous and careless of public opinion, Austrian at heart, though queen of France, and opposed to Necker as she had been to Turgot, and to all the reforms and economies her husband, Bonhomme Louis, was willing to institute. From July 14 onward Marie Antoinette headed the party of reaction and armed opposition to the Revolution, and became unwittingly the means of her husband's unpopularity and downfall; for she always had influence enough to prevent his carrying out the frank, honest policy of reform which he desired, but not enough to make him adopt hers in its stead, and is to blame for his vacillations in decisive moments. Left to himself, Louis would, from the beginning of his reign, have been a reforming king like Charles III. of Spain, and the great outbreak might have passed over. To trace her policy minutely from 1789 to 1793 is made very difficult by the numerous pretended letters of hers which have been published, and till recently believed in. She inspired the collection of foreign troops round Paris, contrary to the king's opinion, and thus brought on the taking of the Bastille. She was present at the banquet at Versailles which caused the march of the women to Versailles and the transference of the royal family to Paris. When there, she still looked forward to undoing all that had been done, and would never frankly recognize her position. When brought into negotiation with Mirabeau, she refused to trust him or deal frankly with him. Had she done so, she would probably have established a strong constitutional government, but she would not have been the self-willed Marie Antoinette. He advised her to go with the king and royal family to some provincial capital, declare the royal adherence to all the early acts of the assembly, but declare also that its later acts were passed under constraint, and were null and void; but she must not do two things—she must not fly towards the frontier, else she would be suspected of seeking foreign aid, and she must not depend on the army but the people. She would not act while Mirabeau was alive,—she was too independent to act by any one's advice; but when he was dead she did what he had advised her not to do, fled towards the frontier, and to Bouillé's army. The royal family were stopped at Varennes, and brought back to Paris, but from that time were regarded as traitors to France. She had yet two more chances. She might have thrown herself into the hands of Barnave, Duport, and the constitutional party of the constituent assembly, who were ready to rally round their constitutional king, but she would not trust them or take their advice. When she was at the end of her power, when the Tuileries had been stormed, and she was in prison, and the republic proclaimed, Dumouriez was ready, after his victory of Valmy, to turn his army on Paris, dissolve the Jacobins, and re-establish the old constitution, but she would not trust him. It was her last chance. When once the republic was proclaimed, it was evident that Louis must die both to cement its foundations and to remove a dangerous centre of reaction; and in January 1793 Marie Antoinette became a widow, never to the last recognizing that she had sacrificed her husband to her obstinacy and self-will. Harrowing descriptions have been given of her treatment in prison during the few remaining months of her life, but, though she was separated from her children, she had every material comfort, no less a sum than 1110 livres being spent on her food alone between August and October, at the rate of 15 livres a day. At last her trial came on,—a mock trial indeed, as all those of the time, for her execution was determined before she came before the tribunal. Much has been said of the shameful charges made against her; but, shameful as they were, they were based on a confession made by her son, which, though probably forced from him and utterly false, was yet put in evidence. The trial was soon over, and on the same day, October 16, 1793, she was guillotined.

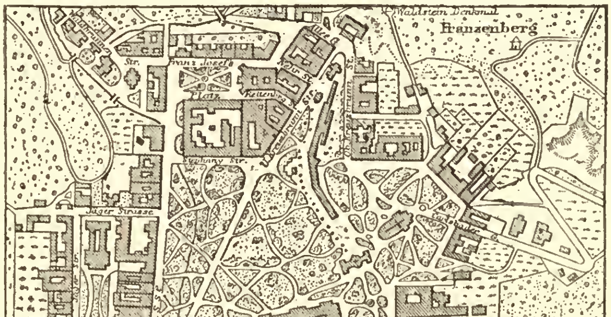
It is hard to speak of Marie Antoinette with justice; her faults were caused by her education and position rather than her nature, and she expiated them far more bitterly than was deserved. She was thoroughly imbued with the imperial and absolutist ideas of Maria Theresa, and had neither the heart nor the understanding to sympathize with the aspirations of the lower classes. Her love of pleasure and of display ruined both her character and her reputation in her prosperous years, and yet, after a careful examination of many of the libels against her, it may be asserted with confidence that she was personally a virtuous woman, though always appearing to be the very reverse. Innocence is not always its own protection, and circumspection is as necessary for a queen as for any other woman. Her conduct throughout the Revolution is heart-rending; we, who live after the troubled times, can see her errors and the results of her pride and her caprice, but at the time she was the only individual of the royal family who could inspire the devotion which is always paid to a strong character. In the Marie Antoinette who suffered on the guillotine we pity, not the pleasure-loving queen, not the widow, who had kept her husband against his will in the wrong course, not the woman, who throughout her married life did not scruple to show her contempt for her slow and heavy but good-natured and loving king, but the little princess, sacrificed to state policy, and cast uneducated and without a helper into the frivolous court of France, not to be loved, but to be suspected by all around her, and eventually to be hated by the whole people of France.

For lives and memoirs of Marie Antoinette before 1863, as well as engravings of her, the student is referred to a complete and careful bio-bibliography, contained in M. de Lescure's *La Vraie Marie Antoinette*, Paris, 1863. This work, however, contains many forged letters, purporting to be hers, and leads to the question of Marie Antoinette's published letters. There can be no doubt that very many fabrications by autograph makers for autograph collectors are published as authentic in D'Hunolstein, *Correspondance inédite de Marie Antoinette*, Paris, 1864; and in Feuillet des Conches, *Louis XVI., Marie Antoinette, et Madame Elisabeth, lettres et documents inédites*, Paris, 1865. The falsity of these letters was shown by Professor Von Sybel and by M. Geffroy in the *Revue des Deux Mondes*, and still more clearly in the latter's appendix to his *Gustave III. et la cour de France*, Paris, 1867. To study Marie Antoinette as she really lived, the student must consult Von Arneth's numerous publications on her and her mother and brothers, and particularly Arneth and Geffroy, *Marie Antoinette: Correspondance secrète entre Marie-Thérèse et le Comte de Mercy-Argenteau*, Paris, 3 vols., 1874, in which Marie Antoinette's daily life for ten years, from 1770–80, is described for her mother's own eyes. For the affair of the necklace read Carlyle's *Essay*. For her imprisonment, trial, and execution, see Campardon's *Tribunal Révolutionnaire*, vol. i., and the same author's *Marie Antoinette à la Conciergerie*, Paris, 1863. (H. M. S.)

MARIE DE FRANCE is one of the most interesting figures in the literary history of the Middle Ages. She is also one of the most mysterious. Nothing is known of her except from her own statements, which amount to little more than that her name was Marie and her country France, that she dedicated one of her works to an unnamed king, and another to a certain Count William. She is mentioned by Denis Pyramus, who was her contemporary, and who says that she was very popular, but gives no particulars. Attempts have been made to identify conjecturally the king and the count,—the most probable hypotheses being that the former was Henry III. of England, and the latter William Longsword of Salisbury; that is to say, Marie lived in the first half of the 13th century, and rather towards the beginning than the end of that half. Her work which remains to us is entirely poetical, and by no means inconsiderable in extent. It falls naturally into three divisions. The first consists of *lais* or narrative poems in octosyllabic couplets. There are fourteen of them, the titles being *Gugemer*, *Equitan*, *Le Frêne*, *Le Bisclavaret*, *Lanval*, *Les deux amants*, *Ywenec*, *Le Laustic* ("the Nightingale"), *Milon*, *Le Chaitivel* ("the Unhappy One"), *Le Chèvrefeuille*, *Eliduc*, *Graelent*, *L'Épine*. The longest of these contains nearly twelve hundred lines; the shortest only just exceeds a hundred. The term *lai* is of Breton origin, and is believed to have had reference originally to the kind of music to which it was performed. But in Marie it is simply a short romance, generally of an amatory character. The merits of these poems are very great. They have much tenderness and delicacy of expression, flowing and melodious verse, and not a little descriptive power. The dialect is decidedly Norman in character, and English words occasionally occur, but are invariably explained in French. Some of these poems were paraphrased by the late Mr O'Shaughnessy in his *Lays of France* (London, 1872), but the translator indulged to such an extent in amplification that the effect is very dissimilar to that of the original. The second division of Marie's work is of less poetical but of greater general interest. It consists of an *Ysopet* (a general term in the Middle Ages for a collection of fables) of one hundred and three fables, of which Marie tells us that Henry Beauclerk translated it from Latin into English, and that for the love of Count William, "the most valiant of this realm," she herself rhymed it from English into French. The fables are exceedingly well told, with a liveliness, elegance of verse, and ingenious aptness of moral which make Marie a worthy forerunner of La Fontaine. The question has been debated whether the great fabulist was acquainted with her work. All that can be said is that, though it is by no means impossible, and from internal evidence not even wholly improbable, it cannot be said to be very likely. The third of Marie's works is a poem of two thousand three hundred verses, describing the purgatory of Saint Patrick, written at the request of an unidentified "prudom," or man of worship. Marie has been longer and better known than most of the poets of mediæval France, and perhaps she has been relatively a little overvalued, but her positive excellence is very considerable. Her style is a good example of the pure and highly organized language of the 13th century; and despite its great age it can be read by any person acquainted with modern French with a very small expense of attention, and with but slight use of glossaries.

The standard edition of Marie's works is by B. de Roquefort, 2 vols., Paris, 1820.

MARIENBAD, one of the prettiest and most frequented watering-places on the Continent of Europe, with a station (about $1\frac{1}{4}$ miles S.E. of the town) on the Kaiser Franz Josephs Railway, lies in a pleasant valley in the district of Tepl, in the north-west of Bohemia, about 18 miles south of Carlsbad, and nearly 2000 feet above the level of the sea. The gently-sloping hills which enclose it on all sides except the south are picturesquely wooded with fragrant pine forests. The town has an attractive and clean appearance, and is amply provided with buildings for the lodging and amusement of its thirteen thousand annual visitors, including a theatre and a large kurhaus. The handsome Roman Catholic church and the tasteful little



Plan of Marienbad.

English church are among the chief ornaments of the place. The springs resemble those of Carlsbad, except that they are cold, and contain nearly twice the quantity of purgative salts. The water is used both internally and externally, and is deemed efficacious in disorders of the stomach and other organs, skin diseases, gout, and nervous complaints. About one million bottles are annually exported. The curative appliances of Marienbad also include the use of goats' milk whey, and peat, pine-cone, and gas baths. The climate is healthy and bracing, the mean annual temperature being about 45° Fahr. The springs of Marienbad, though previously used by the peasantry of the district, first came into general notice about the beginning of this century through the instrumentality of Dr Nehr, to whom a monument was erected here in 1857. They belong to the rich abbey of Tepl, which lies about 9 miles to the east. The permanent population of Marienbad was 2009 at the census of 1880.

MARIENBURG (in Polish, *Malborg*), the chief town of a circle in the district of Dantzic, Prussia, lies 30 miles to the south-east of Dantzic, in a fertile plain on the right bank of the Nogat, a channel of the Vistula, here spanned by a handsome railway bridge and by a bridge of boats. Marienburg contains a large chemical wool-cleaning work and several other factories, carries on a considerable trade in grain, wood, linen, feathers, and brushes, and is the seat of important cattle, horse, and wool markets. Its educational institutions include a gymnasium and a Protestant normal school. In the old market-place, many of the houses in which are built with arcades in the Italian style, stands a Gothic town-house, dating from the end of the 14th century. The town is also embellished with a good statue of Frederick the Great, who added this district to Prussia, and a monument commemorating the war of 1870–71. The population in 1880 was 9559. Marienburg is chiefly interesting from its having been for a century and a half the residence of the grand masters of the Teutonic order. The large castle of the order here was originally founded in 1274 as the seat of a simple commandery against the pagan Prussians, but in 1309 the headquarters of the grand master were transferred hither from Venice, and the "Marienburger Schloss" soon became one of the largest and most strongly fortified buildings in Germany. On the decline of the order in the middle of the 15th century, the castle passed into the hands of the Poles, by whom it was allowed to fall into neglect and decay. It came into the possession of Prussia in 1772, and was carefully restored at the beginning of the present century. This interesting and curious building consists of three parts, the Alte or Hohe Schloss, the Mittel Schloss, and the Vorburg. It is built of brick, in a style of architecture peculiar to the Baltic provinces, and is undoubtedly one of the most important secular buildings of the Middle Ages in Germany.

Of the numerous monographs published in Germany on the castle of Marienburg, it will suffice to mention here Büsching's *Schloss der Deutschen Ritter zu Marienburg*, Berlin, 1828; Voigt's *Geschichte von Marienburg*, Königsberg, 1824; and Bergau's *Ordenshaupthaus Marienburg*, Berlin, 1871.

MARIETTA, a city of the United States, the capital of Washington county, Ohio, lies on the right bank of the Ohio, at the mouth of the Muskingum, 85 miles south-east of Columbus, and is the eastern terminus of the Marietta and Cincinnati Railroad, and the southern terminus of the Cleveland and Marietta Railroad. The surrounding country being rich in petroleum, iron, and coal, the city has become the seat of no inconsiderable industry in the shape of oil-works, iron foundries, and machine-shops, a rolling mill, tanneries, and carriage, car, bucket, and chair factories. Marietta College, chartered in 1835, and maintained by voluntary endowment and subscription, is a flourishing institution, with eight instructors and a library of 25,000 volumes, occupying a fine group of buildings in the midst of extensive grounds. The population of the city has risen from 3175 in 1850 to 5444 in 1880. At the latter date the township, which includes the village of Harmar (1572), contained 8830 persons.

Marietta, founded in 1788 by General Putnam, and named in honour of Marie Antoinette, is the oldest town in Ohio. It is built on the site of a remarkable group of prehistoric monuments, the largest of which are two enclosures, respectively 40 and 20 acres in extent, formed by walls from 20 to 30 feet broad at the base, and still in some places 5 and 6 feet high. See Squier and Davis, *Ancient Monuments of the Mississippi Valley*.

MARIETTE, AUGUSTE FERDINAND FRANÇOIS, elder son of François P. Mariette, advocate and town-clerk of Boulogne-sur-Mer, was born in that town on the 11th of February 1821. Educated at the Boulogne municipal college, he distinguished himself in geometry, physics, chemistry, history, Latin, Greek, and English. He also evinced a remarkable talent for art. In 1839, when but eighteen years of age, he went to England in the capacity of professor of French and drawing at a boys' school at Stratford-on-Avon, which occupation he exchanged in 1840 for that of pattern-designer to a ribbon manufacturer at Coventry. Weary of ill-paid exile, he returned that same year to Boulogne, resumed his interrupted studies, and in March 1841 took his bachelor's degree (with honourable mention) at Douai. He now became a professor at the college where he had formerly been a student, and for some years supplemented his modest salary by giving private lessons, and writing on historical and archæological subjects for various local periodicals. In the meanwhile his cousin, Nestor L'Hôte, the friend and fellow-traveller of Champollion, died; and upon Auguste Mariette devolved the pious task of sorting the multitudinous papers of the deceased savant. The young man thenceforth became passionately interested in Egyptology, devoted himself to the study of hieroglyphs and Coptic, and in 1847 published a *Catalogue Analytique* of the Egyptian Gallery of the Boulogne Museum. He had now found his vocation, and in 1849, being appointed to a subordinate position in the Louvre, left Boulogne for Paris. Entrusted shortly after with a Government mission for the purpose of seeking and purchasing Coptic, Syriac, Arabic, and Ethiopic MSS. for the national collection, he started for Egypt in 1850. Soon after his arrival he made his celebrated discovery of the ruins of the Serapeum and the subterraneous catacombs of the Apis-bulls, buried for probably some two thousand years under the sands of the Libyan desert (see vol. vii. p. 773). His original mission being abandoned, funds were now advanced for the prosecution of his researches, and he remained in Egypt for four years, excavating, discovering, and despatching archæological treasures to the Louvre, of which museum he was, on his return, appointed an assistant conservator. In 1858, by permission of his own Government, he accepted the position of conservator of Egyptian monuments to the ex-khedive, Ismail-Pasha, and so removed with his family to Cairo. His history thenceforth becomes a chronicle of unwearied exploration and brilliant success. The pyramid-fields of Memphis and Sakkara, and the necropolises of Meydum, Abydos, and Thebes were ransacked for sepulchral treasures; the great temples of Denderah and Edfoo were disinterred, and, with their tens of thousands of inscriptions and bas-reliefs, restored to the light of day; important excavations were carried out at Karnak, Medinet-Habu, and Deir-el-Bahari; Tanis (the Zoan of the Bible) was partially explored in the Delta; and even Gebel Barkal in the far Soudan was made to yield monuments of the Ethiopic kings. The Sphinx was also bared to the rock-level, and the famous granite and alabaster monument miscalled the "Temple of the Sphinx" was discovered. In the meanwhile Mariette, raised successively to the rank of bey and then of pasha, had founded the "École Française d'Égyptologie" and the "Institut Égyptien," and created *ab ovo* the museum at Bulak, the richest and by far the most interesting Egyptian collection in the world. Honours and orders were showered upon him. Poor in purse but rich in fame, he received in 1852 the grand cross of the Legion of Honour and of the Medjidie, in 1855 the Red Eagle (first class) of Prussia, in 1857 the Italian order of SS. Maurice and Lazarus, and in 1858 the Austrian order of Francis-Joseph. In 1873 the Academy of Inscriptions decreed to him the great biennial prize of 20,000 francs, and in 1878 he was elected a member of the Institute. He was also an honorary member of most of the learned societies of Europe. Though of herculean strength and indomitable energy, he was not proof against over-work of all kinds, physical, mental, and official. Prostrated in 1877 by a first attack of the insidious malady from which only death released him, he lingered for a few years, working to the last, and died at Cairo January 19, 1881. His remains, enclosed in an ancient Egyptian sarcophagus chosen by himself for that purpose, are interred within the precincts of the museum-garden at Bulak, facing the entrance to that unrivalled collection which is his own noblest monument.

Of Mariette's numerous and important contributions to the literature of Egyptology, we may here especially note the following works, which are not only distinguished for their erudition and accuracy, but for the exquisite grace of style with which they are written:—*Le Sérapéum de Memphis*, folio, 1857 and following years; *Dendérah*, five folios and one 4to, 1873–75; *Abydos*, two folios and one 4to, 1870–80; *Karnak*, folio and 4to, 1875; *Deir-el-Bahari*, folio and 4to, 1877; *Listes géographiques des pylônes de Karnak*, folio, 1875; *Catalogue du Musée de Boulaq*, six editions, 1864–76; *Aperçu de l'histoire d'Égypte*, four editions, 1864–74, &c. His last, and one of his most important works, *Les Mastabas de l'Ancien Empire*, text and illustrations facsimiled from the original MSS., folio, is now in course of publication, edited by Professor G. Maspero.

MARIGNOLLI, GIOVANNI DE', a notable traveller to the far East of the 14th century, born probably prior to 1290, and sprung from a noble family in Florence. The family is long extinct, but a street near the cathedral (Via de' Cerretani) formerly bore the name of the Marignolli.

In vol. v. pp. 628–29 some account has been given of the extraordinary episode of intercourse between Europe and China in the first half of the 14th century. In 1338 there arrived at Avignon, where Benedict XII. held his court, an embassy from the great khan of Cathay, bearing letters to the pontiff from the khan himself, and from certain Christian nobles of the Alan race in his service. These latter represented that they had been eight years without a spiritual guide, and earnestly desired one. The pope replied to the letters, and appointed four ecclesiastics as his legates to the khan's court. The name of Marignolli, a Franciscan of some repute for learning, appears, as John of Florence, third on the letters of commission. We know not what became of his colleagues; he was the chief if not the sole envoy who actually went.

The mission left Avignon in December 1338, picked up the Tartar envoys at Naples, and sailed across the Black Sea to Caffa, whence they travelled to the court of Mohammed Uzbek, khan of the Golden Horde, at Sarai on the Volga. The khan entertained them hospitably during the winter of 1339–40, and then sent them across the steppes to Armalec or Almaligh, the northern seat of the house of Chaghatai, in what is now the province of Ili. "There," says Marignolli, "we built a church, bought a piece of ground . . . . sung masses, and baptized several persons, notwithstanding that only the year before the bishop and six other minor friars had there undergone glorious martyrdom for Christ's salvation." Quitting Almaligh in 1341, they seem to have reached Peking (by way of Kamil or Hami) in May or June 1342. They were well received by the reigning khan, the last of the Mongol dynasty in China.

"The grand kaam, when he beheld the great horses (*dextrarios*) and the pope's presents, with his letter, and that of King Robert (of Naples) too, with their golden seals, and when he saw us also, rejoiced greatly, being delighted, yea exceedingly delighted with everything. . . . And when I entered the kaam's presence, it was in full festival vestments, with a very fine cross carried before me, and candles and incense, whilst *Credo in unum Deum* was chaunted, in that glorious palace where he dwells. And when the chaunt was ended I bestowed a full benediction, which he received with all humility."

An entry in the Chinese annals fixes the year of Marignolli's presentation by its mention of the arrival of the great horses from the kingdom of Fulang (*Farang* or Europe), one of which was 11 feet 6 inches in length, and 6 feet 8 inches high, and black all over!

Marignolli stayed at Peking or Cambalec three or four years, after which he travelled through eastern China to Zayton or CHINCHEW (*q.v.*), quitting China apparently in December 1347, and reaching Columbum (Kaulam or Quilon in Malabar) in Easter week of 1348. At this place he found a church of the Latin communion, probably founded by Jordanus of Séverac, who had been consecrated bishop of Columbum by Pope John XXII. in 1328. Here Marignolli remained sixteen months, after which he proceeded on what seems a most devious voyage. First he visited the shrine of St Thomas near the modern Madras, and then proceeded to what he calls the kingdom of Saba, and identifies with the Sheba of Scripture, but which seems from various particulars to have been Java. Taking ship again for Malabar on his way to Europe, he encountered great storms, of which he gives an imaginative account:—

. . . . "The sea as if in flames, and fire-spitting dragons flying by, which, as they passed, slew persons on board the other junks, whilst ours remained untouched, by God's grace, and by virtue of the Body of Christ which I carried with me, and through the merits of the glorious Virgin and of St Clare."

They found shelter in the little port of *Pervilis* (Beruwala or Berberyn) in the south-west of Ceylon; but here the legate fell into the hands of "a certain tyrant Coya Jan (Khoja Jahán), an eunuch and an accursed Saracen," who professed to treat him with all deference, but detained him four months, and plundered all the gifts and Eastern rarities that he was carrying home. This detention in "Seyllan" enables Marignolli to give a variety of curious particulars regarding Adam's Peak and other marvels. After this we have only fragmentary notices, showing that his route to Europe lay by Ormuz, the ruins of Babel, Baghdad, Mosul, Aleppo ("where there were many Christians who dressed after the Latin fashion, and spoke a language very near the French; at any rate like the French of Cyprus"), and thence to Damascus and Jerusalem. In 1353 he arrived at Avignon, and delivered a letter from the great khan to Pope Innocent VI. In the following year the emperor Charles IV., on a visit to Italy, made Marignolli one of his chaplains. Soon after, the pope made him bishop of Bisignano; but he seems to have been in no hurry to reside there. He appears to have accompanied the emperor to Prague; in 1356 he is found acting as envoy to the pope from Florence; and in 1357 he is at Bologna. We know not when he died. The last trace of Marignolli is a letter addressed to him, which was found last century among the records in the Chapter Library at Prague. The writer is an unnamed bishop of Armagh, easily identified with Richard Fitz Ralph, a strenuous foe of the Franciscans, who had broken lances in controversy with Ockham and Burley. The letter implies that some intention had been intimated from Avignon of sending

Marignolli to Ireland in connexion with matters then in debate. The wrath of Fitz Ralph is sorely stirred at this, and he brandishes the shillelah in a style of energetic metaphor very like what we have been used to from like quarters in later days.

Fitz Ralph's contemptuous language had probably a good deal of foundation. The fragmentary notes of Marignolli's Eastern travels often contain most vivid remembrance and graphic description, but combined with an incontinent vanity, and an incoherent lapse from one thing to another, matched by nothing in literature but the conversation of Mrs Nickleby. They have no claim to be called a narrative, and it is with no small pains that anything like a narrative can be pieced out of them. Indeed the mode in which they were elicited curiously illustrates how little mediæval travellers thought of publication. The emperor Charles, instead of urging his chaplain to write a history of his vast journeys, set him to the repugnant task of recasting the annals of Bohemia; and he consoled himself by salting the insipid stuff by interpolations, *à propos de bottes*, of his recollections of Asiatic travel.

Nobody seems to have noticed the work till 1768, when the chronicle was published in vol. ii. of the *Monumenta Hist. Bohemiæ nusquam antehac edita* by Father Gelasius Dobner. But, though Marignolli was thus at last in type, no one seems to have read him till 1820, when an interesting paper on his travels was published by J. G. Meinert. The late Professor Kunstmann of Munich also devoted to the subject one of a series of very intelligent papers on the ecclesiastical travellers of the Middle Ages. And the whole of the passages bearing on the journey were excerpted, translated, and commented on by Col. H. Yule in a collection printed in 1866.

Monumenta Historica, &c., collegit, &c., P. Gelasius Dobner a S. Catherina, tom. ii., Prague, 1768; Meinert, in *Abhandl. der K. Böhm. Gesellsch. der Wissenschaften*, vii.; Kunstmann, in *Historische Politische Blättern von Phillips und Görres*, Bd. xxxviii. pp. 701, 793, Munich, 1859; Wadding, *Annales Minorum*, vii.; Sbaralea, *Supplem. et Castigatio ad Scriptores Trium Ordd. S. Francisci a Waddingo*, Rome, 1806; *Cathay and the Way Thither*, Hak. Soc., 1866. (H. Y.)

MARIGOLD. This name has been given to several plants, of which the following are the best known:—*Calendula officinalis*, L., the pot-marigold; *Tagetes erecta*, L., the African marigold; *T. patula*, L., the French marigold; and *Chrysanthemum segetum*, the corn marigold. All these belong to the order *Compositæ*; but *Caltha palustris*, L., the marsh marigold, is a ranunculaceous plant.

The first-mentioned is the familiar garden plant with large orange-coloured blossoms, and is a native of the meadows of southern Europe (DC., *Prod.*, vi. p. 451). It is unisexual, the "ray" florets being female, the "disk" florets male. This and the double variety have been in cultivation for at least three hundred years, as well as a proliferous form, *C. prolifera*, or the "fruitful marigolde" of Gerard (*Herball*, p. 602), in which small flower-heads proceed from beneath the circumference of the flower. The figure of "the greatest double marigold," *C. multiflora maxima*, given by Gerard (*l.c.*, p. 600) is larger than most specimens now seen, being 3 inches in diameter. He remarks of "the marigolde" that it is called *Calendula* "as it is to be seene to flower in the calends of almost euerie moneth." It was supposed to have several specific virtues, but they are now discredited. "The marigold, that goes to bed wi' the sun," is mentioned by Shakespeare, *Winter's Tale*, iv. 3.

Tagetes patula, L., and *T. erecta*, L. (DC., *Prod.*, v. p. 643), the French and African marigolds, are natives of Mexico, and are equally familiar garden plants, having been long in cultivation. Gerard figures four varieties of *Flos africanus*, of the single and double kinds (*l.c.*, p. 609); but they do not appear to be specifically distinct; indeed Parkinson (*Par.*, p. 303, 1629) regarded them as one. Besides the above species the following have been introduced later, *T. lucida*, Cav., *T. signata*, also from Mexico, and *T. tenuifolia*, Cav., from Peru (Hemsley's *Handbook of Hardy Trees*, &c., p. 247).

Chrysanthemum segetum, L., the yellow corn marigold, is indigenous to Great Britain, and is frequent in corn-fields in most parts of England. A decoction of the fresh plant gathered before flowering is acrid, and is said to be useful medicinally. When dried it has been employed as hay It is also used in Germany for dyeing yellow (Baxter, *Brit. Gen. of Pl.*, vol. iv. 306). Gerard observes that in his day "the stalke and leaues of Corne Marigolde, as Dioscorides saith, are eaten as other potherbes are."

Caltha palustris, L., the marsh marigold, the "winking Mary-buds" of Shakespeare (*Cymb.*, ii. 3), is a common British plant in marshy meadows and beside water. It bears cordate leaves, the flowers having a golden yellow calyx but no corolla, and blossoming in March and April. The flower-buds preserved in salted vinegar are a good substitute for capers. A double-flowered variety is often cultivated, and is occasionally found wild (Baxter, *l.c.*, vol. ii. 153).

MARINES. With all maritime nations, especially if they be insular and capable of taking the offensive in war, there must frequently be cases in which naval operations can be supplemented by the landing of a force. The armament, equipment, and discipline of the armies and navies of such nations were in early days practically alike. But with the introduction of more regular levies and better organization arose the necessity for having on board ships-of-war an armed body organized to meet the altered condition of things. Sailors were but engaged for periods during which ships were commissioned; and their previous history and training did not tend to furnish the material required. Regular armies on shore called for disciplined forces afloat,—that is to say, for marines, or sea soldiers, who should have the steadiness of the troops of the line, be accustomed to the peculiar duties of ship life, and be subordinate to the naval authorities.

Previous to 1664 the British navy had been manned chiefly by "impress"; but in that year an order in council appeared, authorizing the formation of a force of 1200 soldiers, in six companies, to be raised for sea service during the Dutch War. Probably it was recruited from the London Trained Bands, as the Royal Marines, with the 3d battalion of the Grenadier Guards, the East Kent Regiment, and the Royal London Militia, alone possess the privilege of marching through the city with colours flying and bayonets fixed. Recruits were also obtained from the foot guards; and in 1672 companies of the guards were employed on shipboard. The Army List of 1684 shows for the first time the organized battalion of marines, in H.R.H. the duke of York and Albany's maritime regiment of foot or "Admiral's Regiment," which, in that year, mustered on Putney Heath twelve companies, with a full proportion of officers. This stood third in seniority in the line, and eventually became the Coldstream Guards; the 4th, or "Holland Regiment," which also sent companies to sea, and had like the above regiment been raised by the City of London, taking its place as 3d or "Old Buffs." Several other maritime regiments were successively formed and disbanded, until, in 1702, Queen Anne directed the addition to the army of six regiments as a marine corps, while six existing regiments were also appointed "for sea service." These were done away with in 1714, three only being retained, as the 30th, 31st, and 32d of the line. Independent companies, for service in the West Indies, were also formed, becoming in 1742 the 49th foot. In 1739 six fresh regiments were levied, and augmented in 1742 to ten, of 1000 men in ten companies each; while three others were collected in America for colonial duty. Though commanded by generals and colonels of the army, they were to be quartered in the neighbourhood of the dockyards at Portsmouth, Sheerness, Chatham, Deptford, Woolwich, and Plymouth; and the proportion of officers, viz., 100 men with a captain to twenty with a subaltern, was fixed for the different classes of vessels. No field officer was embarked unless a full battalion were sent. In

1745 two other battalions were specially raised for service at Cape Breton, becoming finally the 50th and 51st foot; and in 1746 the ten regiments were restored to the army, taking rank from the 44th to the 53d. Previous to their disbandment as marines they had been partially under the orders of the lord high admiral.

By an order in council of 1755 a force of 5000 men in 50 companies was raised and definitely placed under the naval authorities. They were to be stationed at Chatham, Portsmouth, and Plymouth, the 4th or Woolwich division not being added until 1805; and this body was gradually increased to 19,000 men in 1762, but reduced in 1763 to about 4000. Commissions ceased to be purchasable, but exchange with the army was, for a time, sanctioned. Naval admirals and captains were appointed generals and colonels of marines in 1760, in consequence of a representation from the commandants of divisions that there was an insufficient number of field officers "for the discipline of the service." This absurd anomaly existed until 1833, when these useless sinecures were abolished.

The revolt of the American colonies in 1775 led, again, to an increase in the establishment, which by 1783 had reached 25,291 men,—followed by a reduction to 4495 the ensuing year. So urgent was the demand for marines during the struggle that men were frequently embarked untrained; yet, so popular was the service, they still "recruited better in every part of the island" than the army. Owing to this unwise policy of reduction, the force, on the outbreak of the French War in 1793, had to be supplemented, as formerly, by companies from the line; and at its conclusion the marine corps again reached a total strength of more than 30,000 men. But there had been differences between the military and naval authorities as to the employment of soldiers from the army; so that from 1815, when the numbers again fell to about 6000, there has been a steady increase, until an establishment suitable to the wants of the navy has been fixed. During the long war, moreover, the necessity for the formation of a body of marine artillery had become increasingly apparent. The services of marines in this capacity had been previously demanded during the American War, when they were employed in the half-moon battery and citadel at Halifax, and elsewhere in batteries on shore, as some of them had been "trained in the service of great guns" by Lieutenant Gillespie of the Royal Artillery. By an order in council of the 18th August 1804, therefore, "in consequence of the inconvenience of embarking the Royal Artillery," it was directed that one company of marine artillery, composed of the most intelligent and experienced officers and men, should be formed at each division to be employed for the training of the infantry, so as to embark efficient artillerymen in other vessels besides "bombs." This force suffered a reduction to two companies in 1822, since which date it also has been steadily increased; and in 1862 the artillery companies were separated from the light infantry and formed into a separate division at Fort Cumberland, Portsmouth, whence the headquarters were transferred to Eastney in 1869. In 1869 the Woolwich division was abolished, a depôt for the training of recruits being formed at Walmer. At present the Royal Marine force numbers 48 companies of infantry and 16 of artillery, showing a total force of 2532 artillery and 9862 infantry, at an expenditure of £913,456.

Each division of Royal Marines has a total force of 16 companies, with a colonel commandant, second commandant, 4 lieutenant-colonels, 14 majors, 20 captains, and 42 subalterns, inclusive of the divisional staff of instructors of gunnery, musketry, &c. The headquarter staff, in London, consists of a deputy and an assistant adjutant-general, &c.; and there are, in addition, three generals, three lieutenant-generals, and six major-generals on the active list. The men are recruited by special parties; they are enlisted for twelve years, with permission to re-engage for nine more. All recruits undergo their preliminary training at Walmer, and are then drafted to the several divisions,—those who reach a higher standard being allowed to volunteer for the artillery. The standard for infantry and artillery, and the system of pay, equipment, pension, and divisional administration, are similar to those of the line and Royal Artillery respectively. Officers are obtained by open competition from the pass-lists for entrance to the Military Academy, Woolwich, and the Royal Military College, Sandhurst. The successful infantry candidates are drafted to their several divisions, and undergo a course of instruction under the military instructor to the corps,—those for the artillery receiving a special training for two years at the Royal Naval College, Greenwich.

The Royal Marines, reckoning as part of the naval forces, are accounted for in the navy estimates; though the names of the officers appear both in the Army and Navy Lists. They are particularized in the Army Act as subject to military law at stated times, serving on shore under the Act and the regulations in force in the garrisons, where they perform the same duties as the land forces. Afloat they are subject to the Naval Discipline Act; and a Marine Mutiny Act was formerly passed annually for the "regulation of Her Majesty's Royal Marine forces while on shore," stating that they were under the direction of the lord high admiral, &c. On board ship their duties are of a purely military character, being confined to guard mounting, assisting to man boats for shore operations, and helping to form the crews for the heavy guns. Though under the supreme command of the naval authorities, they are only obliged to aid in work on deck, and when landed are entirely commanded by their own officers.

The war services of the corps are so numerous that they can be but briefly referred to. First employed at Cork in 1690, they have been present in nearly all the actions in which the navy has since then been engaged; and between that date and 1800 they took part in 227 sea fights and 70 important operations on shore. At Gibraltar and Manila, at Belleisle and Bunker's Hill, at Negapatam, the Cape, and Acre, they earned the special commendation of the leaders, as well as for Lord Howe's victory, and the great sea fights of Camperdown, Cape St Vincent, and the Nile. Nor were their enemies backward in recognizing their worth. At Belleisle the French, in describing the troops whose valour had been most conspicuous, designated the battalions of marines "les petits grenadiers"; and at Acre General Berthier bore testimony to the conspicuous gallantry of Major Oldfield, who fell in the attack on the fortress. From 1800 to 1815 they saw constant service in 99 coast operations and 142 naval actions. After the landing at Aboukir Bay in 1801 the "Bull Dogs" received high praise for the way in which they had done their work. At the siege of Gaeta, at Rosas, and at Santa Maura, the marines again distinguished themselves; and they took part in the decisive battles at Copenhagen, Trafalgar, San Domingo, and the Dardanelles. Three battalions were also specially brigaded with the line for active service in America and Holland in 1813-15. Since that period the marines have shared in the naval actions at Algiers, Navarino, Acre, the Baltic, and Black Sea, and have fought by the side of the land forces at the Cape, in India, China, New Zealand, Abyssinia, Ashantee, and Zululand, as also in those numerous petty skirmishes in which the navy has been so repeatedly engaged. In the bombardment of Alexandria (1882), and in the operations that followed it, the corps has again seen service by sea and land. Nor have their services been less important in other cases. Though forming part of the ships' companies, and therefore at times suffering from the same grievances, they have always been faithful to their trust. In 1797, a period of much sedition throughout the country, all efforts to shake their allegiance were fruitless, and the duke of York especially commended their loyalty and zeal. Between that year and 1802, after the mutinies of the Nore, Spithead, and Bantry Bay, of the "Temeraire," "Castor," "Impétueux," "Hermione," "Gibraltar," and "Excellent," the marines were publicly thanked for their devotion.

As part of a ship's company in naval actions, as a force landed to assist in coast operations, and as troops acting in concert with the army, the marines have won distinction and the commendation of both naval and military authorities for two hundred years. The motto of the corps, "Per mare per terram," needs no explanation; the title "Royal" was added in 1802 "for its many and varied services during the war," and its former facings were altered from white to royal blue; it was also in 1820, by an order in council, placed next in seniority to the 49th Regiment. In 1827 the globe, surrounded by the laurel wreath, for the siege of Belleisle, together with "Gibraltar," in commemoration of the services performed there, was added by George IV. In 1855 the infantry branch of the corps became "light infantry."

Although in the "armed strengths" of the great European powers marines and marine artillery are mentioned, these troops have little in common with those in the British navy. In France their duties are to garrison the five military ports and colonies, and to take part in marine and other wars. In Germany the marine battalions and artillery divisions at Kiel and Wilhelmshafen are intended for coast defence only. In Holland, Austria, and Italy also they have a military organization, but do not form a recognized part of the complements of sea-going ships. America alone employs marines in the same manner as England; and they have won, as their British comrades have, the approbation of the naval authorities and, on nineteen occasions, the thanks of Congress. Admiral Farragut's opinion that "the marine guard is one of the great essentials of a man-of-war" is corroborated by that of Admiral Wilkes, who considered that "marines constituted the great difference between a man-of-war and a privateer." Formed in 1775 for the "publick defense," they rank as the oldest force in the American service; and since that time they have shared in land and sea operations in all parts of the world. In the famous battles between the "Bonhomme Richard" and "Serapis" in 1777, and in that between the "Chesapeake" and "Shannon," they displayed brilliant gallantry; and while on the one hand they at Derne in 1803 first planted the American flag on a fortress of the Old World, for which exploit "Tripoli" is inscribed on their colours, they on the other shared in the hard fighting of the Mexican war as well as all the important coast actions of the civil war of 1861-65. A proposal to incorporate them with the army after the struggle met with universal condemnation from the authorities best qualified to judge of their value. At present they number seventy-eight officers and two thousand men under the command of a commandant, who ranks as brigadier-general, with headquarters at Washington. Their administration, organization, and equipment are, as in England, identical with those of the soldiers of the line. They are enlisted for five years, must be 5 feet 6 inches in height, between eighteen and thirty-five years of age, and able to read and write. The complement on board ship varies from thirteen to fifty-one officers and men, depending on the rating of the vessel. Their device is a globe resting on an anchor and surmounted by an eagle. "Ever faithful" is the title which Captain Luce, the historian of the force, appropriately applies to them. (C. C. K.)

MARINI, or Marino, Giambattista (1569-1625), Italian poet, was born at Naples on October 18, 1569. At an early age he secured the powerful patronage of Cardinal Aldobrandini, whom he accompanied from Rome to Ravenna and Turin. His ungoverned pen and disordered life compelled him to take refuge from 1615 to 1622 in Paris, where he was favourably recognized by Mary de' Medici. He died at Naples on March 25, 1625. See Italy, vol. xiii. p. 511.

MARINUS I. (Martinus II.) succeeded John VIII. in the pontificate about the end of December 882. On three separate occasions he had been employed by the three popes who preceded him as legate to Constantinople, his mission in each case having reference to the controversy excited by Photius. Among his first acts as pope were the restitution of Formosus, cardinal bishop of Porto, and the anathematizing of Photius. He died in May or June 884, his successor being Adrian III.

MARINUS II. (Martinus III.), pope from 942 to 946, was preceded by Stephen IX., and followed by Agapetus II.

MARION, Francis (1732-1795), American general, was born in 1732 at Winyah, near Georgetown, South Carolina. In 1759-61 he served as lieutenant in expeditions against the Cherokees, and in 1775 he was elected a member of the provincial congress of South Carolina. This voted two regiments of infantry, and Marion was elected captain in the second. He was made lieutenant-colonel after the defence of Fort Moultrie at the entrance of Charleston harbour (June 28, 1776), and was present at the unsuccessful attack on Savannah, September 1779. In August he joined Gates, but was detached a few days before Gates's defeat at Camden on August 16; at Nelson's Ferry, on the 20th, he rescued one hundred and fifty of the prisoners from a strong guard. He soon received a general's commission. Pursued by Tarleton and Wemyss, he was driven to North Carolina, but soon returned. After successful skirmishes against superior forces, he formed a camp at Snow's Island in the midst of the swamps of the Pedee and the Santee. In March 1781 he defeated Watson at Black River; but meanwhile Doyle had destroyed Marion's camp. In April Lee and Marion took Fort Watson, and in May Fort Motte. In June Greene detached Sumter with Marion and others to make an incursion into the low country. At Quinby Marion's men fought well against Coates; and in August he made a forced march to Parker's Ferry and rescued Colonel Harden, pressed by a superior force. At Eutaw Springs he commanded the right under Greene. After the British retreat to Charleston, Marion went to an important session of the colonial assembly; on the very day that he returned to his brigade, February 24, 1782, it was surprised and dispersed, Marion arriving too late to recover the day. After the war he occupied himself with farming. He died February 27, 1795.

MARIONETTES (probably from *morio*, a fool or buffoon), Fantoccini (from *fantino*, a child), or Puppets (*poupée*, a baby or doll), are figures, generally below life-size, suspended by threads or wires and imitating with their limbs and heads the movements of living persons.

The high antiquity of puppets appears from the fact that figures with movable limbs have been discovered in the tombs of Egypt and among the remains of Etruria; they were also common among the Greeks, from whom they were imported to Rome. Plays in which the characters are represented by puppets or by the shadows of moving figures, worked by concealed performers who deliver the dialogue, are not only popular in India and China at the present day, but during several centuries past maintained an important position among the amusements of the people in most European countries. Goethe and Lessing deemed them worthy of attention; and as late as 1721 Le Sage wrote plays for puppets to perform. Every one remembers in Don Quixote "the curious puppet show, which represents the play of Melisandra and Don Gayferos, one of the best shows that has been acted time out of mind in this kingdom." Reference to puppet shows is frequent in English literature from Chaucer onward. Thus Davenant says:—

> "And man in chimney hid to dress
> Puppet that acts our old Queen Bess,
> And man that, while the puppets play,
> Through nose expoundeth what they say."

The earliest performances in English were drawn or founded upon Bible narratives and the lives of the saints, in the same vein as the "morality" plays which they succeeded. Popular subjects in the 16th century were *The Prodigal Son* and *Nineveh, with Jonah and the Whale*. And in a pamphlet of 1641, describing Bartholomew Fair, we read, "Here a knave in a fool's coat, with a trumpet sounding or a drum beating, invites you to see his puppets. Here a rogue like a wild woodman, or in an antic shape like an incubus, desires your company to view his motion." In 1667 Pepys recorded how, at Bartholomew Fair, he found "my Lady Castlemaine at a puppet play, Patient Grizill." Besides *The Sorrows of Griselda*, other puppet plays of the period were *Dick Whittington*, *The Vagaries of Merry Andrew*, and *The Humours of Bartholomew Fair*. Powell's noted marionette show was the subject of an article in *The Tatler*, 1709, and again in *The Spectator*, 1711. The latter refers also to Pinkethman, a "motion-maker," in whose scenes the divinities of Olympus ascended and descended to the strains of music. An idea of the class of representation may be gathered from an advertisement of Crawley, a rival of Pinkethman, which sets forth—"The Old Creation of the World, with the addition of Noah's Flood," also several fountains playing water during the time of the play. The best scene represented "Noah and his family coming out of the ark, with all the animals two by two, and all the fowls of the air seen in a prospect sitting upon trees; likewise over the ark is the sun rising in a gorgeous manner; moreover a multitude of angels in a double rank," the angels ringing bells. "Likewise machines descending from above, double, with Dives rising out of hell and Lazarus seen in Abraham's bosom; besides several figures dancing jiggs, sarabands, and country dances, with the merry conceits of Squire Punch and Sir John Spendall." Yates showed a moving picture of a city, with an artificial cascade, and a temple,—with mechanical birds in which attention was called to the exact imitation of living birds, the quick motion of the bills, just swelling of the throat, and fluttering of the wings. The puppets were wax figures 5 feet in stature. Toward the end of the 18th century, Flockton's show presented five hundred figures at work at various trades. Brown's Theatre of Arts showed at country fairs, from 1830 to 1840, the battle of Trafalgar, Napoleon's army crossing the Alps, and the marble palace of St Petersburg; and at a still later date Clapton's similar exhibition presented Grace Darling rescuing the crew of the "Forfarshire" steamer wrecked on the Fern Islands, with many ingenious moving figures of quadrupeds, and, in particular, a swan which dipped its head into imitation water, opened its wings, and with flexible neck preened and trimmed its plumage. In these mechanical scenes the figures, painted upon a flat surface and cut out, commonly of pasteboard, are slid along grooves arranged transversely in front of the set scenery, the actions of legs and arms being worked by wires from the hands of persons below the stage, though sometimes use is made of clockwork.

Marionettes proper, and the dolls exhibited in puppet shows (not including Punch and his companion actors), are constructed of wood or of pasteboard, with faces of composition, sometimes of wax; and each figure is suspended by a number of threads to a short bar of wood which is commonly held in one hand of the hidden performer while the finger of his other hand poses the figure or gives action to it by means of the threads. In the mode of constructing the joints, and the greater elaboration with which the several parts of the limbs are supported and moved, and especially in the fine degrees of movement given to the heads, marionettes have been so improved as to present very exact imitations of the gestures of actors and actresses, and the postures and evolutions of acrobats; and, in addition, ingenious exhibitors such as Theodon, who introduced many novelties from twenty to thirty years ago, have employed mechanical arrangements for accomplishing the tricks of pantomime harlequinade. Among the puppet personages presented in the small street shows are generally included a sailor who dances a hornpipe, a hoop-dancer, a dancer of the Highland fling, a wooden-legged pensioner, a vaulter on a pole also balancing two chairs, a clown playing with a butterfly, a dancing figure without head until the head rises out of the body, gradually displaying an enormously long neck, a juggler tossing gilt balls which, sliding up and down upon tight invisible threads, fall into his hands again, a milk-woman carrying buckets out of which fly white dolls, and a skeleton, seen at first in scattered parts lying about the stage, but piece successively flying to piece, the body first sitting up, then standing, and finally capped by the skull, when the completed figure begins to dance.

Ombres Chinois are the shadows of figures projected upon a stretched sheet of thin calico or a gauze scene painted as a transparency. The cardboard flat figures are held behind this screen, illuminated from behind,—the performer supporting each figure by a long wire held in one hand while wires from all the movable parts terminate in rings in which are inserted the fingers of his other hand.

MARIOTTE, EDME (died 1684), a celebrated French physicist, was a native of Burgundy. He lived chiefly near Dijon as prior of St Martin sous Beaune, and was one of the first members of the Academy of Sciences, which was founded at Paris in 1666. He died at Paris May 12, 1684. The first volume of the *Histoire et Mémoires de l'Académie* (1733) contains many original papers by him upon a great variety of physical subjects, such as the motion of fluids, the nature of colour, the notes of the trumpet, the barometer, the fall of bodies, the recoil of guns, the freezing of water, &c. His *Essais de Physique*, four in number, of which the first three were published at Paris between 1676 and 1679, are his most important works, and form, together with an elaborate treatise on the percussion of bodies, the first volume of the *Œuvres de Mariotte* (2 vols., Leyden, 1717). The second of these essays ("De la Nature de l'Air") contains the statement of the law connecting the pressure and volume of a gas which, though very generally called by the name of Mariotte, was discovered seven years before by Boyle. The fourth essay is a systematic treatment of the nature of colour, with a description of many curious experiments and a discussion of the rainbow, halos, parhelia, diffraction, and the more purely physiological phenomena of colour. The discovery of the blind spot is noted in a short paper in the second volume of his collected works.

MARITIME LAW. See SEA LAWS.

MARITIME PROVINCE (Russian, *Primorskaya Oblast*), a province of the Russian empire, and part of the general-governorship of Eastern Siberia, is a strip of territory which extends along the Siberian coast of the Pacific from Corea to the Arctic Ocean, and also includes the peninsula of KAMCHATKA (*q.v.*), the island of Saghalien or Sakhalin, and several small islands scattered along the coast. Its western boundary stretches northwards from the Corean town of King-hing (41° 45′ N. lat.) by Lake Khangka and along the Usuri, keeping to the eastward of the hilly tracts and prairies of northern Manchuria; it then follows an imaginary line which runs due north from the mouth of the Usuri to the bay of Udskoy, separating the province from the lowlands and mountain wildernesses of the Amur province; it next runs along the Stanovoy watershed between the Pacific and the Arctic Ocean, leaving to the west the elevated tracts of the Siberian plateau, and finally it crosses the spurs of this plateau through barren *tundras* belonging to Yakutsk, reaching the Arctic Ocean at the Chaunskaya Bay (70° N. lat.). The province has a length of 2300 miles and a width varying from 40 to 420 miles; it covers an area of 730,000 square miles, and exhibits very great varieties of climate, scenery, and population. The northern part, known as the land of the Chukchees, occupies the north-eastern peninsula of Asia between the Arctic Ocean on the one side and the Seas of Behring and Okhotsk on the other, and has the character of a barren plateau from 1000 to 2000 feet high, deeply indented by the rivers of the Anadyr basin, and by long fiords, such as the Koluchin Bay (the wintering-place of Nordenskjöld's "Vega"), the Gulf of Anadyr, and the Bays of Penzhina and Ghizhiga. To the north this plateau is bordered by a chain of mountains, the highest known within the Arctic circle, several summits of which reach a height of 8200 feet (Makachinga peak and others), while the promontories by which the Asiatic continent terminates towards Behring Strait—Serdtze-kamen, Cape Vostochnyi (the most easterly point of Asia), and Cape Chukotskiy—have heights ranging from 1000 to 2000 feet. Only lichens and mosses, with a few dwarf species of Siberian trees, cover this district, in marked contrast to the rich forests of the corresponding part of Arctic America. The fauna, however, is far richer than might have been expected, owing to the migrations of animals along the plateaus of Eastern Siberia, which extend in a north-eastern direction from the very heart of Asia to Behring Strait. The fauna is further enlarged by a few American birds and mammals, which cross the strait when it is frozen. This country, and still more the seas by which it is surrounded, have been for the last two centuries the paradise of hunters, and have supplied Siberian trade with its best furs. Entire species of animals have been exterminated within this short period; the renowned blue fox and black sable have nearly disappeared, and the whale, which was hunted a few decades ago by hundreds of American vessels, has become very rare. The sea-otter, of which the party of Steller killed seven hundred during its eight months' stay on Behring's Island, is rapidly becoming extinct, as well as the sea-lion (*Otaria stelleri*); whilst the sea-cow (*Rhytina stelleri*) was completely extirpated in the course of forty years. Thanks to the care taken by an American company which has the monopoly of hunting on Behring and Copper Islands, the sea-bear (*Otaria ursina*), which was likely to meet with the same fate, is nearly domesticated at present, and multiplies rapidly, yielding no less than twelve thousand skins per annum. The inhabitants of this region, the Chukchees (Tuski, or Chaouktoos), who number no more than 12,000 souls (according to some authorities only 5000), seem to have immigrated from the south; their racial characters make them an ethnological link between the Mongols of Central Asia and the Indians of America; they are also very nearly akin in their features and customs to the Eskimo. They are subdivided, however, into two distinct branches, with different customs and languages. Those of the interior support themselves by reindeer breeding (herds of ten thousand being not uncommon) and by hunting; whilst those of the coast live by fishing, and are very poor. All travellers who have had dealings with Chukchees speak in the highest terms of the character of the former branch, and of the fraternal feelings shown by them in their mutual relations. The Koryaks (about 5000), who occupy the southern part of this region, are nearly akin to Chukchees. They extend their migrations also to the northern part of Kamchatka. Those of the interior are reindeer proprietors and hunters, and like the Chukchees are quite independent, own no superiors, and live in federations of families. They have firmly resisted Russian conquest; and there are tribes among them which still refuse to pay the *yasak* (tribute in furs) to the Russian authorities. Their national character is described by travellers as very different from that of the settled Koryaks of the coast, who live in the utmost poverty, and have acquired vicious habits from their intercourse with European and American sailors.

The middle part of the Maritime Province is a narrow strip of land (40 to 60 miles wide) along the shores of the Sea of Okhotsk, including the basin of the Ud in the south. This area is occupied by wild mountains, 4000 to 7000 feet high, forming the eastern border of the high plateau of Eastern Siberia. Thick forests of larch clothe the mountains to nearly one-half of their height, as well as the deep valleys, where short streams discharge into the Pacific the water produced by the melting of accumulations of snow and ice (*nakipi*, *naledi*). The undulating hills of the basin of the Ud, which is a continuation to the south-west, between the Stanovoy and Bureya mountains, of the deep indentation of the Sea of Okhotsk, are covered with forests and marshes. Only Tunguses visit these inhospitable mountain wildernesses and the bays of the coast, living by hunting or fishing.

The southern part of the province includes two distinct regions. From the north-eastern extremity of the Bureya, or Little Khingan range, of which the group of the Shantar Islands is a continuation, a wide and deep depression runs south-westwards to the junction of the Amur and Usuri, and thence to the lowlands of the lower Sungari. It is for the most part less than 500 feet above sea-level.

The Amur, which takes a north-eastern course after reaching these lowlands, runs close to their eastern boundary, at the foot of the mountains of the sea-coast; whilst on its left or western bank it spreads into numberless lakes and marshes, large and small, and extensively inundates the swamps at time of flood. The area on the right banks of the Amur and Usuri, between these rivers and the sea-coast, is occupied by a very little known hilly tract consisting of several intricate systems of mountains, usually represented on maps as a single range, and known under the general name of Sikhota-alin. The summits reach the height of 5150 feet (Golaya Gora peak) and the average elevation of the few passes is about 2500 feet. There is, however, one depression in these mountains, occupied by Lake Kizi, which may have been at one time an outflow of the Amur to the sea. The Sikhota-alin mountains are covered with thick impracticable forests, through which a passage can be forced only by means of the hatchet. The lowlands and the countless islands of the Amur are covered with a grass vegetation as luxuriant as that of the forests, and present the same difficulties to the pioneer. Herbaceous plants, 7 to 10 feet high, intertwined with numberless climbing plants, cover the soil with an impenetrable thicket, and, when destroyed by fire, rapidly grow again to their former height. The flora and fauna of this region (especially in the Usuri district) exhibit a striking combination of species of warm climates with those of subarctic regions; the wild vine clings to the larch and cedar-pine, and the tiger meets the bear and the sable. The quantity of fish in the rivers is immense, and in August the wide channels of the Amur and Usuri literally swarm with the ascending salmon. The mountain-wildernesses are visited by nomadic Tunguses, while the banks of the great rivers are inhabited, besides Russians, by Golds and Orochons, both of Tungusian origin, and the lower Amur by Ghilyaks, closely allied to the Ainos of Saghalien. Manchus and Chinese are scattered here and there among the Russian population on the right bank of the Usuri.

The best part of the Maritime Province is at its southern extremity, in the valley of the Suifun river, which enters the Pacific in the Gulf of Peter the Great, and on the shores of the bays of the southern coast, where new settlements have appeared since this territory was annexed to Russia in 1860. But even here the climate is very harsh. The warm sea-current of the Kuro-sivo does not reach the coasts of Siberia, while a cold current, originating in the Sea of Okhotsk, brings its icy water and chilling fogs to the coasts of Saghalien, and flows along the Siberian shores to the eastern coast of Corea. The high mountains of the sea-coast and the monsoons of the Chinese Sea contribute to produce in the southern parts of the Maritime Province cold winters and wet summers. Accordingly, at Vladivostok (in the Gulf of Peter the Great), which has the same latitude as Marseilles, the average yearly temperature is only 39°·5 Fahr., and the harbour is frozen for nearly three months; the Amur and Usuri are frozen in November. Towards the end of summer the moist monsoons cause heavy rainfalls, which destroy the harvests and bring about such inundations that even in the two miles wide channel of the Amur the water within a few days rises more than 15 feet, and covers the lowlands to a breadth of 15 to 20 miles; the navigation also becomes dangerous for small river steamers and barges, on account of storms from the Chinese Sea. The sea-coast farther north has a continental and arctic climate. At Nikolayevsk, temperatures as low as − 41°·5 Fahr. are observed in winter, and as high as 94°·6 in summer, the average yearly temperature being below zero (− 0·9). At Ayan (56° 27′ N. lat.) the average temperature of the year is 25°·5 (− 0°·4 in winter, and 50°·5 in summer), and at Okhotsk (59° 21′ N. lat.) it is 23° (− 6° in winter, and 52°·5 in summer).

Russian settlements occur at intervals throughout the whole of the province, but, with exception of those on the banks of the Amur and Usuri, and the southern ports of the sea-coast, they are mere centres of administration. Anadyrsk on the Anadyr river, Penzhinsk and Ghizhiga at the heads of bays of the same name, Ayan on the coast of the Sea of Okhotsk, and Udskoy Ostrog on the river Ud, all have played an important part in the conquest of Siberia by Cossacks and merchants; but at present they are only small blockhouses with a few buildings around them, and the seat of local authorities; the population of none exceeds two hundred. Okhotsk, which has given its name to the sea between Kamchatka and the Siberian coast, is one of the oldest towns of Eastern Siberia, having been founded in 1649. Until the acquisition by Russia of the Manchurian sea-coast, this port, 700 miles distant from Yakutsk, poor though it is, was an object of special solicitude to the Russian Government for the maintenance of its possessions on the Pacific. It is connected by a bridle path with Yakutsk, and even in 1851–56, during the conquest of the Amur, all communication with the mouth of the Amur was by this route. It has now but 210 inhabitants. Nikolayevsk, on the left bank of the Amur, 23 miles from its mouth, was until lately the capital of the Maritime Province. Great expectations were formed regarding it when it was founded in 1851. It was provided with machine-works, foundries, and dockyards, and was proclaimed a free port. But the difficulties of navigation and of communication with the interior, and the complete failure of the governmental colonization of the Amur, made the prosperity of the new Russian port on the Pacific impossible, and the seat of government was transferred to the more central Khabarovka. At present Nikolayevsk has only 3500 inhabitants, nearly all military or officials, and a few foreign merchants trading chiefly in groceries and spirits. The port is visited every year by from twenty to twenty-five ships, importing manufactured and grocery wares to the value of about £100,000, and of wines and spirits estimated at £20,000. On the banks of the Amur, from Nikolayevsk to the mouth of the Usuri, is a chain of Russian settlements at distances not exceeding 25 miles. Their inhabitants, free settlers from Russia, are very badly off on account of the difficulties of agriculture in this region, and from the bad selection of sites. Many have migrated to the sea-coast, whilst those who still remain are for the most part very poor, and almost every year require to be provided by Government with corn brought from Transbaikalia. Sofiysk (1000 inhabitants, of whom 700 are military) is a purely military post. Khabarovka, on a high promontory at the confluence of the Amur and Usuri, is the present capital of the Maritime Province. It has a settled population of about seven hundred, besides military and officials. A few Russian merchants carry on an active trade in furs with natives (about £20,000 a year), in silver money brought from Russia and sold to Chinese, and in spirits and groceries. The Russian settlements on the right bank of the Usuri are very like those of the lower Amur. The peasants, who have received the name of Cossacks, and have a military organization, with the exception of a few settlements on the upper Usuri, are mostly in a wretched condition, and since 1859 have been dependent for food almost every year on Government aid. A line of posts and settlements connects the villages of the Usuri with the settlements on the shores of the Gulf of Peter the Great. This wide gulf, divided into two long bays,—those of Amur and Usuri, which are connected by an inlet called the Eastern Bosphorus,—is regarded as the principal port of Russia on the Pacific, and the town on the inlet has received the name of Vladivostok ("ruler of the East"); its spacious harbour, very similar to that of Sebastopol, has been called the Golden Horn. At present Vladivostok has, however, merely the aspect of a middle-sized Russian village. One-half of its 8500 inhabitants are Chinese and Coreans, the other half being military and officials. All necessaries of life, including rye-bread biscuits, continue to be imported by sea, and every spring, before the opening of the navigation, provisions become scarce. The trade is in the hands of Chinese, who export stag-horns, sea-weed, and mushrooms to a value of about £10,000 a year, and of Germans, who import groceries and spirits (£218,500 in 1879). The entrance to the harbour is well-fortified, and the town possesses a machine-work, storehouses, and a station of the Northern Telegraph Company. Other settlements (at the Imperial, Vladimir, and Olga harbours, &c.) are developing very slowly. Altogether the Russian population of these settlements has still a provisional character, and has to overcome great difficulties before it can become independent of the interior for its means of subsistence. The total population of the Maritime Province is estimated at 20,000 Russians, (12,000 military and officials), and at about 37,000 natives; but this is certainly under the truth. The province is made up of one territory—that of the Usuri—and six circles (*okrughi*):—Nikolayevsk, Sofiysk, Petropavlovsk (Kamchatka), Okhotsk, Ghizhighinsk, and Udskoy; the territory of the Usuri is subdivided into five circles:—Usuri, Suifun, Khangka, Avvakumovo, and Suchan. (P. A. K.)

MARIUPOL, a seaport of Russia, on the northern shore of the Sea of Azoff, at the mouth of the Kalmius, in the government of Ekaterinoslav, 55 miles west of Taganrog. It is connected by a branch railway with the line between Kharkoff and Taganrog, and is situated on the highway between the latter town and the Crimea. The place is said to have been inhabited in remote times under the name of Adamakha; but the present town was built only in 1779 by Greek emigrants from the Crimea who settled on the shores of the Sea of Azoff and on the left bank of the lower Kalmius. Mariupol is the chief town of this district, the 40,000 inhabitants of which are engaged in agriculture, cattle-breeding, and fishing, and sell their produce in the town. In export trade Mariupol ranks next to Taganrog among the ports of the Sea of Azoff; but its harbour is open to the south-east and shallow, the line of 14 feet being $1\frac{1}{2}$ miles from the shore, with a narrow strip, 12 to 22 feet deep, which allows larger flat-bottomed ships to approach the town, especially during south-east winds. Like all ports on this sea it is becoming more and more shallow. Mariupol is visited every year by about 150 foreign ships (about 30,000 tons) and by 700 to 800 coasting vessels (65,000 tons), mainly carrying wheat and linseed, as also skins and tallow, from the Greek district, and from the provinces of Don and Ekaterinoslav. The importance of the port may increase when the mineral riches of the district (coal close to the sea-shore, kaolin, and quartz sand) are exploited. Population, with two suburbs, Marinsk and Karasou, 9800

MARIUS, CAIUS (155–86 B.C.), is one of the most striking figures in Roman history. Born the son of a small farmer at Arpinum (Arpino), the birthplace also of Cicero, in 155 B.C., he worked his way up from this humble origin, in spite of the most determined opposition from the senate and the aristocracy, to the highest position in the state, was seven times consul, and was spoken of as a third Romulus and a second Camillus. He began life as a soldier, and first saw war in Spain under the great Scipio Africanus, whose good opinion he won, and so rose from the ranks to be an officer. But this was not enough to help him forward, on his return to Rome, in rising to those political offices which were invariably a stepping-stone to the highest military rank. He had, however, when about forty years of age, the good luck to marry a great lady, of patrician rank, Julia, the aunt of Julius Cæsar; and, being at the same time a popular favourite, as a man of plain and simple tastes, and a brave energetic soldier, he was in 115 B.C. elected prætor, which gave him an opportunity of still further showing his military ability in the thorough subjugation of the troublesome province of Further Spain (Spain west of the Ebro), where a good officer was specially wanted to check the marauding raids of a number of wild tribes. But it was in the war with Jugurtha, from 109 to 106 B.C., that he distinctly came to the front as the lieutenant of the consul Quintus Metellus. It would seem that his conduct towards his superior officer was not perfectly straightforward and honourable, as he tried to make the Roman traders in Africa, and through them the people of Rome, believe that the war was intentionally prolonged from corrupt motives. Under the circumstances this was comparatively easy, as political feeling was just at this time particularly bitter, and the senate was reputed, not without some good reason, to be venal and corrupt. Already Marius had achieved some important successes over Jugurtha, and had shown that he was the man to settle a tiresome guerilla war, and now, when he was a little over fifty, in 107 B.C., he was, amid great popular enthusiasm, elected consul for the first time. In the following year, in conjunction with his future political rival, Sulla, he brought the war to a triumphant issue, and passed two years in his province of Numidia, which he thoroughly subdued and annexed to Rome's dominion.

By this time Marius was generally recognized as the ablest general of the day, and in face of the great peril now beginning to threaten Rome from the north of the Alps, where an immense multitude of Cimbri and Teutones were hanging on the borders of Italy, public opinion promptly summoned him to the chief command. Two armies had been utterly destroyed in the neighbourhood of the Lake of Geneva, and it seemed as if a repetition of the disaster of Allia in 390 B.C., and the capture of Rome itself, might be not impossible. Marius, out of unpromising materials and a demoralized soldiery, organized a well-disciplined army, with which he inflicted on the invading hordes two decisive defeats, the first in 102 B.C. at Aquæ Sextiæ (Aix in the department of Bouches du Rhône, some way north of Marseilles), and the second in the following year at Vercellæ (Vercelli, about midway between Turin and Milan), the result being that for a period of some centuries Rome had nothing to fear from the northern barbarians. Deservedly indeed was Marius elected consul a fifth time, hailed as the "saviour of his country," and honoured with a triumph of unprecedented splendour.

The really glorious part of his career was now over, and the remainder of his life is associated with the worst cruelties and horrors of civil war, revolution, and proscription. The hideous strifes of Marius and Sulla have passed into a proverb. It is indeed a dreadful and monotonous story of bloodshed, but it must be carefully studied if we are to understand the nature of the political changes which had their final development in imperialism. Marius was a plain, rough, though very able, soldier, without any of the intellectual culture which is indispensable to a statesman, and which the Gracchi, his political ancestors, possessed. As a politician he on the whole failed, though almost to the last he had the confidence of the popular party. But he unfortunately associated himself with low and vulgar demagogues, men probably more degraded than the worst of the senators and of the aristocracy, and thus, although perhaps he never quite sank to their level, he let himself be guilty of cruel and perfidious acts, which it is hard to reconcile with the character of a brave man and a hero. He was indeed appointed in 88 B.C., after a riot and partial revolution, to the command in the war in the East with Mithridates, but the triumph of Sulla and the aristocratical party almost immediately afterwards drove him as an outlaw from Rome, and he had to seek safety amid the marshes round Minturnæ (Garigliano) in Latium. The Gallic trooper sent by the local authorities to strike off the old man's head quailed, it is said, before the fire of his eye, and fled with the exclamation, "I cannot kill Caius Marius." Meantime, in the absence of Sulla, who had left Italy for the Mithridatic war, Cinna's sudden and violent revolution had put the senate at the mercy of the popular leaders, and Marius greedily caught at the opportunity of a bloody vengeance, which became in fact a reign of terror in which senators and nobles were slaughtered wholesale. He had himself elected consul, for the seventh time, in fulfilment of a prophecy given to him in early manhood. Thus, full of honours in one sense, but really hated and execrated, he closed his career, dying in the delirium of fever in 86 B.C., at seventy years of age.

Marius was not only a great and successful general, but also a great military reformer. A citizen militia was from his time exchanged for a professional soldiery, which had hitherto been as little liked by the Roman people as it was by our own ancestors. A standing army, their instincts told them, would be a ready tool of despotism; and indeed the changes of which Marius was the author paved the way for the subsequent military imperialism. The Roman soldier was henceforth a man who found his home in the camp, and who had no trade but war. A great general could hardly fail to become the first and foremost man in the state. Marius, however, himself did not attempt to overturn the oligarchy, as Cæsar afterwards did, by means of the army, but rather by such expedients as the constitution seemed to allow, though they had to be backed up by street riots and mob violence. He failed as a political reformer because the merchants and the moneyed classes, whom the more statesmanlike Gracchi tried to conciliate, feared that they would themselves be swept away by a revolution of which the mob and its leaders would be the ultimate controllers. The farmer's son, the rough blunt soldier, the saviour of his country in middle life, and its curse and pest in his old age, had a decided tinge of fanaticism and that vein of superstition which is often allied to such natures. In matters so important as canvassing for the consulship he would be guided by the counsels of an Etruscan soothsayer, and would be accompanied in his campaigns by a Syrian prophetess. The fashionable accomplishments of the day, and the new Greek culture, were wholly alien to his taste, and he was thus really disqualified for the political life of his time. When his military career was once ended, failure and disgrace became a certainty for him.

For the life of Marius our original sources are a multitude of passages in Cicero's works, Sallust's *Jugurthan War*, the epitomes of the lost books of Livy, Plutarch's *Lives*, &c. In Smith's *Biographical Dictionary* the life is given at great length, and the details stated generally with great accuracy. In Mommsen's *History of Rome*, bk. iv. chaps. 6, 7, 8, a clear picture of the whole period is presented to us; and Niebuhr's *Lectures on Roman History* (Lectures 81–86) may be consulted with great advantage.

MARIVAUX, PIERRE CARLET DE CHAMBLAIN DE (1688–1763), novelist and dramatist, was born at Paris on the 4th February 1688. His father was a financier of Norman extraction, whose real name was Carlet, but who after the loose fashion of the period assumed the surname of Chamblain, and then, finding that others of his class had chosen the same, superadded that of Marivaux. M. Carlet de Marivaux, however, was a man of good reputation, and he received the appointment of director of the mint at Riom in Auvergne, where and at Limoges the young Pierre was brought up. It is said that he developed literary tastes early, and wrote his first play, the *Père Prudent et Equitable*, when he was only eighteen; it was not, however, published till 1712, when he was twenty-four. His chief attention in those early days was paid to novel writing, not the drama. In the three years from 1713 to 1715 he produced three novels—*Les Effets Surprenantes de la Sympathie*, *La Voiture Embourbée*, and a book which had three titles *Pharsamon*, *Les Folies Romanesques*, and *Le Don Quichotte Moderne*. All these books were in a curious strain, not in the least resembling the pieces which long afterwards were to make his reputation, but following partly the Spanish romances and partly the heroic novels of the preceding century, with a certain intermixture of the marvellous. Then Marivaux's literary ardour took a new phase. He fell under the influence of La Motte, and thought to serve the cause of that ingenious paradoxer by travestying Homer, an ignoble task, which he followed up by performing the same office in regard to Fénelon. His friendship for La Motte, however, introduced him to the *Mercure*, the chief newspaper of France, where in 1717 he produced various articles of the "Spectator" kind, which were distinguished by much keenness of observation and not a little literary skill. It was at this time that the peculiar style called Marivaudage first made its appearance in him. The year 1720 and those immediately following were very important ones for Marivaux; not only did he produce a comedy, now lost except in small part, entitled *L'Amour et la Vérité*, and another and far better one entitled *Arlequin Poli par l'Amour*, but he wrote a tragedy, *Annibal*, which was and deserved to be unsuccessful. Meanwhile his worldly affairs underwent a sudden revolution. His father had left him a comfortable subsistence, but he was persuaded by friends to risk it in the Mississippi scheme, and after vastly increasing it for a time lost all that he had. His prosperity had enabled him to marry a certain Mademoiselle Martin, of whom much good is said, and to whom he was deeply attached, but who died very shortly. His pen now became almost his sole resource. He had a connexion with both the fashionable theatres, for his *Annibal* had been played at the Comédie Française and his *Arlequin Poli* at the Comédie Italienne, where at the time a company who were extremely popular, despite their imperfect command of French, were established. He endeavoured too to turn his newspaper practice in the *Mercure* to more account by starting a weekly *Spectateur Français*, to which he was the sole contributor. But his habits were the reverse of methodical; the paper appeared at the most irregular intervals; and, though it contained some excellent work, its irregularity killed it. For nearly twenty years the theatre, and especially the Italian theatre, was Marivaux's chief support, for his pieces, though they were not ill received by the actors at the Français, were rarely successful there. The best of a very large number of plays (Marivaux's theatre numbers between thirty and forty items) were the *Surprise de l'Amour* (1722), the *Triomphe de Plutus* (1728), the *Jeu de l'Amour et du Hasard* (1730), *Les Fausses Confidences* (1737), all produced at the Italian theatre, and *Le Legs*, produced at the French. Meanwhile he had at intervals returned to both his other lines of composition. A periodical publication called *L'Indigent Philosophe* appeared in 1727, and another called *Le Cabinet du Philosophe* in 1734, but the same causes which had proved fatal to the *Spectateur* prevented these later efforts from succeeding. In 1731 Marivaux published the first two parts of his best and greatest work, *Marianne*, a novel of a new and remarkable kind. As was usual, however, with him when he ventured on any considerable task, he was very slow with it. The eleven parts appeared in batches at intervals during a period of exactly the same number of years, and after all it was left unfinished. In 1735 another novel, the *Paysan Parvenu*, was begun, but this also was left unfinished. The year afterwards Marivaux, who was then nearly fifty years of age, was elected of the Academy. He survived for more than twenty years, and was not idle, again contributing occasionally to the *Mercure*, writing plays, "reflexions" (which were seldom of much worth), and so forth. He died on the 12th February 1763, aged seventy-five years.

The personal character of Marivaux was curious and somewhat contradictory, though not without analogies, one of the closest of which is to be found in Goldsmith. He was, however, unlike Goldsmith, at least as brilliant in conversation as with the pen. He was extremely good-natured, but fond of saying very severe things, unhesitating in his acceptance of favours (he drew a regular annuity from Helvetius), but exceedingly touchy if he thought himself in any way slighted. He was, though a great cultivator of *sensibilité*, on the whole decent and moral in his writings, and was unsparing in his criticism of the rising *Philosophes*. This last circumstance, and perhaps jealousy as well, made him a dangerous enemy in Voltaire, who lost but few opportunities of speaking disparagingly of him. Not very much is known of his life, though anecdotes of his sayings are not uncommon. He had good friends, not merely, as has been said, in the rich, generous, and amiable Helvetius, but in Madame de Tencin, in Fontenelle, and even in Madame de Pompadour, who gave him, it is said, a considerable pension, of the source of which he was ignorant. It is even asserted that annoyance at the discovery of the origin of a benefit which he thought came directly from the king hastened his death; and, though this is scarcely likely, his extreme sensitiveness is shown by many stories, one of which carries out in real life and almost to the letter Farquhar's famous *mot* as to "laughing consumedly." He had one daughter, who took the veil, the duke of Orleans, the regent's successor, furnishing her with her dowry.

We have no space here for a detailed criticism of Marivaux's extensive work. The so-called Marivaudage is the main point of importance about it, though the best of the comedies have great merits, and *Marianne* is an extremely important step in the legitimate development of the French novel,—legitimate, that is, in opposition to the brilliant but episodic productions of Le Sage. The subject-matter of Marivaux's peculiar style has been generally and with tolerable exactness described as the metaphysic of love-making. His characters, in a happy phrase of Crebillon's, not only tell each other and the reader everything they have thought, but everything that they would like to persuade themselves that they have thought. The style chosen for this is justly regarded as derived mainly from Fontenelle, and through him from the Précieuses, though there are traces of it even in La Bruyère. It abuses metaphor somewhat, and delights to turn off a metaphor itself in some unexpected and bizarre fashion. Now it is a familiar phrase which is used where dignified language would be expected; now the reverse. In the same criticism of Crebillon's which has been already quoted occurs another happy description of Marivaux's style as being "an introduction to each other of words which have never made acquaintance, and which think that they will not get on together," a phrase as happy in its imitation as in its satire of the style itself. Yet this fantastic embroidery of language has a certain charm, and suits perhaps better than any other style the somewhat unreal gallantry and *sensibilité* which it describes and exhibits. The author possessed, moreover, both thought and observation, besides considerable command of pathos. He is not, and is never any more likely to be, generally popular, but he is one of the authors in whom those who do like them are sure to take particular delight.

The best and most complete edition of Marivaux is that of 1781, 12 vols. 8vo. There is a good modern edition of the plays by E. Fournier, and another of *Marianne* and the *Paysan Parvenu* in two volumes. J. Fleury's *Marivaux et le Marivaudage* (Paris, 1881) is worth consulting by those who are interested in the subject. (G. SA.)

MARK, the traditional name of the author of the Second Gospel. The name Mark occurs in several books of the New Testament. In the Acts of the Apostles, chap. xii. mention is made of "John whose surname was Mark," to the house of whose mother, Mary, at Jerusalem, Peter went when miraculously released from prison.[1] This John Mark went with Barnabas and Paul on their missionary journey, as far as Perga in Pamphylia, and then, "departing from them, returned to Jerusalem" (Acts xii. 25; xiii. 13). His departure was afterwards the occasion of a "sharp contention" between Paul and Barnabas; the former "thought not good to take with them him who withdrew from them from Pamphylia, and went not with them to the work"; the latter "took Mark, and sailed away into Cyprus" (Acts xv. 38, 39). On the subsequent history of Mark the Acts of the Apostles are silent.

The same name Mark occurs in three Pauline epistles. (1) In Col. iv. 10 the writer enumerates Mark among his fellow-workers, mentioning also that he was a nephew (some translate "cousin") of Barnabas, and implying that he was a Jew ("of the circumcision"). He is evidently about to send him, in accordance with a previous intimation, on a special mission to the Colossians; but there is no evidence, except the statement of the Coptic subscription to the epistle, to show whether the contemplated journey took place. (2) In Philemon 24 the writer also mentions Mark as one of his fellow-workers, *i.e.*, probably in preaching the gospel during his imprisonment at Rome. (3) In 2 Tim. iv. 11 the writer gives the charge to Timothy, "Take Mark and bring him with thee, for he is useful to me for ministering." It is a plausible conjecture that this is a request that Mark might be brought back to Rome after his mission to Colossæ.

The same name also occurs in 1 Peter v. 13, "Mark, my son." This expression has sometimes been taken literally; but it is more usually understood in a metaphorical sense, as meaning that Peter had converted Mark. Those who take "Babylon" in the same passage to mean Rome necessarily infer that Mark was with Peter at Rome; a tradition to the same effect is mentioned in fragments of Clement of Alexandria, preserved in Eusebius, *H. E.*, ii. 15; vi. 14.

The preponderance of patristic and mediæval tradition is in favour of the hypothesis that the same person is designated in all these passages of the New Testament. But other hypotheses have found favour, especially among those writers of various schools who have felt a difficulty in understanding how the same person should be an intimate companion at once of St Paul and of St Peter. It has been supposed (1) that the John Mark of the Acts is the Mark of the Pauline epistles, but not the Mark of 1 Peter; (2) that the John Mark of the Acts, the Mark of the Pauline epistles, and the Mark of 1 Peter are all different; (3) that the John Mark of the Acts is the Mark of 1 Peter, but not the Mark of the Pauline epistles. Into the arguments for these several hypotheses it is unnecessary to enter here; they are of course complicated by the prior question of the authenticity and date of the books of the New Testament in which the name occurs. The most elaborate modern discussion of the question, which arrives at the conclusion that the first of the three hypotheses just mentioned is the true one, is contained in the work of Molini, whose title is given below. But, whether there was only one Mark or more than one, there is a general belief, which rests ultimately on the testimony of the presbyter (John) who is quoted by Papias (ap. Euseb., *H. E.*, iii. 39, 15), that the second canonical Gospel, or its original, is to be ascribed to the Mark who was the disciple of St Peter.[2] Of this Mark

[1] This double name, the one Jewish, the other Roman, may be compared with the double name "Saul, who is also called Paul," in succeeding chapters of the Acts; sometimes the double name, sometimes one or other of the single names, is used.

[2] Most of the arguments by which Kienlen (*Stud. u. Krit.*, 1843, pp. 423 *sq.*) endeavours to show that the Gospel is the work of the

the evangelist, as of other persons whose names are prominent in the New Testament, there is a large mass of traditional biography, in which possible fact and obvious fiction are so closely interwoven as not to be easily disentangled, and which would not be worth recording were it not for the later historical associations which have clustered round it.

Of Mark's birth and country nothing is positively known; the majority of mediæval writers state that he was a Levite; but this is probably no more than an inference from his supposed relationship to Barnabas. The Alexandrian tradition seems to have been that he was of Cyrenæan origin; and Severus, a writer of the 10th century, adds to this the statement that his father's name was Aristobulus, who, with his wife Mary, was driven from the Pentapolis to Jerusalem by an invasion of barbarians (Severus Aschimon, ap. Renaudot, *Hist. Patriarch. Alex.*, p. 2). In the apocryphal Acts of Barnabas, which profess to be written by him, he speaks of himself as having been formerly a servant of Cyrillus, the high priest of Zeus, and as having been baptized at Iconium. The presbyter John, whom Papias quotes, says distinctly that "he neither heard the Lord nor accompanied Him" (ap. Eusebius, *l.c.*); and this positive statement is fatal to the tradition, which does not appear until about two hundred and fifty years afterwards, that he was one of the seventy disciples (Epiphanius, pseudo-Origen *De recta in Deum fide*, and the author of the *Paschal Chronicle*). Various other results of the tendency to fill up blank names in the gospel history must be set aside on the same ground; it was, for example, believed that Mark was one of the disciples who "went back" because of the "hard saying" (pseudo-Hippolyt., *De LXX. Apostolis* in Cod. Barocc. ap. Migne, *Patrol. Græc.*, vol. x. 955); there was an Alexandrian tradition that he was one of the servants at the miracle of Cana of Galilee, that he was the "man bearing a pitcher of water" in whose house the last supper was prepared, and that he was also the owner of the house in which the disciples met on the evening of the resurrection (Renaudot, *l.c.*); and even in modern times there has been the conjecture that he was the "certain young man" who "fled naked" from Gethsemane, Mark xiv. 51, 52 (Olshausen).

A tradition which was widely diffused, and which is not in itself improbable, was that he afterwards preached the gospel and presided over the church at Alexandria (the earliest extant testimony is that of Eusebius, *H. E.*, ii. 16, 1; ii. 24; for the fully-developed legend of later times see Symeon Metaphrastes, *Vita S. Marci*, and Eutychius, *Origines Ecclesiæ Alexandrinæ*). There was another, though perhaps not incompatible, tradition that he preached the gospel and presided over the church at Aquileia in North Italy. The earliest testimony in favour of this tradition is the vague statement of Gregory of Nazianzus that Mark preached in Italy, but its existence in the 7th century is shown by the fact that in 629 A.D. Heraclius sent the patriarchal chair from Alexandria to Grado, to which city the patriarchate of Aquileia had been then transferred (*Chron. Patriarch. Gradens.*, ap. Ughelli, *Italia Sacra*, tom. v. p. 1086; for other references to the general tradition see De Rubeis, *Monum. Eccles. Aquileien.*, c. 1; *Acta Sanctorum*, ad April. xxv.). It was through this tradition that Mark became connected with Venice, whither the patriarchate was further transferred from Grado; an early Venetian legend, which is represented in the Cappella Zen in the basilica of St Mark, antedates this connexion by picturing the evangelist as having been stranded on the Rialto, while it was still an uninhabited island, and as having had the future greatness of the city revealed to him (Danduli, *Chron.*, iv. 1, ap. Muratori, *Rer. Ital. Script.*, vol. xii. 14).

The earliest traditions appear to imply that he died a natural death (Eusebius, Jerome, and even Isidore of Seville); but the Martyrologies claim him as a martyr, though they do not agree as to the manner of his martyrdom. According to the pseudo-Hippolytus he was burned; but Symeon Metaphrastes and the *Paschal Chronicle* represent him to have been dragged over rough stones until he died. But, however that may be, his tomb appears to have been venerated at Alexandria, and there was a firm belief at Venice in the Middle Ages that his remains had been translated thither in the 9th century (the fact of the translation is denied even by Tillemont; the weakness of the evidence in support of the tradition is apparent even in Molini's vigorous defence of it, lib. ii., c. 2; the minute account which the same writer gives, lib. ii. c. 11, of the discovery of the supposed actual bones of the evangelist in 1811 A.D., is interesting). There was another though less widely accepted tradition, that the remains soon after their translation to Venice were retranslated to the abbey of Reichenau on Lake Constance; a circumstantial account of this retranslation is given in the treatise *Ex Miraculis S. Marci*, ap. Pertz, *Mon. Hist. German. Script.*, tom. iv. p. 449. It may be added that the Venetians prided themselves on possessing, not only the body of St Mark, but also the autograph of his Gospel; this autograph, however, proved on examination to be only part of a 6th-century book of the Gospels, the remainder of which was published by Bianchini as the *Evangeliarium Forojuliense*; the Venetian part of this MS. was found some years ago to have been wholly destroyed by damp.

It has been at various times supposed that Mark wrote other works besides the Gospel. Several books of the New Testament have been attributed to him: viz., the Epistle to the Hebrews (Spanheim, *Op. Miscell.*, vol. ii. p. 240), the Epistle of Jude (*cf.* Holtzmann, *Die Synoptische Evangelien*, p. 373), the Apocalypse (Hitzig, *Ueber Johannes Marcus*, Zürich, 1843). The apocryphal *Acta Barnabæ* purport to have been written by him. There is a liturgy which bears his name, and which exists in two forms; the one form was found in a MS. of the 12th century in Calabria, and is, according to Renaudot, the foundation of the three liturgies of St Basil, St Gregory Nazianzen, and St Cyril; the other is that which is used by the Maronite and Jacobite Syrians. Both forms have been published by Renaudot, *Liturg. Oriental. Collect*, vol. i. p. 127, and vol. ii. p. 176, and in Neale's *History of the Holy Eastern Church*; but neither has any substantial claim to belong to the ante-Nicene period of Christian literature.

The symbol by which Mark is designated in Christian art is usually that of a lion. Each of the "four living creatures" of Ezekiel and the Apocalypse has been attributed to each of the four evangelists in turn; Augustine and Bede think that Mark is designated by the "man"; Theophylact and others think that he is designated by the eagle; Anastasius Sinaita makes his symbol the ox; but mediæval art acquiesced in the opinion of Jerome that he was indicated by the lion. Most of the martyrologies and calendars assign April 25 as the day on which he should be commemorated; but the *Martyr. Hieron.* gives September 23, and some Greek martyrologies give January 11. This unusual variation probably arises from early differences of opinion as to whether there was one Mark or more than one.

The work of Canon Molini of Venice, *De Vita et Lipsanis S. Marci Evangelistæ*, edited, after the author's death, by S. Pieralisi, the librarian of the Barberini library, in 1864, gives full information on all that relates to the subject of the present article. (E. HA.)

Pauline and not of the Petrine Mark are used by other writers in support of the hypothesis that in its present form it is not the work of which Papias speaks.

MARK, GOSPEL OF. See GOSPELS.

MARKIRCH (in French, *Ste-Marie-aux-Mines*), a flourishing industrial town of Germany, in Upper Alsace, circle of Rappoltsweiler, is prettily situated in the valley of the Leber or Liepvrette, an affluent of the Rhine, near the French frontier. The once productive silver, copper, and lead mines of the neighbourhood are now no longer worked; and the present chief industries of the place are weaving and dyeing. In and about Markirch there are nearly forty wool and cotton factories, besides numerous looms in the cottages of the weavers; and these produce cloth to the annual value of £625,000. It is estimated that there are about 40,000 workpeople in the industrial district of which Markirch is the centre. The small river Leber, which intersects the town, was at one time the boundary between the German and French languages, and traces of this separation still exist. The German-speaking inhabitants on the right bank were Protestants, and subject to the counts of Rappoltstein, while the French inhabitants were Roman Catholics, and under the rule of the dukes of Lorraine. The population in 1880 was 11,824.

MARLBOROUGH, a municipal and parliamentary borough of Wiltshire, England, situated on the great high-road between London and Bath, and distant 75 miles from the former, 32 from the latter, and 13 from Devizes. It stands on the left bank of the Kennet, a tributary of the Thames, in 51° 25′ N. lat. and 1° 43′ W. long. It is an agricultural centre, and has a weekly market. In the days of its prosperity forty-two public coaches halted daily at its doors, and it had a fair trade in corn and malt; but its traffic was to a great extent diverted by the opening of the Great Western Railway, and it now carries on a very small trade in tanning, rope-making, and malting. It consists mainly of a long and broad street, terminated at one end by St Mary's church and the town-hall, and at the other by St Peter's church and the college. The municipal council consists of a mayor, four aldermen, and twelve councillors, and the borough returns one member to parliament. In 1881 the population of the municipal borough (area 186 acres) was 3343, and of the parliamentary borough (area 4665 acres) 5180.

The name has been a frequent matter for discussion, some declaring it to be the hill (*berg*) or fortress (*bury*) of Merlin the Briton, others the *Marl* borough, in allusion to the surrounding soil, which, however, is chalk. A great British mound exists at the south-west extremity of the town, and a castle was erected around it by William the Conqueror. This became a somewhat notable place. Henry I. kept Easter here in 1110, and Henry II. granted it to John Lackland. Henry III. held his last parliament here in 1267, and passed the "Statutes of Marleberge." Later the castle served as an occasional royal residence; it was probably dismantled during the Wars of the Roses. The town was besieged and taken during the civil wars, and a few years later (1653) was almost entirely consumed by fire. A large mansion was erected by Lord Seymour in the reign of Charles II. near the site of the castle, and this, after various vicissitudes, was in 1843 converted into "Marlborough College,"—a public school designed mainly for the education of the sons of the clergy. A large group of buildings—chapel, schools, dining hall, racket courts, &c.—soon sprung up around the original building, and the school numbered five hundred and eighty in 1882.

MARLBOROUGH, a town of the United States, in Middlesex county, Massachusetts, about 25 miles west from Boston, with stations on the Old Colony and the Fitchburg Railways. It lies in a fertile hilly district, and contains a beautiful sheet of water 160 acres in extent, known as Williams Lake. Shoemaking is the staple industry, some of the factories in the department rivalling the largest in the world. There is a good public library; and three weekly newspapers are published in the town. The population increased from 8474 in 1870 to 10,126 in 1880. Marlborough, colonized by settlers from Sudbury in 1655, and incorporated in 1661, occupies the site of the Christian Indian village of Okommakamesitt.

MARLBOROUGH, JOHN CHURCHILL, DUKE OF (1650–1722). In the small manor house of Ashe, situated in the parish of Musbury in Devonshire, but hardly a stone's throw beyond the parish of Axminster, John Churchill the first duke of Marlborough was born 24th of June 1650. Arabella Churchill, his eldest sister, and the mother of the duke of Berwick, was born in the same house on the 28th of February 1648. They were the children of Winston Churchill of Glanville Wotton in Dorset and Elizabeth the fourth daughter of Sir John Drake, who after the close of the civil war received his son-in-law into his own house. For a year or two after the Restoration John Churchill went to St Paul's school, and there is a tradition that during this period he showed the bent of his taste by reading and re-reading Vegetius *De Re Militari*. When fifteen years old he obtained a place in the household of the duke of York, and about the same time his sister Arabella became maid of honour to the duchess, two events which contributed greatly to the advancement of the Churchills. Next year, in 1666, he received, through the influence of his master, a commission in the guards, and left England for service at Tangiers. Such fighting as was waged with the Moors did not accord with his feelings, and he soon returned to his own country. For a few years afterwards Churchill remained in attendance at the court, and it was during this period that the natural carefulness of his disposition was shown by his investing in an annuity a present of £5000 given him by a court beauty. In 1672, when England to her shame sent six thousand troops to aid Louis XIV. in his attempt to subdue the Dutch, Churchill formed one of the company, and soon attracted the attention of Turenne, by whose profound military genius the whole army was directed. At the siege of Nimeguen Churchill acquitted himself with such success that the French commander predicted his ultimate rise to distinction. When Maestricht was besieged he saved the life of the duke of Monmouth, and received the thanks of Louis XIV. for his services. Early in 1678 he was married to Sarah Jennings, the favourite attendant on the Princess Anne, the younger daughter of the duke of York. Her father Richard Jennings, a Hertfordshire squire, had twenty-two brothers and sisters; one of the latter married a London tradesman called Hill, and their daughter Abigail Hill afterwards succeeded her cousin the duchess of Marlborough as favourite to Queen Anne. Sarah Jennings had as little money as her husband, but this deficiency was more than compensated for by an abundance of energy and ambition.

On the accession of James II. the Churchills received a great increase in fortune. Colonel Churchill had been created a Scotch peer in 1682, and as a reward for his services in going on a special mission from the new monarch to Louis XIV. he was advanced to the English peerage under the title of Baron Churchill of Sandridge in Hertfordshire, the village in which the Jennings's property was situated. A step in the army was at the same time conferred upon him, and when the duke of Monmouth attempted his ill-fated enterprise in the western counties the second position in command was bestowed on Lord Churchill. Through his vigilance and energy victory declared itself on the king's side. After the death of Monmouth he withdrew as far as possible from the administration of public business. Whilst on his embassy to the French court he had declared with emphasis that if the king of England should change the religion of the state he should at once leave his service, and it was not long before the design of James became apparent to the world. Churchill was one of the first to send overtures of obedience to the prince of Orange. Although he continued in a high position under James, and drew the emoluments of his places, he promised William of Orange to use every exertion to bring over the troops to his side. James had been warned against putting any trust in the loyalty of the man on whom he had showered so many favours, but the warnings were in vain, and on the landing of the Dutch prince at Brixham Churchill was sent against him with five thousand men. When the royal army had advanced to the downs of Wiltshire and a battle seemed imminent, James was disconcerted by learning that in the dead of night his general had stolen away like a thief into the opposite camp. For this timely act of treachery Churchill received another advancement in the peerage. He had now become the earl of Marlborough and a member of the privy council, a mark of royal favour which during this and the next reign was more than an unmeaning honour. William felt, however, that he could not place implicit reliance in his friend's integrity; and, with a clear sense of the manner in which Marlborough's talents might be employed without any detriment to the stability of his throne, he sent him with the army into the Netherlands and into Ireland. For some time there was no open avowal of any distrust in Marlborough's loyalty, but in May 1692 the world was astonished at the news that he had been thrown into the Tower on an accusation of treason. Though the evidence which could be brought against him was slight, and he was soon set at liberty, there is no doubt that Marlborough was in close relations with the exiled king at St Germains, and that he even went so far as to disclose to his late master the intention of the English to attack the town of Brest. The talents of the statesmen of this reign were chiefly displayed in their attempts to convince both the exiled and the reigning king of England of their attachment to his fortunes. The sin of Marlborough lay in the fact that he had been favoured above his fellows by each in turn, and that he betrayed both alike apparently without scruple or without shame. Once again during the Fenwick plot he was charged with treason, but William, knowing that if he pushed Marlborough and his friends to extremities there were no other statesmen on whom he could rely, contented himself with ignoring the confessions of Sir John Fenwick, and with executing that conspirator himself. Not long afterwards the forgiven traitor was made governor to the young duke of Gloucester, the only one of Anne's numerous children who gave promise of attaining to manhood. During the last years of William's reign Marlborough once more was placed in positions of responsibility. His daughters were married into the most prominent families of the land: the eldest became the wife of the eldest son of Lord Godolphin; the second, the loveliest woman at the court, with her father's tact and temper and her mother's beauty, married the only son of Lord Sunderland. Higher honours were in store for his family, and they came on the accession of Queen Anne in March 1702. She had not been more than three days upon the throne before the knighthood of the Garter was conferred upon Marlborough. He was made captain-general of the English troops both at home and abroad, and master-general of the ordnance. The new queen did not forget the life-long service of his wife; three positions at the court by which she was enabled to continue by the side of the sovereign as closely as she had lived with the princess were united in her person. The queen showed her devotion to her friend by another signal mark of favour. The rangership of Windsor Park was granted her for life, with the especial object of enabling Lady Marlborough to live in the Great Lodge. These were the opening days of many years of fame and power. A week or two after the death of William it was agreed by the three great powers, England, Holland, and Austria, which formed the grand alliance, that war should be declared against France on the same day, and on May 4, 1702, the declaration was made by the three countries. Marlborough was made commander-in-chief of the united armies of England and Holland, but throughout the war his plans were impeded by the jealousy of the commanders who were nominally his inferiors, and by the opposite aims of the various countries that were striving to break the power of France. He himself wished to penetrate into the French lines; the anxiety of the Dutch was for the maintenance of their frontier and for an augmentation of their territory; the desire of the Austrian emperor was to ensure his son's rule over Spain. To secure concerted action by these different powers taxed all the diplomacy of Marlborough, but he succeeded for the most part in his desires. In the first year of the campaign it was shown that the armies of the French were not invincible. Several fortresses which Louis XIV. had seized upon surrendered themselves to the allies. Kaiserswerth on the Rhine and Venloo on the Meuse soon passed from the hands of the French to the English. The prosperous commercial town of Liége with its commanding citadel quickly capitulated. The successes of Marlborough caused much rejoicing in his own country, and for these brilliant exploits he was raised to the highest rank in the peerage, and rewarded with a handsome annuity. In the spring of the following year a crushing blow fell upon the duke and duchess. Their eldest and only surviving son, the marquis of Blandford, was seized whilst at King's College, Cambridge (under the care of Hare, afterwards bishop of Chichester), with the small-pox, and died on the 20th February 1703, in his seventeenth year. If the character of the youth which is given by Cole, the Cambridge antiquary, can be accepted as true, and Cole was not likely to be prejudiced in favour of the family of Churchill, his talents had already justified the prediction that he would rise to the highest position in the state.

The result of the campaign of 1703 inspired the French king with fresh hopes of ultimate victory. The dashing plans of Marlborough were frustrated by the opposition of his Dutch colleagues. When he wished to invade the French territory they urged him to besiege Bonn, and he was compelled to accede to their wishes. After this digression from his first purpose he returned to his original plan of attacking Antwerp; but, in consequence of the incapacity of the Dutch leaders, the generals (Villeroi and Boufflers) of the French army surprised the Dutch division and inflicted on it a loss of many thousands of men. Marlborough was forced to abandon his enterprise, and all the compensation which he received was the capture of the insignificant forts of Huy and Limburg. After a year of comparative failure for the allies, Louis XIV. was emboldened to enter upon an offensive movement against Austria; and Marlborough, smarting under the misadventures of 1703, and conscious that the war could only be brought to an end by more decisive measures, was eager to meet him. A magnificent army was sent by the French king under the command of Marshal Tallard, with instructions to strike a blow at Vienna itself. Marlborough divined the intention of the expedition, and, without communicating his intentions to his colleagues, led his troops into Bavaria. The two armies (that under Marlborough and Prince Eugène numbering more than fifty thousand men, whilst Tallard's forces were nearly ten thousand stronger) met in battle array near the village of Blenheim. The French commander made the mistake of supposing that the enemy's attack would be directed against his position in the village, and he concentrated an excessive number of his troops at that point. The early part of the fight was in favour of the French. Three times were the troops led by Prince Eugène driven back in confusion; Marlborough's cavalry failed on their first attack in breaking the line of the enemy. But in the end the victory of the allies was conclusive. Nearly thirty thousand of the French and Bavarians were killed and wounded, and in Blenheim alone ten thousand were made prisoners. Never was a victory more eagerly welcomed than this, and never was a conquering leader more rewarded than Marlborough. On his return to his own country he was received with enthusiasm on all sides. Poets and prose writers were employed to do him honour, and the lines of Addison comparing the English commander to the angel who passed over "pale Britannia" in the storm of 1703 have been famous for nearly two centuries. The manor of Woodstock, which was transferred by Act of Parliament from the crown to the duke, was a reward more after his own heart. The gift even in that form was a noble one, but the queen heightened it by instructing Sir John Vanbrugh to build a palace in the park at the royal expense, and, although the works subsequently caused much anxiety to the duke and duchess, £240,000 of public money was spent on the buildings.

The following year was not marked by any stirring incident. Marlborough was hampered by tedious formalities at the Hague and by jealousies at the German courts. The armies of the French were again brought up to their full standard, but the generals of Louis were instructed to entrench themselves behind earthworks and to act on the defensive. In the darkness of a July night these lines were broken through, and the French were forced to take shelter under the walls of Louvain. Marlborough urged an attack upon them in their new position, but his passionate arguments were spent in vain, and when 1705 had passed away the forces of the French king had suffered no diminution. This immunity from disaster tempted Villeroi in the next spring into meeting the allied forces in an open fight, but his assurance proved his ruin. The battle of Ramillies (23d May 1706) ended in the total rout of the French, and caused the transference of nearly the whole of Brabant and Flanders to the allies. Five days afterwards the victor entered Brussels in state, and the inhabitants acknowledged the rule of the archduke. Antwerp and Ostend surrendered themselves with slight loss. Menin held out until three thousand of the soldiers of the allies were laid low around its walls, but Dendermonde, which Louis had forty years previously besieged in vain, quickly gave itself up to the resistless Marlborough. Again a year of activity and triumph was succeeded by a period of languor and depression. During the whole of 1707 fortune inclined to the other side, with the result that early in the next year Ghent and Bruges returned to the allegiance of the French, and Marlborough, fearing that their example might be followed by the other cities, advanced with his whole army towards Oudenarde. Had the counsels of Vendome, one of the ablest of the French generals, prevailed, the fight might have had a different issue, but his suggestions were disregarded by the duke of Burgundy, the grandson of Louis, and the battle, like its predecessor, ended in their defeat. After this victory Marlborough, ever anxious for decisive measures, wished to advance on Paris, but he was overruled. The allied army invested the town of Lille, on the fortifications of which Vauban had expended an immensity of thought; and after a struggle of nearly four months, and the loss of thirty thousand men, the citadel surrendered. By the end of the year Brabant was again subject to the rule of the allies. The suffering in France at this time weighed so heavily upon the people that its proud king humbled himself to sue for peace. Each of the allies in turn did he supplicate, and his minister endeavoured by promises of large sums of money to obtain the support of Marlborough to his proposals. These attempts were in vain, and when the winter passed away a French army of one hundred and ten thousand, under the command of Villars, took the field. On the 3d of August 1709 Tournay capitulated, and the two leaders, Marlborough and Eugène, led their forces to Mons, in spite of the attempt of Villars to prevent them. For the last time during the protracted war the two armies met in fair fight at Malplaquet, 11th September 1709, where the French leader had strengthened his position by extensive earthworks. The fight was long and doubtful, and, although the French ultimately retreated under the direction of Boufflers, for Villars had been wounded on the knee, it was in good order, and their losses were less than those of their opponents. The campaign lasted for a year or two after this indecisive contest, but it was not signalized by any such "glorious victory" as Blenheim. All that the English could plume themselves on was the acquisition of a few such fortresses as Douai and Bethune, and all that the French had to fear was the gradual tightening of the enemy's chain until it reached the walls of Paris. The energies of the French were concentrated in the construction of fresh lines of defence, until their commander boasted that his position was impregnable. In this way the war dragged on until the conclusion of the peace of Utrecht.

All that Marlborough had effected on the battlefield during these years of war had not prevented his position from being undermined by party intrigues at home. In the early part of Queen Anne's reign his political friends were to be found among the Tories, and the ministry was chiefly composed of members of that party. After a year or two, however, the more ardent Tories withdrew, and two younger adherents of the same cause, Harley and St John (both of whom were at present content to conceal their animosity to Marlborough), were introduced into the ministry. The duchess, partly through the influence of her son-in-law, the earl of Sunderland, and partly through the opposition of the Tories to the French war, had gone over to the Whig cause, and she pressed her views on the sovereign with more vehemence than discretion. She had obtained for her indigent cousin, Abigail Hill, a small position at court, and the poor relation very soon began to injure the benefactor who had befriended her. With Hill's assistance Harley and St John widened the breach with the queen which was commenced by the imperious manner of the duchess. The love of the two friends changed into hate, and no opportunity for humiliating the family of Marlborough was allowed to pass away neglected. Sunderland and Godolphin were the first to fall (July–August 1710); a few months later the duchess was dismissed from her offices; and, although Marlborough himself was permitted to continue in his position a short time longer, his fall was only delayed until the last day of 1711. Life in England had become so unpleasant that he went to the Continent, and he remained abroad until the death of Anne (1st August 1714). Then he once more returned to the shores of England and resumed his old military posts, but he took little part in public affairs. Even if he had wished to regain his commanding position in the country, ill health would have prevented him from obtaining his desires. Johnson, indeed, says, in the *Vanity of Human Wishes*, that "the streams of dotage" flowed from his eyes; but it is not desirable to examine too critically the assertions of a poem which relied for its success upon the strength of its comparisons. It is certain that at the time of his death he was able to understand the remarks of others and to express his own wishes. At four o'clock on the morning of the 16th June 1722, he died at Cranbourn Lodge near Windsor. His remains were at first deposited in Westminster Abbey, in the vault at the east end of King Henry VII.'s chapel, but they now rest at Blenheim.

His widow, to whom must be assigned a considerable share both in his rise and in his fall, survived till October 1744. Those years were spent in bitter animosity with many within and without her own family. Left by her husband with the command of boundless wealth, she used it for the vindication of his memory and for the justification of her own resentment. Two of the leading opponents of the ministry, Chesterfield and Pitt, were especially honoured by her attentions. To Pitt she left ten thousand pounds, to the other statesman twice that sum and a reversionary interest in her landed property at Wimbledon. Whilst a widow, she received numerous offers of marriage from many titled suitors. She refused them all: from her marriage to her death her heart had no other inmate than the man as whose wife she had become almost a rival to royalty.

Marlborough obtained his first start in life through a handsome pension, and his rapid rise to the highest position in the state was due to his singular tact and to his skill in the management of men. In an age remarkable for grace of manner and for adroitness of compliment, his courteous demeanour and the art with which he refused or granted a favour extorted the admiration of every one with whom he came in contact. Through his consideration for the welfare of his soldiers he held together for years an army drawn from every nation in Christendom. His talents may not have been profound (he possessed "an excellent plain understanding and sound judgment" is the opinion of Lord Chesterfield); but they were such as Englishmen love. Alike in planning and in executing, he took infinite pains in all points of detail. Nothing escaped his observation, and in the hottest moment of the fight the coolness of his intellect shone conspicuous. His enemies indeed affected to attribute his uniform success in the field to fortune, and they magnified his love of money by drawing up balance sheets which included every penny which he had received, but omitted the pounds which he had spent in the cause he had sincerely at heart. All that can be-alleged in excuse of his attempt to serve two masters, the king whom he had deserted and the king who had received him into favour, is that not one of his associates was without sin in this respect.

The books on Marlborough are very numerous. Under his name in the catalogue of the British Museum there are 121 entries, and 32 under that of his wife. The chief works are Lediard's, Coxe's, and Alison's *Lives*; a French memoir in 3 volumes, 1808; Marlborough's *Letters and Despatches*, edited by Sir George Murray (5 volumes); and Mrs Creighton's interesting summary. The descriptions in Mr John Hill Burton's *Reign of Queen Anne* of the battle scenes of Marlborough are from personal observation. A good account of his birthplace and country will be found in Pulman's *Book of the Axe District*; and for the home of the duchess the reader can refer to Mr Cussan's *History of Hertfordshire*. Long after the death of the duke there were many pamphlets written on the conduct of his wife from her appearance at court; but they relate to matters of little interest at the present time. (W. P. C.)

MARLOW, Great, a parliamentary borough of Buckinghamshire, England, is finely situated on the Thames, and on a branch of the Great Western Railway, 37 miles west of London and 25 south-east of Oxford. It consists principally of two streets which cross each other at right angles. The church of All Saints, in the Later English style, erected in 1835, and lately extensively restored, possesses a number of brasses. The former bluecoat school has been reorganized under the endowed schools commission as a grammar school. The town has paper-mills, a brewery, and manufactures of lace and embroidery. It is also a favourite resort for boating and fishing. Marlow, anciently *Merlaw*, is a very ancient manor, and for some time after William the Conqueror it was in the possession of the crown. It returned members to parliament from the 28th of Edward I. till the 2d of Edward II., and the privilege was again restored in the 21st of James I.; since 1868 it has returned but one member. The borough includes Great and Little Marlow, Medmenham, and Bisham in Berkshire, which is united with Great Marlow by a suspension bridge, erected in 1835, at a cost of £20,000. The population of the borough, which has an area of 14,514 acres, 2424 being in the county of Berks, was 6627 in 1871 and 6779 in 1881.

MARLOWE, Christopher (1564–1593), the father of English tragedy and the creator of English blank verse, was born at Canterbury in February 1564, and christened on the 26th of that month. John Marlowe, his father, is said, on authority which satisfied the best editor of the poet, to have been a shoemaker by trade; it is supposed also that he was clerk of his parish, and survived his illustrious son for upwards of eleven years. The boy was educated at the King's School, Canterbury; matriculated as pensioner of Benet College, Cambridge, March 17, 1581; took the degree of bachelor of arts in 1583, and that of master of arts four years later. Before this date he had produced the first tragedy worthy of that name in our language, and called into existence that highest and most difficult of all its other than lyrical forms of verse, which alone has proved worthy of acceptance among his countrymen as the fit and adequate instrument of tragic drama. At some uncertain date of his early life he is supposed to have been an actor, and said to have broken his leg in the practice of his profession. But for this and many other traditions of his career and conversation there is no better evidence than that of a religious libeller. His first tragedy of *Tamburlaine the Great*, in two parts, was successively followed by *Doctor Faustus*, *The Jew of Malta*, *Edward the Second*, and *The Massacre at Paris*. The tragedy of *Dido*, *Queen of Carthage*, was probably completed for the stage after his death by Thomas Nash, the worthiest English precursor of Swift in vivid, pure, and passionate prose, embodying the most terrible and splendid qualities of a social and personal satirist; a man gifted also with some fair faculty of elegiac and even lyric verse, but in no wise qualified to put on the buskin left behind him by the "famous gracer of tragedians," as Marlowe had already been designated by their common friend Greene from among the worthiest of his fellows.

The only authentic record concerning the death of Marlowe is an entry "in the burial-register of the parish church of St Nicholas," Deptford: "Christopher Marlowe, slain by Francis Archer, June 1, 1593." Two Puritan scribblers have left two inconsistent reports as to the circumstances of this manslaughter. On the more respectable authority of Francis Meres the critic (1598) we are told that Marlowe was "stabbed to death" by a "servingman" of bad character, "a rival of his in his lewd love." The one thing unhappily certain is that one of the greatest among English poets died of a wound received in a brawl (stabbed in the head, according to one account, with his own dagger) at the untimely age of twenty-nine years and three months. Like Sir Walter Raleigh and a few less memorable men of the same generation, he was attacked in his own time not merely as a freethinker, but as a propagandist or apostle of atheism; nor was the irregularity of his life thought worthier of animadversion than the uncertainty of his livelihood. The informer whose name has survived as that of his most venomous assailant was duly hanged the year after Marlowe's death; and the list of his charges, first published by Ritson, is hardly a document which can commend itself to any man's confidence as plausibly or even possibly accurate in all its detailed report of the violent and offensive nonsense attributed to the freethinking poet in common conversation "concerning his damnable opinions."

The majestic and exquisite excellence of various lines and passages in Marlowe's first play must be admitted to relieve, if it cannot be allowed to redeem, the stormy monotony of Titanic truculence which blusters like a simoom through the noisy course of its ten fierce acts. With many and heavy faults, there is something of genuine greatness in *Tamburlaine the Great*; and for two grave reasons it must always be remembered with distinction and mentioned with honour. It is the first poem ever written in English blank verse, as distinguished from mere rhymeless decasyllabics; and it contains one of the noblest passages, perhaps indeed the noblest in the literature of the world, ever written by one of the greatest masters of poetry in loving praise of the glorious delights and sublime submission to the everlasting limits of his art. In its highest and most distinctive qualities, in unfaltering and infallible command of the right note of music and the proper tone of colour for the finest touches of poetic execution, no poet of the most elaborate modern school, working at ease upon every consummate resource of luxurious learning and leisurely refinement, has ever excelled the best and most representative work of a man who had literally no models before him, and probably or evidently was often if not always compelled to write against time for his living.

The just and generous judgment passed by Goethe on the *Faustus* of his English predecessor in tragic treatment of the same subject is somewhat more than sufficient to counterbalance the slighting or the sneering references to that magnificent poem which might have been expected from the ignorance of Byron or the incompetence of Hallam. And the particular note of merit observed, the special point of the praise conferred, by the great German poet should be no less sufficient to dispose of the vulgar misconception yet lingering among sciolists and pretenders to criticism, which regards a writer than whom no man was ever born with a finer or a stronger instinct for perfection of excellence in execution as a mere noble savage of letters, a rough self-taught sketcher or scribbler of crude and rude genius, whose unhewn blocks of verse had in them some veins of rare enough metal to be quarried and polished by Shakespeare. What most impressed the author of *Faust* in the work of Marlowe was a quality the want of which in the author of *Manfred* is proof enough to consign his best work to the second or third class at most. "How greatly it is all planned!" the first requisite of all great work, and one of which the highest genius possible to a greatly gifted barbarian could by no possibility understand the nature or conceive the existence. That Goethe "had thought of translating it" is perhaps hardly less precious a tribute to its greatness than the fact that it has been actually and admirably translated by the matchless translator of Shakespeare—the son of Victor Hugo; whose labour of love may thus be said to have made another point in common, and forged as it were another link of union, between Shakespeare and the young master of Shakespeare's youth. Of all great poems in dramatic form it is perhaps the most remarkable for absolute singleness of aim and simplicity of construction; yet is it wholly free from all possible imputation of monotony or aridity. *Tamburlaine* is monotonous in the general roll and flow of its stately and sonorous verse through a noisy wilderness of perpetual bluster and slaughter; but the unity of tone and purpose in *Doctor Faustus* is not unrelieved by change of manner and variety of incident. The comic scenes, written evidently with as little of labour as of relish, are for the most part scarcely more than transcripts, thrown into the form of dialogue, from a popular prose *History of Dr Faustus*, and therefore should be set down as little to the discredit as to the credit of the poet. Few masterpieces of any age in any language can stand beside this tragic poem—it has hardly the structure of a play—for the qualities of terror and splendour, for intensity of purpose and sublimity of note. In the vision of Helen, for example, the intense perception of loveliness gives actual sublimity to the sweetness and radiance of mere beauty in the passionate and spontaneous selection of words the most choice and perfect; and in like manner the sublimity of simplicity in Marlowe's conception and expression of the agonies endured by Faustus under the immediate imminence of his doom gives the highest note of beauty, the quality of absolute fitness and propriety, to the sheer straightforwardness of speech in which his agonizing horror finds vent ever more and more terrible from the first to the last equally beautiful and fearful verse of that tremendous monologue which has no parallel in all the range of tragedy.

It is now a commonplace of criticism to observe and regret the decline of power and interest after the opening acts of *The Jew of Malta*. This decline is undeniable, though even the latter part of the play is not wanting in rough energy and a coarse kind of interest; but the first two acts would be sufficient foundation for the durable fame of a dramatic poet. In the blank verse of Milton alone, who perhaps was hardly less indebted than Shakespeare was before him to Marlowe as the first English master of word-music in its grander forms, has the glory or the melody of passages in the opening soliloquy of Barabas been possibly surpassed. The figure of the hero before it degenerates into caricature is as finely touched as the poetic execution is excellent; and the rude and rapid sketches of the minor characters show at least some vigour and vivacity of touch.

In *Edward the Second* the interest rises and the execution improves as visibly and as greatly with the course of the advancing story as they decline in *The Jew of Malta*. The scene of the king's deposition at Kenilworth is almost as much finer in tragic effect and poetic quality as it is shorter and less elaborate than the corresponding scene in Shakespeare's *King Richard II*. The terror of the death-scene undoubtedly rises into horror; but this horror is with skilful simplicity of treatment preserved from passing into disgust. In pure poetry, in sublime and splendid imagination, this tragedy is excelled by *Doctor Faustus*; in dramatic power and positive impression of natural effect it is as certainly the masterpiece of Marlowe. It was almost inevitable, in the hands of any poet but Shakespeare, that none of the characters represented should be capable of securing or even exciting any finer sympathy or more serious interest than attends on the mere evolution of successive events or the mere display of emotions (except always in the great scene of the deposition) rather animal than spiritual in their expression of rage or tenderness or suffering. The exact balance of mutual effect, the final note of scenic harmony, between ideal conception and realistic execution is not yet struck with perfect accuracy of touch and security of hand; but on this point also Marlowe has here come nearer by many degrees to Shakespeare than any of his other predecessors have ever come near to Marlowe.

Of *The Massacre at Paris* it is impossible to judge fairly from the garbled fragment of its genuine text which is all that has come down to us. To Mr Collier, among numberless other obligations, we owe the discovery of a noble passage excised in the piratical edition which gives us the only version extant of this unlucky play, and which, it must be allowed, contains nothing of quite equal value. This is obviously an occasional and polemical work, and being as it is overcharged with the anti-Catholic passion of the time has a typical quality which gives it some empirical significance and interest. That antipapal ardour is indeed the only note of unity in a rough and ragged chronicle which shambles and stumbles onward from the death of Queen Jeanne of Navarre to the murder of the last Valois. It is possible to conjecture, what it would be fruitless to affirm, that it gave a hint in the next century to Nathaniel Lee for his far superior and really admirable tragedy on the same subject, issued ninety-seven years after the death of Marlowe.

In the tragedy of *Dido, Queen of Carthage*, a servile fidelity to the text of Virgil's narrative has naturally resulted in the failure which might have been expected from an attempt at once to transcribe what is essentially inimitable and to reproduce it under the hopelessly alien conditions of dramatic adaptation. The one really noble passage in a generally feeble and incomposite piece of work is, however, uninspired by the unattainable model to which the dramatists have been only too obsequious in their subservience. It is as nearly certain as anything can be which depends chiefly upon cumulative and collateral evidence that the better part of what is best in the serious scenes of *King Henry VI.* is mainly the work of Marlowe. That he is at any rate the principal author of the second and third plays passing under that name among the works of Shakespeare, but first and imperfectly printed as *The Contention between the two Famous Houses of York and Lancaster*, can hardly be now a matter of debate among competent judges. The crucial difficulty of criticism in this matter is to determine, if indeed we should not rather say to conjecture, the authorship of the humorous scenes in prose, showing as they generally do a power of comparatively high and pure comic realism to which nothing in the acknowledged works of any pre-Shakespearean dramatist is even remotely comparable. Yet, especially in the original text of these scenes as they stand unpurified by the ultimate revision of Shakespeare or his editors, there are tones and touches which recall rather the clownish horseplay and homely ribaldry of his predecessors than anything in the lighter interludes of his very earliest plays. We find the same sort of thing which we find in their writings, only better done than they usually do it, rather than such work as Shakespeare's a little worse done than usual. And even in the final text of the tragic or metrical scenes the highest note struck is always, with one magnificent and unquestionable exception, rather in the key of Marlowe at his best than of Shakespeare while yet in great measure his disciple.

Had every copy of Marlowe's boyish version or perversion of Ovid's *Elegies* deservedly perished in the flames to which it was judicially condemned by the sentence of a brace of prelates, it is possible that an occasional bookworm, it is certain that no poetical student, would have deplored its destruction, if its demerits could in that case have been imagined. His translation of the first book of Lucan alternately rises above the original and falls short of it,—often inferior to the Latin in point and weight of expressive rhetoric, now and then brightened by a clearer note of poetry and lifted into a higher mood of verse. Its terseness, vigour, and purity of style would in any case have been praiseworthy, but are nothing less than admirable, if not wonderful, when we consider how close the translator has on the whole (in spite of occasional slips into inaccuracy) kept himself to the most rigid limit of literal representation, phrase by phrase and often line by line. The really startling force and felicity of occasional verses are worthier of remark than the inevitable stiffness and heaviness of others, when the technical difficulty of such a task is duly taken into account.

One of the most faultless lyrics and one of the loveliest fragments in the whole range of descriptive and fanciful poetry would have secured a place for Marlowe among the memorable men of his epoch, even if his plays had perished with himself. His *Passionate Shepherd* remains ever since unrivalled in its way—a way of pure fancy and radiant melody without break or lapse. The untitled fragment, on the other hand, has been very closely rivalled, perhaps very happily imitated, but only by the greatest lyric poet of England—by Shelley alone. Marlowe's poem of *Hero and Leander*, closing with the sunrise which closes the night of the lovers' union, stands alone in its age, and far ahead of the work of any possible competitor between the death of Spenser and the dawn of Milton. In clear mastery of narrative and presentation, in melodious ease and simplicity of strength, it is not less pre-eminent than in the adorable beauty and impeccable perfection of separate lines or passages.

The place and the value of Christopher Marlowe as a leader among English poets it would be almost impossible for historical criticism to overestimate. To none of them all, perhaps, have so many of the greatest among them been so deeply and so directly indebted. Nor was ever any great writer's influence upon his fellows more utterly and unmixedly an influence for good. He first, and he alone, guided Shakespeare into the right way of work; his music, in which there is no echo of any man's before him, found its own echo in the more prolonged but hardly more exalted harmony of Milton's. He is the greatest discoverer, the most daring and inspired pioneer, in all our poetic literature. Before him there was neither genuine blank verse nor a genuine tragedy in our language. After his arrival the way was prepared, the paths were made straight, for Shakespeare. (A. C. S.)

MARLY-LE-ROI, chief place of a canton in the department of Seine-et-Oise, France, 5 miles to the north of Versailles and 3 miles to the south of St Germain-en-Laye, is, notwithstanding some fine country houses, a dull and unattractive village of 1250 inhabitants, which owes all its celebrity to the sumptuous chateau of Louis XIV. It was originally designed as a simple hermitage to which the king could occasionally retire with a few of his more intimate friends from the pomp of Versailles, but gradually it grew until it became one of the most ruinous extravagances of the Grand Monarque. The central pavilion (inhabited by the king himself) and its twelve subsidiary pavilions were intended to suggest the sun surrounded by the signs of the zodiac. Seldom visited by Louis XV., and wholly abandoned by Louis XVI., it was demolished after the Revolution, its art treasures having previously been dispersed, and all that now remains consists of a few mouldering ivy-grown walls, some traces of parterres with magnificent trees, the park, which is well stocked with game, and the forest of 8½ square miles, one of the most pleasant promenades of the neighbourhood of Paris.

Close to the Seine, half-way between Marly-le-Roi and St Germain, is the village of Port-Marly (500 inhabitants), and 1 mile farther up is the hamlet of Marly-la-Machine. Here, under Louis XIV., an immense hydraulic engine, driven by the current of the river, was erected; it raised the water to a high tower of 155 metres (508 English feet), where the aqueduct of Marly commenced (2100 English feet in length, 75 in height, with 36 arches, still well-preserved), carrying the waters of the Seine to Versailles. The first engine of Marly began to work in 1682, but it was necessary to modify it in 1803. In 1826 a steam-engine was substituted, and since 1858 an atmospheric engine has been employed.

MARMONT, Auguste Frédéric Louis Viesse de (1774–1852), duke of Ragusa, and marshal of France, one of Napoleon's earliest friends and most trusted generals, was born at Châtillon-sur-Seine, on July 20, 1774. He was the son of an ex-officer in the army, who belonged to the *petite noblesse*, and had adopted the principles of the Revolution. His love of soldiering soon showing itself, his father took him to Dijon to learn mathematics prior to entering the artillery, and there he made the acquaintance of Bonaparte, which he renewed after obtaining his commission when he served in Toulon. The acquaintance ripened into intimacy; Marmont became General Bonaparte's aide-de-camp, and accompanied him to Italy and Egypt, winning distinction and promotion as general of brigade. In 1799 he left Egypt with Bonaparte to the mercy of the English; he was present at the revolution of the 18th Brumaire, and organized the artillery for the expedition to Italy, which he commanded with great effect at Marengo. For this he was at once made general of division. In 1801 he became inspector-general of artillery, and in 1804 grand officer of the Legion of Honour. In 1805 he received the command of a corps, with which he did good service at Ulm. He was then directed to occupy Dalmatia with his army; he defeated the Russians on October 30 at Castel Nuovo, and occupied Ragusa. The next five years were the most creditable in his life; he was both military and civil governor of Dalmatia, and has still left traces there both in great public works and in the memories of the people. In 1807 he was made duke of Ragusa, and in 1809, being summoned up to the help of Napoleon, who was closely beset in the island of Lobau, earned the marshal's baton by his conduct at Wagram. In July 1810 he was hastily summoned from his palace, where he lived in Eastern luxury, to succeed Masséna in the command of the French army in the north of Spain, called the army of Portugal. The skill with which he manœuvred his army during the year he commanded it has been always acknowledged. His relief of Ciudad Rodrigo in the autumn of 1811 in spite of the presence of the English army was a great feat, and in the tactics which preceded the battle of Salamanca he had the best of it. The extension of his left on the 22d July 1812 was, however, fatal, and its result was the great defeat of Salamanca, in which Marmont was severely wounded in the right arm and side. He retired to France to recover, and was still hardly cured when in April 1813 Napoleon gave him the command of the 6th corps. With it he served at the battles of Lützen, Bautzen, and Dresden, and throughout the great defensive campaign of 1814, until the last desperate battle before the walls of Paris, from which he drew back his forces to the commanding position of Essonne. Here he had 20,000 men in splendid condition, and was the pivot of all thoughts. Napoleon said of Essonne, "C'est là que viendront s'addresser toutes les intrigues, toutes les trahisons; aussi y ai-je placé Marmont, mon enfant élevé sous ma tente." Marmont betrayed this trust and suffered for it. On the restoration of the Bourbons he was made a peer of France, and a major-general of the royal guard, and in 1820 a knight of St Esprit and a grand officer of the order of St Louis, but he was never trusted, never popular. He was the major-general of the guard on duty in July 1830, and was ordered to put down with a strong hand any opposition to the ordinances (see FRANCE). After persevering some time he gave way, and allowed the republicans to succeed in their revolution. This defection brought more obloquy upon him, and the Duc d'Angoulême even ordered him under arrest, saying, "Will you betray us, as you betrayed him?" After this Marmont left France and wandered about the Continent for twenty years, publishing many volumes of travels, an edition of Cæsar and of Xenophon, and his *Esprit des Institutions Militaires.* Much of his time was spent upon his *Mémoires*, which are of real value for the military history of his time, though they must be read as a personal defence of himself in various junctures rather than as an unbiassed account of his times. They show Marmont, as he really was, an embittered man, who never thought his services sufficiently requited, a great artillery general indeed, but without the fire of genius which is so striking in several of his contemporaries, and above all, a man too much in love with himself and his own glory to be a true friend or a faithful servant.

For Marmont's military ability consult Napier, Jomini, and the historians of the time, particularly General Pelet. His own works are *Voyage en Hongrie*, &c., 4 vols., 1837; *Voyage en Sicile*, 1838; *Esprit des Institutions Militaires*, 1845; *César*; *Xenophon*; and *Mémoires*, 8 vols., published after his death in 1856. See also a long and careful notice by Sainte-Beuve, *Causeries du Lundi*, vol. vi.

MARMONTEL, JEAN FRANÇOIS (1723-1799), one of the most distinguished men of letters in Paris during the latter half of the 18th century, was born of poor parents in Limousin, on the 11th July 1723. After studying with the Jesuits at Mauriac, he taught in their colleges at Clermont and Toulouse; and in 1745, acting on the advice of Voltaire, he set out for Paris to try for literary honours. From 1748 to 1753 he wrote a succession of tragedies which,[1] though for the most part considered prolix and artificial by modern readers, had great success on the stage, and secured to Voltaire's new disciple a good position in literary and fashionable circles. Being now associated with Diderot and D'Alembert, he wrote for the great *Encyclopédie* a series of articles evincing considerable critical power and insight, which in their collected form, under the title *Éléments de Littérature*, still rank among the higher French classics. He also wrote several comic operas, the two best of which probably are *Sylvain* and *Zémire et Azore.* In 1758 he gained the patronage of Madame Pompadour, and was soon after appointed manager of the official journal *Le Mercure*, in which he had already commenced a series of elegant and attractive tales. These were the *Contes Moraux*, on which, according to some critics, Marmontel's literary reputation mainly rests. Their merit lies partly in the literary style, which in delicate finish frequently rivals that of his master Voltaire, but mainly in their graphic and charming pictures of French society under Louis XV. After being elected to the French Academy, in 1763, he appears to have been ambitious to create a new literary style, exemplified notably in his dull prose-epic romance *Bélisaire*, now remarkable only on account of a chapter on religious toleration which incurred the censure of the Sorbonne and the archbishop of Paris. Marmontel retorted in *Les Incas*, by tracing the cruelties in Spanish America to the religious fanaticism of the Roman Catholic invaders.

After being appointed historiographer of France, secretary to the Academy (1783), and professor of history in the Lycée (1786), Marmontel in 1788 wrote a history of the regency, which is of little value. To compensate for this, however, he in 1795 began his *Mémoires*, the most interesting and valuable if not the greatest of his works, being a picturesque review of his whole life, a literary history of two important reigns, a great gallery of portraits extending from the venerable Massillon, whom more than half a century previously he had seen at Clermont, to the fiery Mirabeau amidst the tempestuous first years of the French Revolution. Reduced to poverty by the Revolution, Marmontel in 1792 retired from the Reign of Terror to Evreux, and soon after to a cottage near Gaillon, in the department of Eure. To that retreat we owe the *Mémoires*, and there, after a short stay in Paris when elected in 1797 to the Conseil des Anciens, he died on the 31st December 1799.

See Villenave, *Notices sur Marmontel*; Sainte-Beuve, *Causeries*, vol. iv.; Morellet, *Éloge*, 1805; *Edinburgh Review*, January 1806.

MARMORA, SEA OF. See BLACK SEA.

MARMOT. The word marmot may be considered to include animals belonging to the three following genera:—the true marmots, forming the genus *Arctomys* ("bear-mouse"), so called from the thickset, bear-like form of its members; the prairie marmots of North America, better known as the "prairie dogs" (*Cynomys*, "dog-mouse"); and the pouched marmots, or sousliks, comprising the genus *Spermophilus*, or seed-lovers, so named from the character of their food. These three genera are all closely allied to each other, and together form the subfamily *Arctomyinæ* of the great squirrel family, the *Sciuridæ*, of which the only other subfamily, the *Sciurinæ*, consists of the true squirrels (*Sciurus*) and the flying-squirrels (*Pteromys*). The members of the marmot subfamily are confined to the northern hemisphere, and in fact are almost entirely limited to the north temperate zone, in marked contrast to the genera of the subfamily *Sciurinæ*, which attain their greatest development in tropical or semi-tropical countries.

The *Arctomyinæ* agree in the possession of somewhat short, stumpy bodies, comparatively short tails (except in certain sousliks), and long and powerful claws suitable for burrowing. They all have broad, strong, and ungrooved incisors or cutting teeth, two pairs of premolars above and one below, and three pairs of true molars in each jaw. The grinding teeth are all on the whole very similar, the first upper premolar much smaller than the others, and nearly round, the next three teeth triangular in outline, and each with either two or three transverse grooves upon the crown; the last molar is rather broader and more complicated than the others, as is shown in fig. 2. The general form of the skeleton is very similar to that of the true squirrels, but the bones as a rule are stouter and heavier.

1. The following are the generic characters of *Arctomys*. External form stout and heavy, ears short, tail short and hairy, cheek-pouches rudimentary or absent. Fore feet with four well-developed toes, and a rudimentary thumb provided with a flat nail; skull (see MAMMALIA, p. 417, fig. 92) similar in general form to that of the other genera, but very much larger and heavier, the post-orbital processes

[1] *Denys le Tyran*, 1748; *Aristomène*, 1749; *Cléopâtre*, 1750; *Héraclides*, 1752; *Egyptus*, 1753.

stouter, and at right angles to the axis of the skull. Incisors broad and powerful. First upper premolar nearly as large as the second. Molar series nearly parallel, scarcely converging behind at all.

The various species of marmot, about ten in number, are all much alike in general appearance, ranging in size from about 15 to 25 inches in length, with tails from 3 to 6 inches long. The following are the species now generally recognized, though the Central-Asiatic forms are still very imperfectly known :—

Arctomys marmotta, Linn., southern Europe, the Alps, Pyrenees, and Carpathians; *A. bobac*, Schreb., eastern Europe and Siberia; *A. himalayanus*, Hodgs., south-west Tibet; *A. hemachalanus*, Hodgs., Nepal; *A. caudatus*, Jacquemont, Cashmere; *A. dichrous*, Anderson, Afghanistan; *A. aureus*, Blanford, Turkestan; *A. monax*, Linn., eastern North America; *A. flaviventer*, Aud. and Bach, western United States; *A. pruinosus*, Gmel., north-western North America.

It will thus be seen that one species only is peculiar to Europe, and three to North America, while at least six, and perhaps more, are found in various parts of Central Asia,—one of these, *A. bobac*, occurring also as far west as Russia and eastern Germany.

Fig. 1.—Alpine Marmot (*Arctomys marmotta*). After Brehm.

The following account of the habits of the Alpine marmot, *A. marmotta*, extracted from Professor Blasius's well-known work on the mammals of Germany, applies, with but little variation, to all the members of the genus.

Marmots live high up in the snowy regions of the mountains, generally preferring exposed cliffs, whence they may have a clear view of any approaching danger, for which, while quietly basking in the sun or actively running about in search of food, a constant watch is kept. When one of them raises the cry of warning, the loud piercing whistle so well known to travellers in the Alps, they all instantly take to flight and hide themselves in holes and crannies among the rocks, often not reappearing at the entrance of their hiding-places until several hours have elapsed, and then frequently standing motionless on the look-out for a still longer period. Their food consists of the roots and leaves of various Alpine plants, which, like squirrels, they lift to their mouths with their fore paws.

For their winter quarters they make a large round burrow, with but one entrance, and ending in a sleeping-place thickly padded with hay. Here often from ten to fifteen marmots pass the winter, all lying closely packed together fast asleep until the spring. On awaking, hungry with their long fast, they remove the hay with which they stuff up the doors of their burrows, and resume their life of activity and watchfulness. The breeding season is in the early summer, when they bring forth from four to six young ones. Their flesh, although coarse and rank, is eaten by the peasants, and their fur, though of but little value, is also made use of.

2. Our second genus is *Cynomys*, containing only the well-known "prairie dogs," or more correctly "prairie marmots," of the United States. The genus may be characterized as follows. Size and form intermediate between *Arctomys* and *Spermophilus*. Ears and tail short. Cheek-pouches shallow. Fore feet with five claws, that on the thumb as large as that on the fifth toe. Skull heavily built, the post-orbital processes directed outwards. Dentition, as shown in fig. 2, remarkably heavy, the molar teeth differing from those of *Arctomys* and *Spermophilus* by having three instead of two transverse grooves on their crowns. First premolar nearly as large as the second. Molar series strongly convergent behind.

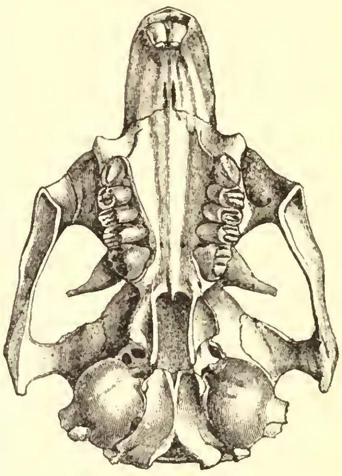


Fig. 2.—Under Side of Skull of *Cynomys ludovicianus*.

Of this genus two species have been described, very closely allied to each other, but separable by their slightly different size and coloration. The larger and better-known of the two is the eastern prairie marmot, *C. ludovicianus*, Ord., inhabiting the open prairies of the central United States, while the smaller species, *C. columbianus*, Ord., is found to the westward as far as the Rocky Mountains.

The habits of the prairie marmots have been so often described that every one is familiar with their custom of forming their burrows in groups or "towns," of sitting outside to watch intruders, and of making the peculiar barking sound from which they have derived their erroneous popular name of prairie dogs. In the burrows made by them there are commonly found three strange and, notwithstanding the earlier travellers' tales, certainly unwelcome visitors, namely, rattlesnakes, owls, and weasels, all of which at times probably prey upon the young marmots. Prairie marmots do not truly hibernate, although in the more northern and colder parts of their range they retire to their burrows during the very severest weather. They feed on grasses and roots, for whose mastication, however, their grinding teeth appear to be unnecessarily powerful.

3. The last genus to which the name marmot may be applied is that of the sousliks or pouched marmots (*Spermophilus*), of which the following are the characters. Size much smaller than that of *Arctomys* or *Cynomys*, and form more slender and squirrel-like. Tail very variable, from 1 to 8 or 9 inches in length. Cheek-pouches always present. Fore feet with four well-developed toes and a rudimentary thumb, of which the claw may be either present or absent. Skull much more lightly built than that of either of the preceding genera, and the post-orbital processes slender and directed backwards. Molar series nearly parallel, as in *Arctomys*, but all much smaller and lighter; the first premolar simply rounded, never more than about one-third of the size of the second.

The members of this large genus present a far greater range of variation than is found among the true marmots, some of them, such as the European souslik, being scarcely as large as a common squirrel, almost entirely without external ears, and with the tail reduced to a mere stump, barely an inch long, while others again are more than three times this size, with long and often tufted ears and long bushy squirrel-like tails. These differences, and other corresponding cranial ones, have caused the genus to be divided into the three following subgenera:—*Spermophilus* proper, containing thirteen or fourteen species, of small size, with rudimentary ear-conches, short stumpy tails, and comparatively large teeth; *Otospermophilus*, two species, of squirrel-like build, with large and tufted ears, and long bushy tails; and *Ictidomys*, with four species, of very slender, weasel-like form, with short ears, long but slender tails, and comparatively small teeth. The last two subgenera are confined to North America, while the range of the first is extremely similar to that of *Arctomys*, although certain species penetrate somewhat farther south in the New World, and none are found so far west in Europe. Professor Blasius gives the following details of the habits of the common European souslik (*S. citillus*, L.).

It lives in dry treeless plains, especially on a sandy or clayey soil, and is never found either in forests or on swampy ground. It forms burrows, often 6 or 8 feet deep, in which food is stored up and the winter sleep takes place. Each burrow has but one entrance, which is closed up when winter approaches,—a second hole, however, being previously formed from the sleeping-place to just below the surface of the ground. This second hole is opened the next year, and used as the ordinary entrance, so that the number of closed up holes round a burrow gives an indication of the length of time that it has been occupied. Sousliks ordinarily feed on roots, seeds, berries, &c., but occasionally also on animal food, preying readily on eggs, small birds, and mice, the remains of these latter being often found in their burrows. They bring forth in the spring from four to eight young ones, which, if taken early, may be easily tamed. They are often eaten by the peasants, the inhabitants of the Russian steppes considering their flesh an especial delicacy. (O. T.)

MARNE, a department of the north-east of France, made up from Champagne-Pouilleuse, Rémois, Perthois, Vallage, and La Brie-Champenoise, districts formerly belonging to Champagne. Its chief town, Châlons-sur-Marne, is 92 miles in a direct line east of Paris. Bounded on the W. by Seine-et-Marne and Aisne, on the N. by Ardennes, on the E. by Meuse, on the S. by Haute-Marne and Aube, it is situated between 48° 31′ and 49° 26′ N. lat., and 3° 25′ and 5° E. long. Its greatest length from north-east to south-west is 73 miles, and the area 3159 square miles. About one half of this consists of Champagne-Pouilleuse, a monotonous and barren plain covering a bed of chalk 1300 feet in thickness. On the west and on the east it is commanded by two ranges of hills. The highest point in the department (920 feet) is in the hill district of Rheims, which rises to the south-west of the town of the same name, between the Vesle and the Marne. The lowest level (164 feet), where the Aisne leaves the department, is not far distant. To the south of the Marne the hills of Rheims are continued by the heights of La Brie (700 to 800 feet). All these belong geologically to the basin of Paris. They slope gently towards the west, but command the plain of Champagne-Pouilleuse by a steep descent on the east. On the further side of the plain are the heights of Argonne (860 feet), formed of beds of the Lower Chalk, and covered by forests; they unite the calcareous formations of Langres to the schists of Ardennes, and a continuation of them stretches southward into Perthois and the marshy Bocage. The department belongs entirely to the Seine basin, but of that river there are only 13 miles, in the south-west; it there receives the Aube, which has 10 miles within the department. The principal river is the Marne, which runs through the department for 105 miles in a great sweep concave to the south-west, passing Vitry-le-François, Châlons, Épernay, and Dormans. In its course through the department it falls from 410 to 213 feet. The principal tributaries are the Saulx (which receives the Ornain) on the right, and on the left the Blaise, which waters Vassy, the Somme Soude, and the Surmelin (with its tributary the Dhuis), whence Paris is supplied; besides the Petit Morin and the Grand Morin. Of the last three only the upper courses lie within the department. The Aisne enters the department at a point 12 miles from its source, and traverses it for 35 miles, watering Ste Menehould. Two of its affluents on the left, the Suippe and the Vesle, on which stands Rheims, have a longer course from south-east to north-west across the department.

Marne has the climate of the region of the Seine; the annual mean temperature is 50° Fahr., the rainfall about 24 inches. Of the total area about three-fourths consists of arable land, and a sixth is under forest, whilst a twenty-fifth is meadow land. Vineyards cover 63·7 square miles. The department is largely stocked with sheep (536,000, of which 133,000 are a mixed merino breed, whose wool is used in the manufacture of merinoes, flannels, and cashmeres). Cattle are estimated to number 95,260; horses, 53,000; pigs, 62,000; goats, 6000; and asses, 6000; these last are used in the narrow pathways which intersect the vineyards. About 600,000 ℔ of honey and 240,000 ℔ of wax are produced. The vineyards, though not of great extent, are of high value from the quality of their products. The manufacture of the sparkling wines of Champagne is an important industry, of which Épernay, Rheims, and Châlons are the chief centres. The yearly exportation is about 20,000,000 bottles, at the average value of half a crown a bottle. Cereals are grown in excess of the local consumption. Corn, hay, rye, barley, potatoes, and beetroot are the chief crops. Several communes supply the more valuable vegetables. In 1881 the produce of wine was more than 14½ million gallons. The principal orchard fruits are the apple, plum, and cherry. Pine woods are largely planted in Champagne-Pouilleuse. The department produces iron ore, phosphate of lime, quantities of turf, and excellent millstones and stone for building.

The chief industry is that in wool, which has brought together, in the neighbourhood of Rheims, establishments for spinning, carding, dyeing, and weaving. The materials wrought are flannels, merinoes, tartans, shawls, rugs, and fancy articles. In 1879 the aggregate length of the various stuffs measured at Rheims was 12,198 miles. This business alone occupies 30,000 operatives in the department, and produces annually nearly 800,000 pieces, valued at £18,000,000. Hosiery in woollen employs 420 looms, and in cotton 1800. Marne contains blast-furnaces, iron, copper, and bell foundries, and manufactories of agricultural implements. Besides these there are tanyards, currying and leather-dressing establishments, and glassworks, which, with sugar-works and breweries, complete the list of the most important industries. Biscuits and gingerbread are a specialty of Rheims. The chief imports are wool, coal, and colonial wares; the exports are wine, grain, live stock, stone, whiting, pit-props, and woollen stuffs. Transport is supplied by the river Marne and the canal connecting it with the Rhine and with the Aisne, and by 300 miles of railway. The population in 1881 was 421,027, an increase of 116,371 since 1801. There are five arrondissements—those of Châlons (the chef-lieu), Épernay, Rheims, Ste Menehould, and Vitry-le-François. The department belongs partly to the archbishopric of Rheims and partly to the see of Châlons. Châlons is the headquarters of the 6th army corps; to the north of the town is the great camp devoted to military exercises.

MARNE, HAUTE-, a department of eastern France, made up for the most part of districts belonging to the former province of Champagne (Bassigny, Perthois, Vallage), with smaller portions of Lorraine and Burgundy, and some fragments of Franche-Comté. It lies between 47° 35′ and 48° 40′ N. lat., and between 4° 40′ and 5° 55″ E. long., the capital, Chaumont, being 133 miles east-south-east from Paris in a direct line, and it is bounded on the N.E. by Meuse, on the E. by Vosges, on the S.E. by Haute-Saône, on the S. and S.W. by Côte d'Or, on the W. by Aube, and on the N.W. by Marne. The extreme length from north-north-west to south-south-east is 81 miles, and the area 2402 square miles. Its greatest elevation (1693 feet) is in the plateau of Langres, between the sources of the Marne and those of the Aube; the watershed between the basin of the Rhone on the south and those of the Seine and Meuse on the north, which is formed by the plateau of Langres and the Monts Faucilles, has an average height of 1500 or 1600 feet. The country descends rapidly towards the south, but in very gentle slopes northwards. To the north is Bassigny ("pays bas," as distinguished from the highlands), a district of country characterized by monotonous flats of small fertility, and generally under wood. The lowest level of the department is 360 feet. Hydrographically Haute-Marne belongs for the most part to the basin of the Seine, the remainder to those of the Rhone and the Meuse. The principal stream is the Marne, which rises here, and has a course of 75 miles within the department. Among the more important affluents of the Marne are on the right the Rognon, and on the left the Blaise, one of the rivers of France most fully utilized for the supply of water-power. The Saulx, another tributary of the Marne on the right, also rises in Haute-Marne. Westward the department is watered by the Aube and its tributary the Aujon, both of which have their sources on the plateau of Langres. The Meuse also rises in the Monts Faucilles, and has a course of 31 miles within Haute-Marne. On the Mediterranean side the department sends to the Saône the Apance, the Amance, the Salon, and the Vingeanne. The climate is partly that of the Seine region, partly that of the Vosges, and partly that of the Rhone; the mean temperature is 51° F., nearly that of Paris; the rainfall is slightly below the average for France.

Of the total area rather more than one half is arable, about a third is under wood, a twentieth under meadow, and a fortieth is occupied by vineyards. There are 39,000 horses (extensively bred in Bassigny), 86,000 head of cattle, 170,000 sheep, 58,000 pigs, 6000 goats, 25,000 beehives, and a large quantity of all kinds of poultry. Though not very fertile, the soil is well cultivated, and in 1878 yielded 1,271,363 hectolitres of wheat, 144,348 of barley, 1,446,421 of oats, 1,177,187 of potatoes, besides meslin, rye, buckwheat, dried legumes, colza, beetroot, and hemp. Upwards of 8 million gallons of wine of ordinary quality were produced in 1881. The timber consists chiefly of oak, beech, elm, ash, maple, birch, and aspen; the orchards produce cherries, apples, pears, and prunes. The department is very rich in iron; the annual output of 300,000 tons is exceeded only by that of Meurthe-et-Moselle. Building and paving stones are quarried. The warm springs of Bourbonne-les-Bains are among the longest-known and most frequented in France. The leading industry is the metallurgical; in 1881 76,000 tons of pig iron and 85,000 of wrought iron were produced. The establishments include blast furnaces, foundries, forges, plate-rolling works, and shops for nailmaking and smith work of various descriptions. St Dizier, the place of largest population, is the chief centre of manufacture and distribution. The cutlery trade alone occupies 6000 persons in the neighbourhood of Langres. The department employs 1800 spindles in the woollen manufacture; glove-making, basket-making, brewing, tanning, and other industries are also carried on. The principal import is coal, while iron, stone, wood, and cereals are exported. The population in 1876 was 253,943, making an increase of 27,288 since 1801. There are three arrondissements (Chaumont, Langres, and Vassy), the capital being Chaumont.

MAROCCO. See MOROCCO.

MARONITES (Syriac, *Mârûnôyê*; Arabic, *Mawârina*), an ecclesiastical community, and therefore also, according to the usage of the Christian East, a distinct political or social body, found mainly in or near the Lebanon, acknowledging the headship of the pope and the Latin standard of orthodoxy, but still retaining some peculiar privileges, including the use of a Syriac service—which few even of the priests now understand—and permission for the inferior clergy to marry. Maronite writers, trained either at Rome (in the Maronite college, founded by Gregory XIII. in 1584) or under Roman influences, have not unnaturally striven to prove that their church was always in essential accord with the Church of Rome except in ritual, but there is clear evidence that this is incorrect. The earliest references to the Maronites (beginning in the 8th century) leave no doubt that they were Monothelites, and there is contemporary evidence (William of Tyre) that they only abjured their heresies in 1182, when with their patriarch and some bishops they joined the Latin Church. Even in later times it has cost Rome much pains and money to attach them closely to herself and produce real conformity to Latin or ultimately to Tridentine orthodoxy. The origin of the Maronites and their earlier history are obscure. The name is no doubt connected with the monastery of St Maron, near the source of the Orontes, one of the chief monasteries of Syria in the 6th century;[1] the Maronites themselves (Assemani, *Bib. Or.*, i. 496 *sq.*) have much to tell of their great patriarch John Maron, or rather John of Maron, who studied at the convent of St Maron, converted the Lebanon to orthodoxy, and died 707 A.D. Much of the history of this personage is certainly fabulous.[2]

Though the Maronite college at Rome sent forth some distinguished scholars—the grammarian Amíra, Gabriel Sionita, Abraham Ecchellensis, and the three Assemanis—the Maronite community never took on much Western culture. A simple warlike race, they long maintained a great measure of internal freedom under their native nobility, only paying tribute to the pasha of Tripoli; and for a time, when the princely house of Shiháb left Islam and became Maronites, they greatly outweighed the Druses in their influence in the Lebanon.[3] Since the fall, in 1840, of the Maronite emír Beshír, who was only by outward profession a Moslem, their power has sunk. For their subsequent history see vol. vii. p. 486, and for statistics, &c., at the present time, see LEBANON.

The seat of the Maronite patriarch is at Ḳannóbín (Cœnobium); the bishoprics are Aleppo, Baalbek, Jebeil, Tripoli, Ehden, Damascus, Beirút, Tyre, and Cyprus.

See in general Le Quien, *Oriens Christianus*, iii. 1-100; Nairon, *De origine, etc.*, *Maronitarum*, Rome, 1679; Dandini's account of the mission of 1596 in the French translation with R. Simon's notes (*Voyage du Mont Lebanon*, Paris, 1685); Schnurrer, *De Ecclesia Maronitica*, 1810-1811; and Rödiger's article "Maroniten" in Herzog's *Real-Encycl.*

MAROONS. A *nègre marron* is defined by Littré as a fugitive slave who betakes himself to the woods; a similar definition of *cimarron* (apparently from *cima*, a mountain top) is given in the *Dictionary* of the Spanish Academy. The old English form of the word is *symaron* (see Hawkins's *Voyage*, sec. 68). The designation in modern English is applied almost as a proper name to the descendants of those negroes in Jamaica who at the first English occupation in the 17th century fled to the mountains. See vol. xiii. p. 550.

MAROS-VÁSÁRHELY, a royal free town of Hungary, and capital of the Transylvanian county of Maros-Torda, is situated on the Maros and on the Hungarian Eastern Railway, 50 miles north-east of Hermannstadt, in 46° 30′ N. lat., 24° 31′ E. long. It is the seat of the "royal table" court of appeal for the Transylvanian circle, of royal and circuit courts of law, of a board of works, and of offices of assay and of the Government tobacco monopoly; as also the headquarters both of the militia and regular infantry for the district. The town is well built, partly upon rising ground, and has a citadel with barracks, three churches (one large and handsome), and a college belonging to the Calvinists; Roman Catholic and Greek Orthodox churches, religious houses, and schools; a public library of 80,000 volumes, with a picture gallery and fine collection of minerals; a theatre, a hospital, and several philanthropic and industrial institutes. The trade is chiefly in timber, planks, materials for house-roofing, grain, wine, tobacco, and other products of the neighbourhood. Both weekly and special markets are held. At the end of 1880 the population amounted to 12,843 (6265 males, 6578 females), Magyars and Roumanians by nationality.

[1] The ruins of this place are described by Robinson, *Bib. Researches*, iii. 539; Renan, *Phénicie*, p. 119.

[2] The John of Maron known to Bar-Hebræus (*Chron. Eccles.*, i. 463), and placed in the 10th century, was apparently a Monophysite. That Monophysite as well as Monothelite doctrine was once current among the Maronites appears from various things in their ecclesiastical books, which they now try to explain away or reject as interpolations.

[3] See Niebuhr, *Reisebeschr.*, vol. ii.; Volney, *Voyage*; Robinson, *Researches*, ii. 506.

MAROT, CLÉMENT (1496–1544), one of the most agreeable if not one of the greatest poets of France, and a figure of all but the first importance in her literary history, was born at Cahors, the capital of the province of Quercy, some time during the winter of the year 1496–97. He was, however, not a southern by blood, at least by his father's side. That father, Jean Marot, whose more correct name appears to have been Mares, Marais, or Marets, was a Norman of the neighbourhood of Caen. He was himself a poet of considerable merit, and held the post of *escripvain* (apparently uniting the duties of poet laureate and historiographer) to Anne of Britanny. He had however, on what business or in what capacity is not known, resided in Cahors for a considerable time, and was twice married there, his second wife, whose name is not known, being the mother of Clément. The boy was "brought into France"—it is his own expression, and is not unnoteworthy as showing the strict sense in which that term was still used at the beginning of the 16th century—in 1506, and he appears to have been educated at the university of Paris, and to have then begun the study of the law. But, whereas most other poets have had to cultivate poetry against their father's will, Jean Marot took great pains to instruct his son in the fashionable forms of versemaking, which indeed required not a little instruction. It was the palmy time of the *rhétoriqueurs*, poets who combined stilted and pedantic language with an obstinate adherence to the allegorical manner of the 15th century and to the most complicated and artificial forms of the *Ballade* and the *Rondeau*. Clément himself practised with diligence this poetry (which he was to do more than any other man to overthrow), and he has left panegyrics of its coryphæus Guillaume Crétin, the unfortunate suggester of the Raminagrobis of Rabelais. Nor did he long continue even a nominal devotion to law. He became page to a certain Messire de Neuville, and this opened to him the road of court life. Besides this, his father's interest must have been not inconsiderable, and the house of Valois, which was about to hold the throne of France for the greater part of a century, was devoted to letters. As early as 1514, before the accession of Francis I., Clément presented to him his *Judgment of Minos*, and shortly afterwards he was either styled or styled himself *facteur* (poet) *de la reine* to Queen Claude. In 1519 he was attached to the suite of Marguerite d'Angoulême, the king's sister, who was for many years to be the mainstay not only of him but of almost all French men of letters. In 1524 he drew 95 livres annually from her as a pension, and he had a post in the household of her husband the Duc d'Alençon. It is certain that Marot, like most of Marguerite's literary court, and perhaps more than most of them, was greatly attracted by her gracious ways, her unfailing kindness, and her admirable intellectual accomplishments, but there is not the slightest ground for thinking that his attachment was other than platonic. Indeed the most famous passage of his poems which relates to the future queen, in which he describes her "sweet refusal with a sweeter smile," is tolerably decisive on the point. It is, however, evident that at this time either sentiment or matured critical judgment effected a great change in his style, a change which was wholly for the better. At the same time he celebrates a certain Diane, whom it has been sought to identify with Diane de Poitiers. There is nothing to support this idea and much against it, for it was an almost invariable habit of the poets of the 16th century, when the mistresses whom they celebrated were flesh and blood at all (which was not always the case), to celebrate them under pseudonyms. In the same year 1524, Marot accompanied Francis on his disastrous Italian campaign. He was wounded and taken at Pavia, but soon released, and he was back again at Paris by the beginning of 1525. His luck had, however, turned. Marguerite for intellectual reasons, and her brother for political, had hitherto favoured the double movement of *Aufklärung*, partly humanist, partly Reforming, which distinguished the beginning of the century. Formidable opposition to both forms of innovation, however, now began to be manifested, and Marot, who was at no time particularly prudent, was arrested on a charge of heresy and lodged in the Chatelet, February 1526. But this was only a foretaste of the coming trouble, and a friendly prelate, acting for Marguerite, extricated him from his durance before Easter. The imprisonment gave him occasion to write a vigorous poem on it entitled *Enfer*, which was afterwards imitated by his luckless friend Dolet. His father died about this time, and Marot seems to have been appointed to the place which Jean had latterly enjoyed, that of valet de chambre to the king. He was certainly a member of the royal household in 1528, with a stipend of 250 livres, besides which he had inherited property in Quercy. In 1530, probably, he married. Next year he was again in trouble for heresy, and was again rescued; this time the king and queen of Navarre seem to have bailed him themselves. In 1532 he published, under the title of *Adolescence Clémentine*, a title the characteristic grace of which excuses its slight savour of affectation, the first printed collection of his works, which was very popular, and was frequently reprinted with additions. Dolet's edition of 1538 is believed to be the most authoritative. Unfortunately, however, the poet's enemies were by no means discouraged by their previous ill success, and the political situation was very unfavourable to the Reforming party. In 1535 Marot was again summoned to appear on the charge of heresy, and this time he was advised or thought it best to fly. He passed through Béarn, and then made his way to Renée of Ferrara, a supporter of the French Reformers as steadfast as her aunt Marguerite, and even more efficacious, because her dominions were out of France. At Ferrara he wrote a good deal, his work there including his celebrated *Blasons* (a descriptive poem, improved upon mediæval models), which set all the verse writers of France imitating them. But the duchess Renée was not able to persuade her husband, Ercole d'Este, to share her views, and Marot had to quit the city. He then went to Venice, but before very long obtained permission to return to France. Francis himself, though a fickle and unsafe patron, was attached to him, and in 1539 gave him a house and grounds in the suburbs. It was at this time that his famous translations of the Psalms appeared. The merit of these has been sometimes denied, owing apparently to the absurd partiality which seems in the case of some critics to make it impossible for the reader to appreciate the manner of a work to the matter of which he is opposed on political or religious grounds. It is, however, considerable, and the powerful influence which the book exercised on contemporaries is not denied by any one. The great persons of the court chose different pieces, each as his or her favourite. They were sung in court and city, and they are said, with exaggeration doubtless, but still with a basis of truth, to have done more than anything else to advance the cause of the Reformation in France. Indeed the vernacular prose translations of the Scriptures were in that country of little merit or power, and the form of poetry was still preferred to prose, even for the most incongruous subjects. At the same time Marot engaged in a curious literary quarrel characteristic of the time, with a bad poet named Sagon. Half the verse writers of France ranged themselves among the Marotiques or the Sagontiques, and a great deal of versified abuse was exchanged. The victory, as far as wit was concerned, naturally rested with Marot, but his biographers are probably not fanciful in supposing that a certain amount of odium was created against him by the squabble, and that, as in Dolet's case, his subsequent misfortunes were not altogether unconnected with a too little governed tongue and pen. Although on his last return into France he had formally abjured his errors, the publication of the Psalms gave the Sorbonne a handle, and the book was condemned by that body. In 1543 it was evident that he could not rely on the protection of Francis, who was probably too selfish in any case to have given him inconvenient help, and who, like many of his family, was disposed to compound with the church for a libertine life by ceremonial devotion and by sacrificing heretics liberally. Marot accordingly fled to Geneva; but the stars were now decidedly against him. He had, like most of his friends, been at least as much of a freethinker as of a Protestant, and, notwithstanding the immense service he had done to the cause by the publication of his Psalms, this was fatal to his reputation in the austere city of Calvin. He had again to fly, and made his way into Piedmont, where he seems to have enjoyed a sort of left-handed protection from Francis, who then held it. But the harassing effect of these constant persecutions, assisted very likely by the careless living which was but too common at the time, proved too much for him, and he died at Turin in the autumn of 1544, aged barely forty-eight.

In character Marot seems to have been a typical Frenchman of the old stamp, cheerful, good humoured, and amiable enough, but probably not very much disposed to elaborately moral life and conversation or to serious reflexion. He has sometimes been charged, though on no very definite grounds, with a want of independence of character, and his attitude towards his patrons was certainly not that of almost haughty equality which Ronsard brought in; but it is fair to remember that Marot belonged almost as much to the Middle Ages as to the Renaissance, and that in the Middle Ages men of letters naturally attached themselves as dependants to the great. Such scanty knowledge as we have of his relations with his equals is favourable to him. He certainly at one time quarrelled with Dolet, or at least wrote a violent epigram against him, for which there is no known cause. But, as Dolet quarrelled with almost every friend he ever had, and in two or three cases played them the shabbiest of tricks, the presumption is not against Marot in this matter. Whatever may have been Marot's personal weaknesses, his importance in the history of French literature is very great, and it is wont nowadays to be rather under- than over-valued. Coming immediately before a great literary reform—that of the Pléiade—Marot suffered the drawbacks of his position; he was both eclipsed and decried by the partakers in that reform. In the reaction against the Pléiade he recovered honour; but its restoration to virtual favour, a perfectly just restoration, has again unjustly depressed him. Yet Marot is in no sense one of those writers of transition who are rightly obscured by those who come after them. He himself was a reformer, and a reformer on perfectly independent lines, besides which it may be said that he carried his own reform as far as it would go. It has been said that his early work was couched in the *rhétoriqueur* style, the distinguishing characteristics of which are elaborate metre and rhyme, allegoric matter, and pedantic language. In his second stage he entirely emancipated himself from this, and became one of the easiest, least affected, and most vernacular poets of France. In these points indeed he has, with the exception of La Fontaine, no rival, and the lighter verse writers ever since have taken one or the other or both as model. In his third period he lost a little of this flowing grace and ease, but acquired something in stateliness, while he certainly lost nothing in wit. It is beyond question that Marot is the first poet who strikes readers of French as being distinctively modern. He is not so great a poet as Villon nor as some of his successors of the Pléiade, but he is much less antiquated than the first (whose works, as well as the *Roman de la Rose*, it may be well to mention that he edited) and not so elaborately artificial as the second. Indeed, if there be a fault to find with Marot, it is undoubtedly that in his gallant and successful effort to break up, supple, and liquefy the stiff forms and stiffer language of the 15th century, he made his poetry almost too vernacular and pedestrian. In his hands, and while the *style Marotique* was supreme, French poetry ran some risk of finding itself unequal to anything but graceful *vers de société*. But it is only fair to remember that for a century and more its best achievements, with rare exceptions, had been *vers de société* which were not graceful.

There is a very cheap, handsome, and useful edition of Marot by Jannet and Héricault, 4 vols., Paris, 1873; but M. Georges Guiffrey is slowly producing a costly and splendid work, containing a vast quantity of unpublished matter, which will undoubtedly be the standard. This work contains much biographical detail, which, however, as being still incomplete, is not available to modify former accounts. (G. SA.)

MARQUESAS ISLANDS, or MENDAÑA ISLANDS (French, *Les Marquises*), an archipelago of twelve islands lying between 7° 50′ and 10° 35′ S. lat., and 138° 30′ and 140° 50′ W. long. They extend over 200 miles from S.E. to N.W., and have a total area of 489 square miles. The lower or true Marquesas group consists of the islands Fatouhiva or Magdalena, Motane or San Pedro, Tahouata or Sta Christina, and Hivaoa or Dominica, the last with a coast-line of more than 60 miles. With these is often included the rocky islet of Fetohougo or Hood's, lying in mid-channel to the north of Hivaoa. The north-western or Washington group is formed of seven islands, the four largest being Roa-Poua or Adams, Houahouna or Washington, Noukahiva or Marchand (70 miles in circumference), and Hiaou. Along the centre of each island is a ridge of mountains, sometimes attaining an altitude of 3500 feet, whence rugged spurs forming deep valleys stretch towards the sea. The volcanic origin of the whole archipelago is proved by the principal rocks being of basalt, trachyte, and lava. Except on a few barren peaks the islands are clothed with verdure, and in the valleys, which are well watered with streams and brooks, the vegetation is luxuriant. The flora includes over four hundred known species, many of them identical with those belonging to the Society Islands. The vegetable products comprise bananas, bread-fruit, yams, plantains, wild cotton, bamboos, sugar-cane, cocoa-nut and dwarf palms, and several kinds of timber trees. The land fauna is, however, very poor: there are few mammals with the exception of dogs, rats, and pigs; and amphibia and insects are also generally scarce. Of twenty species of birds more than half belong to the sea, where animal life is as abundant as at other subtropical Polynesian groups.

The climate of the Marquesas, although hot and humid, is not unhealthy. During the greater part of the year moderate easterly trade winds prevail, and at the larger islands there are often both land and sea breezes; the rainy season, accompanied by variable winds, sets in at the end of November, and lasts for about six months. During this period the thermometer varies from 84° to 91° F.; in the dry season its average range is from 77° to 86°.

The inhabitants, a native Polynesian race, have in many respects a great affinity to the Tahitians, but excel them in symmetry of form. They live chiefly on bread-fruit, vegetables, and fish, almost entirely neglect agriculture, but rear hogs and fowls in great numbers. They exchange live stock, timber, vegetables, fruit, and fresh water with traders for iron utensils, firearms, gunpowder, cloth, tobacco, and brandy. They are polite in their intercourse with strangers, susceptible and courageous, but at the same time excitable, revengeful, addicted to stealing, lazy, and immoral. The efforts of missionaries, whether Protestant or Roman Catholic, have hitherto proved of little avail either in converting them to Christianity or in improving their moral and social condition. At the commencement of the present century the population exceeded 20,000, but since then petty warfare, infectious maladies, and various other causes have greatly reduced its number; and on the 31st December 1876 it reached only 5754.

In 1842 the Marquesas archipelago was formally taken possession of for France by Captain Du Petit-Thouars; and the French still maintain a nominal protectorate over the islands, with a resident and a small garrison at Noukahiva. Since 1861, however, French colonization has been virtually abandoned.

The Marquesas Islands were first discovered 21st July 1595, by Alvaro Mendaña, who, however, only knew of the south-east group, to which he gave the name of Marquesas de Mendoza, in honour of the viceroy of Peru. Cook, pursuing the same track, rediscovered this group, with the addition of Fetohougo, in 1774. The north-west islands were first sighted by Ingraham the American in 1791, and were subsequently visited by Marchand (1791) and Hergest (1792). A more extensive investigation of the archipelago was made by Krusenstern in 1804. Of later navigators to the Marquesas the most noteworthy are Stewart (1829), Bennett (1835), and D'Urville (1838), and, since the date of the French occupation, Dumoulin, Jouan, and above all Jardin.

See C. E. Meinicke, *Die Inseln des stillen Oceans*, Leipsic, 1875-76; *Tableaux de pop., &c., des col. franç.* for 1877.

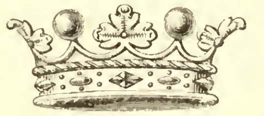
MARQUETRY. See FURNITURE.

MARQUETTE, a city and port of entry of the United States, and the county seat of Marquette county, Michigan, lies on a bluff about 25 feet above a bay of Lake Superior, and is a terminus of the Marquette, Houghton, and Ontonagon, and the Detroit, Mackinac, and Marquette Railroads. Though the population of the city was only 4690 in 1880, Marquette is a place of importance as the chief shipping port for the great iron-ore region of western Michigan (787,150 tons shipped in 1881), and contains a number of blast furnaces, foundries, machine-shops, and powder-mills, while at the same time it has a reputation as a resort for invalids and tourists. A Roman Catholic cathedral, convent, and orphan asylum are among the public buildings.

MARQUETTE, JACQUES, a Jesuit missionary and explorer, was born in 1637 at Laon in France, and died May 18, 1675, on the banks of a small stream, now known as the Marquette, which has its mouth on the eastern shore of Lake Michigan. Having joined the Society of Jesus, he sailed for Canada in 1666, spent eighteen months in the vicinity of Three Rivers, founded the mission of Sault Sainte Marie on Lake Superior in 1668, and followed the Hurons to Mackinaw in 1671. It is mainly, however, as Joliet's companion in his voyage down the Mississippi in 1673 that Marquette holds a permanent position in the history of discovery in America.

His narrative, first published in Thevenot's *Recueil de Voyages* (Paris, 1681), is printed along with other documents relating to him in Shea's *Discovery and Exploration of the Mississippi Valley* (New York, 1852).

MARQUIS, or MARQUESS, a title and rank of nobility, the second in the order of the British peerage, and therefore next to duke. The first marquis in England was Robert de Vere, the ninth earl of Oxford, who by Richard II., 1st December 1385, was created marquis of Dublin. On the 13th of October following the patent of this marquisate was recalled, Robert de Vere then having been raised to a dukedom. John de Beaufort, the second legitimate son of John of Gaunt, was created to the second marquisate as marquis of Dorset, 29th September 1397. From that period this dignity appears to have been dormant till the reign of Henry VI., when it was revived, and thenceforward it maintained its place in the British peerage. A marquis is "most honourable," and is styled "my lord marquis."


Marquis's Coronet.

His wife, who also is "most honourable," is a marchioness, and is styled "my lady marchioness." The coronet is a circlet of gold on which rest four leaves and as many large pearls, all of them of equal height and connected. The cap and lining, if worn, are the same as in the other coronets. The coronet, which in representations displays one central leaf with two pearls and two half-leaves, when without cap or lining, is shown in the annexed woodcut. The mantle of parliament is scarlet, and has three and a half doublings of ermine.

MARRIAGE, LAW OF.[1] Marriage may be defined here as the act, ceremony, or process by which the legal relationship of husband and wife is constituted. In most if not all legal systems it takes the form of a contract—the mutual assent of the parties being the prominent and indispensable feature of the ceremony. Whether it is really a contract or not, and if so to what class of contracts it belongs, are questions which have been much discussed, but into which it is not necessary to enter. While the consent of parties is universally deemed one of the conditions of a legal marriage, all the incidents of the relationship constituted by the act are absolutely fixed by law. In the United States it has been expressly decided that marriage is not a contract within the meaning of the constitutional law, which prohibits state enactments "impairing the obligation of contracts." Mr Bishop, however, in his very valuable book on *Marriage and Divorce*, suggests that a State law permitting the status of marriage to be created without the consent of both parties would not be constitutional; but that is a difficulty arising out of the peculiar relation of the States to the Union. The question whether marriage is merely a contract or more than a contract, whether a purely civil or also a religious act, belongs to a similar order of inquiries. The jurist has only to deal with marriage in so far as it creates the legal status of husband and wife. It should be added that, while marriage is generally spoken of by lawyers as a contract, its complete isolation from all other contracts is invariably recognized. Its peculiar position may be seen at once by comparing it with other contracts giving rise to continuous relationships with more or less indefinite obligations, like those of landlord and tenant, master and servant, &c. In these the parties may in general make their rights and duties what they please, the law only intervening when they are silent. In marriage every resulting right and duty is fixed by the law.[2]

Roman Law.—The three primitive modes of marriage were *confarreatio*, *coemptio in manum*, and *usus*, all of which had the effect of placing the woman in the "power" (*manus*) of her husband, and on the same footing as the children. The first was a religious ceremony before ten witnesses, in which an ox was sacrificed and a wheaten cake broken and divided between the spouses by the priest. *Coemptio* was a conveyance of the woman by *mancipatio*, and might be described as a fictitious sale *per æs et libram*, like that employed in emancipation and testamentary disposition and other processes. *Usus* was the acquisition of the wife by prescription, through her cohabiting with the husband for one year without having been absent from his house three continuous nights. But a true marriage might be concluded without adopting any of these modes, and they all fell into desuetude and with them the subjection of the wife to the manus. Marriage without manus was contracted by the interchange of consent, without writing or formality of any kind. By some jurists it is regarded as incomplete until consummated by delivery of the woman, and is accordingly referred to the class of *real* contracts. The restrictions as to age, relationship by consanguinity and affinity, previous marriage, &c., were in the main those which have continued to prevail in modern Europe with one important exception. The consent of the *paterfamilias* to the marriage of the children under his power was essential.

In the *Canon Law*, which is related on the one hand to the civil law, on the other to the modern matrimonial law of Europe, although marriage was not merely a contract but a sacrament, the validity of marriages by consent was nevertheless admitted. "When the natural and civil contract was formed," says Lord Stowell, "it had the full

[1] See also HUSBAND AND WIFE and DIVORCE.

[2] A full collection of juridical opinion as to the legal character of marriage is to be found in Lord Fraser's *Husband and Wife*, vol. i. chap. ii.

essence of matrimony without the intervention of a priest. It had even in that state the character of a sacrament, for it is a misapprehension to suppose that this intervention was required as a matter of necessity even for that purpose before the council of Trent."[1]

England.—Marriage may be the subject of an ordinary contract on which an action may be brought by either party. It is not necessary that the promise should be in writing, or that any particular time should be named. The parties were formerly inadmissible as witnesses in this action; but they are now competent to give evidence, subject to the condition that the plaintiff shall not recover "unless his or her testimony shall be corroborated by some other material evidence" (32 & 33 Vict. c. 68). The ordinary defences, *e.g.*, fraud, discharge, minority, are available in these actions, and there are also special defences arising from the nature of the contract, such as the bad character of the plaintiff, the relationship of the parties within the prohibited degrees, &c. Promises to marry are not within the meaning of "agreement made in consideration of marriage" in the statute of frauds, which requires such agreements to be in writing. Contracts in restraint of marriage, *i.e.*, whose object is to prevent a person from marrying anybody whatever, are void, as are also contracts undertaking for reward to procure a marriage between two persons. These latter are termed marriage brocage contracts.

Any man and woman are capable of marrying, subject to certain disabilities, some of which are said to be canonical as having been formerly under the cognizance of the ecclesiastical courts, others civil. The effect of a canonical disability as such was to make the marriage not void but voidable. The marriage must be set aside by regular process, and sentence pronounced during the lifetime of the parties. Natural inability at the time of the marriage to procreate children is a canonical disability. So was proximity of relationship within the prohibited degrees, which has been made an absolute avoidance of marriage by 5 & 6 Will. IV. c. 54. A pre-engagement to another person was at one time recognized as a canonical disability. Civil disabilities are (1) the fact that either party is already married and has a spouse still living;[2] (2) the fact that either party is a person of unsound mind; (3) want of full age, which for this purpose is fixed at the age of puberty as defined in the Roman law, viz., fourteen for males and twelve for females;[3] (4) proximity of relationship within the prohibited degrees, already alluded to. The statute which lawyers regard as establishing the rule on this last point is the 32 Henry VIII. c. 38 (repealed in part by 2 & 3 Edw. VI. c. 23, in whole by 1 & 2 P. and M. c. 8, but revived by 1 Eliz. c. 1, and so left as under the Act of Edward), which enacts that "no prohibition, God's law except, shall trouble or impeach any marriage without the Levitical degrees." The forbidden marriages, as more particularly specified in previous statutes, are those between persons in the ascending and descending line *in infinitum*, and those between collaterals to the third degree inclusive, according to the computation of the civil law, which reckons from one of the persons related to the common stock and so down to the other person. The prohibitions extend not only to *consanguinei* (related by blood) but to *affines* (related by marriage). A man may neither marry his sister nor his deceased wife's sister, for both are related to him in the second degree; nor his sister's daughter, nor his deceased wife's sister's daughter, for both are in the third degree; but he may marry his first cousin, for she is in the fourth degree. *Consanguinei* of either spouse are related by affinity to the other; but the *consanguinei* of the one are not necessarily related to the *consanguinei* of the other. Hence two brothers may marry two sisters, or a father and son a mother and daughter. A husband is not related to the *affines* of his wife, and so a man may marry the widow of his deceased wife's brother. The rule as to collaterals includes those related by the half blood and bastards (see Stephen's *Commentaries*, book iii. c. 2). Other disabilities previously admitted were abolished by the statute of Henry. The Act of 5 & 6 Will. IV. c. 54 enacted that "all marriages which shall hereafter be celebrated between persons within the prohibited degrees of consanguinity or affinity shall be absolutely null and void to all intents and purposes whatsoever." They had previously, as already stated, been only voidable. The Act at the same time legalized marriages within the prohibited degrees of affinity (but not consanguinity) actually celebrated before the 31st August 1835.

The celebration of marriages is now regulated wholly by statutory legislation. The most important Acts now in force are the 4 Geo. IV. c. 76 and the 6 & 7 William IV. c. 85.[4] The former regulates marriages within the Church of England, but was intended to be of universal application, Jews and Quakers only being excepted by section 31. It requires either the previous publication of banns, or a licence from the proper ecclesiastical authority. As to banns, the rule of the rubric, so far as not altered by the statute, is required to be observed. They must be published on three successive Sundays at morning service after the second lesson, in the church of the parish in which the parties dwell; the bishop may, however, authorize the publication of banns in a public chapel. Seven days' notice must be given to the clergyman of the names of the parties, their place of abode, and the time during which they have lived there. If either party is under age, the dissent of the parents or guardians expressed at the time of publication of banns renders such publication null and void. Licence in lieu of banns may only be granted by the archbishop, bishop, or other authority, for the solemnization of a marriage within the church of the parish in which one of the parties shall have resided for fifteen days before. Before a licence can be granted an oath must be taken as to the fact of residence and that the necessary consent has been obtained in the case of persons under age. The father, or lawful guardian, or mother if unmarried, or guardian appointed by the court, is each in order of substitution the proper person to consent to the marriage of a minor, and the place of any such person incapacitated mentally is taken by the lord chancellor. The absence of such consent does not, however, avoid a marriage once solemnized. But if persons wilfully intermarry (unless by special licence) in a place not being a church or public chapel, or without due publication of banns or proper licence, or before a person not in holy orders, the marriage is null and void to all purposes. Marriage must be celebrated within three months after banns or licence, and between the hours of eight and twelve in the morning.

For the relief of the great body of dissenters the Act 6 & 7 Will. IV. c. 85 was passed. It permits marriage to be solemnized in two additional ways,—viz. (1) by certificate of the superintendent registrar of a district without licence, and (2) by such certificate with licence. In the first case, notice must be given to the registrar of the district or districts within which the parties have resided for seven days previous, which notice is inscribed in a marriage notice book, open to public inspection at all reasonable times, and thereafter suspended for twenty-one days in some conspicuous place in the registrar's office. The notice must be accompanied by a declaration as to the absence of impediments, necessary consent, &c. Any person whose consent is necessary to an ecclesiastical licence may forbid the issue of a certificate, but in default of such prohibition the certificate will issue at the end of the twenty-one days. The marriage may then take place on any day within three months of the entry of notice, and in one of the following ways:—(1) in a certified place of religious worship, registered for the solemnization of marriage; in that case a registrar of the district with two witnesses must be present, and the ceremony must include a mutual declaration of assent by the parties and a disavowal of any impediment; (2) at the superintendent registrar's office, with the same

[1] Some restrictions on marriage peculiar to the canon law are noticed at the end of this article.

[2] A divorce *nisi* does not enable the parties to marry until it is made absolute.

[3] A marriage in which either of the parties is below the age of consent is, however, said to be not absolutely void; if the parties agree to continue together at the age of consent no new marriage is necessary, but either of them may disagree and avoid the marriage.

[4] A complete list of the acts regulating the solemnization of marriage or confirming marriages which through some defect might be void will be found in Phillimore's *Ecclesiastical Law*, vol. i.

declaration, but with no religious service; (3) in a church according to the usual form, the consent of the minister thereof having been previously obtained; (4) according to the usages of Jews and Quakers. The place of marriage in all cases must have been specified in the notice and certificate.

In the second case, when it is desired to proceed by licence, notice must be given to the registrar of the district in which one of the persons resides, together with a declaration that he or she has resided for fifteen days therein, that there is no impediment, and that the necessary consents if any have been obtained. The notice is not exhibited in the registrar's office, and the certificate may be obtained at the expiration of one whole day after entry, together with the licence. No registrar's licence can be granted for a marriage in church or according to the forms of the Church of England,—the ecclesiastical authorities retaining their monopoly in that respect. It is also provided that in the case of persons wilfully intermarrying in a place other than that mentioned in the notice and certificate, or without notice or certificate, &c., the marriage shall be null and void. And, as under the former Marriage Act of Geo. IV., a valid marriage between persons one of whom is under age, brought about by fraud or false oath, subjects the offending party to a forfeiture of all property that otherwise might accrue to him from the marriage, a like penalty is provided in like cases under the later Act.

It will be observed that the various rules as to consent of parents, &c., to the marriages of minors are regulations of procedure only. The absence of the necessary consent is not a disability invalidating a marriage actually solemnized.

The Act 26 Geo. II. c. 33, commonly known as Lord Hardwicke's Act, which forbids the solemnization of marriage without banns or licence, also enacts that "in no case whatsoever shall any suit or proceeding be had in any ecclesiastical court in order to compel a celebration *in facie ecclesiæ*, by reason of any contract of matrimony whatsoever whether *per verba de presenti* or *per verba de futuro*." Blackstone observes that previous to this Act "any contract made *per verba de presenti*, or in words of the present tense, and in case of cohabitation *per verba de futuro* also, was deemed valid marriage to many purposes; and the parties might be compelled in the spiritual courts to celebrate it *in facie ecclesiæ*." In his celebrated judgment in the case of Dalrymple *v.* Dalrymple, which turned on the effect of promises exchanged between the parties in Scotland, Lord Stowell laid it down "as the basis of the canon law, the known basis of the matrimonial law of Europe," that "in the irregular marriage, *i.e.*, *sponsalia per verba de presenti*, everything was presumed to be complete and consummated in substance but not in ceremony; and the ceremony was enjoined to be undergone as a matter of order. In the *sponsalia de futuro* nothing was presumed to be complete or consummated either in substance or in ceremony, but if the parties who had exchanged the promise had carnal intercourse with each other the effect was to convert the engagement into an irregular marriage." On the other hand, in the case of the Queen *v.* Millis in the House of Lords on appeal from the Irish Queen's Bench, the position of Lord Stowell was strongly criticized. Lord Lyndhurst's conclusion was that, "although a marriage contracted *per verba de presenti* was indissoluble, though it could not be released even by the mutual consent of the parties, though either of them might enforce it and compel solemnization, though it had the effect of rendering voidable a subsequent marriage solemnized *in facie ecclesiæ*, even after the cohabitation and birth of children, though it was considered to be of the essence and substance of matrimony—yet by the law of England it did not confer those rights of property or the more important right of legitimacy consequent on a marriage duly solemnized according to the rites of the church." The lords were equally divided in their decision, and the question has since been agitated not so much with reference to England, where after the Act of Geo. II. it had a merely historical interest, as to the colonies and the United States (see below), where the common law of England prevails unless changed by legislation. Dr Lushington in the case of a marriage in New South Wales declared that, when there has been a "fact of consent between two parties to become man and wife," such is "sufficient marriage to enable me to pronounce when necessary a decree of separation." In the cases noticed the promises had been exchanged before ministers of religion not technically "in holy orders," and the question has accordingly sometimes been put in the form whether, according to the common law, the intervention of a clergyman was necessary to a valid marriage.

Royal Marriages in England have been subject to special laws. The Royal Marriage Act of 1772 (12 Geo. III. c. 11), passed in consequence of the marriages of the dukes of Cumberland and Gloucester, enacted that "no descendant of his late majesty George II. (other than the issue of princesses married or who may marry into foreign families) shall be capable of contracting matrimony without the previous consent of his majesty, his heirs and successors, signified under the great seal. But in case any descendant of George II., being above twenty-five years old, shall persist to contract a marriage disapproved of by his majesty, such descendant, after giving twelve months' notice to the privy council, may contract such marriage, and the same may be duly solemnized without the consent of his majesty, &c., and shall be good except both Houses of Parliament shall declare their disapprobation thereto."

Scotland.—The chief point of distinction, as compared with English law, is the recognition of irregular marriages above noticed. (1) "A public or regular marriage," says Fraser, "is one celebrated, after due proclamation of banns, by a minister of religion; and it may be celebrated either in a church or in a private house, and on any day of the week at any hour of the day." The ministers of the national church at first alone could perform the ceremony; but the privilege was extended to Episcopalians by 10 Anne c. 7, and to other ministers by 4 & 5 Will. IV. c. 28. (2) A marriage may also "be constituted by declarations made by the man and the woman that they *presently* do take each other for husband and wife." These declarations "may be emitted on any day at any time and without the presence of witnesses," and either by writing or orally or by signs, and in any form which is clearly expressive of intention. Such a marriage is as effectual to all intents and purposes as a public marriage. The children of it would be legitimate; and the parties to it would have all the rights in the property of each other, given by the law of Scotland to husband and wife. (3) A promise followed by *copula* does not, according to Fraser, constitute marriage, unless followed either by solemnization *in facie ecclesiæ* or declarator. On the other hand, in Lorimer's *Handbook* it is urged that the promise and copula are mere tokens of consent recognized by the law, and that "the date of the marriage is the date of the copula." However this may be, Lord Moncreiff's opinion in the case of Brown *v.* Burns is admitted on both sides to be good law, viz., that declarator is essential to the constitution of a marriage of this kind, so that, if no such declarator be brought in the lifetime of both parties, the marriage can never be established afterwards. The *copula* is presumed to have reference to the promise, but evidence may be adduced to show that such was not the case.

By 19 & 20 Vict. c. 96, it is enacted that no *irregular* marriage shall be valid in Scotland, unless one of the parties has lived in Scotland for the twenty-one days next preceding the marriage, or has his or her usual residence there at the time.

"Habit and repute" has sometimes been spoken of as constituting marriage in the law of Scotland, but it is more correctly described as evidence from which marriage may be inferred. The repute must be the general, constant, and unvarying belief of friends and neighbours, not merely the controverted opinion of a section of them. The cohabitation must be in Scotland, but in one case proof of cohabitation in another country was allowed, as tending to throw light on the nature of the cohabitation in Scotland.

The consent of parents is not necessary to the validity of the marriage, even of minors, but marriage under the age of puberty with or without such consent is void.

United States.—The absence of ecclesiastical courts has suggested difficulties as to the extent to which the law of England on this subject continued to prevail after the revolution. Bishop holds it to be the universal fact running through all the cases that everywhere in the country the English decisions on marriage and divorce are referred to with the same apparent deference which is shown on other subjects to the decisions of the English common law and equity tribunals. The same author observes that "all our marriage and divorce laws, and of course all our statutes on the subject, in so far as they pertain to localities embraced within the limits of particular States, are State laws and State statutes, the national power with us not having legislative or judicial cognizance of the matter within those localities." Some of the States have extended the ages below which marriage cannot take place. The common law of the States is assumed to be that "a contract *per verba de presenti*, or *per verba de futuro cum copula*, constitutes a complete marriage." Conditions, however, may be imposed by the various State legislatures, and as to these the rule has established itself in American jurisprudence that "a marriage good at common law is good notwithstanding the existence of any statute on the subject, unless the statute contains express words of nullity." Thus in Pennsylvania, where a statute provided that all marriages "should be solemnized before twelve witnesses," marriages not so celebrated were nevertheless held to be good. In New Hampshire justices and ministers of the gospel are authorized to solemnize marriage, and all other persons are forbidden to do so under penalties; yet a marriage by consent, as at common law, without justice or minister, has been held valid. On the other hand, under a very similar statute in Massachusetts, it was held that "parties could not solemnize their own marriage," and that a marriage by mutual agreement, not in accordance with the statute, was void. Bishop regards this as an isolated exception to the general course of the decisions. So when State legislation requires any particular form to be used the want thereof only invalidates the act if the statute expressly so enacts. Many of the State codes inflict penalties on ministers or justices for celebrating the marriage of minors without the consent of the parents or guardians. The original law as to prohibited degrees has been considerably modified in the States. The prohibition of marriage with a deceased wife's sister is said by Bishop to be all but unknown in the United States, Virginia apparently being the only one where it is still retained. Some writers apply the term legislative marriages to cases in which the State by enactment confirms a marriage which was void for some defect. Questions sometimes arise as to whether such enactments are within the constitution of the State.

France.—Articles 144–226 of the Code Napoléon prescribe the qualifications and conditions of marriage. The man must be eighteen and the woman fifteen years of age. A son under twenty-five, and a daughter under twenty-one, cannot marry without consent of the father and mother, or of the father only if they disagree, or of the survivor if one be dead. If both are dead grandfather and grandmother take their place. A man after twenty-five and a woman after twenty-one are still bound formally to ask the consent of their parents; until the age of thirty and twenty-five respectively this request must be repeated twice, and after the third application parties are at liberty to marry without such consent. Even after the age of thirty, formal notice must be served on the parents or grandparents one month before marriage. If neither parents nor grandparents be alive, parties under twenty-one require the consent of the family council. These rules apply to natural children when affiliated; those not affiliated require the consent of a specially appointed guardian. Marriage is prohibited between all ascendants and descendants in the direct line, and between persons related by marriage in the same line, between brother and sister, between uncle and niece, and brother-in-law and sister-in-law.

Before the solemnization of marriage banns are required to be published on two distinct Sundays, containing the names, occupations, and domiciles of the parties and their parents. The marriage cannot take place until three days after the second publication, and if a year is allowed to elapse fresh banns must be put up. On the day appointed by the parties, and in the parish to which one of them belongs, the marriage is celebrated by the civil officer or registrar reading over to them the various necessary documents, with the chapter of the code relating to husband and wife, receiving from each a declaration that they take each other for husband and wife, and drawing up the act of marriage. All this has to be done in the presence of four witnesses.

Marriages contracted abroad between French subjects or between French subjects and foreigners are valid in France if celebrated according to the forms of the foreign law, provided the French conditions as to banns and consent of parents have been observed.

International Law.—In the "conflict of laws" on the subject of marriage, it has been well settled that the *lex loci* governs. If the marriage is valid by the law of the country where it is celebrated it is recognized as valid everywhere; if invalid there it is invalid everywhere. "This rule," says Story, "has received the most deliberate sanction of the English and American courts and of foreign jurists." The most prominent, if not the only known exceptions, Story considers to be marriages (1) involving incest or polygamy, or (2) forbidden by the public law of a country from motives of policy, and (3) marriages celebrated in a foreign country under circumstances which impose on the parties the law of their own country. Westlake (*Private International Law,* chap. iv.) lays it down as indispensable to the validity of a marriage that the *lex loci* should be satisfied in respect of forms, consent of parents and guardians, and capacity of the parties. The law of the parties' domicile should also be satisfied as to capacity unless when it imposes incapacity of a penal nature unknown to the *lex loci.* Story, in reference to the first of the three exceptions alluded to above, attempted to set up a clear and just moral difference between marriages that are incestuous by the law of nature and those that are so by the municipal law of particular States only, with more particular reference to consanguinity and affinity. "It would be a strong point to put that a marriage perfectly valid between a man and the sister of his former deceased wife in New England would be held invalid in Virginia or England, even though the parties formerly belonged to or were born in the latter country or State. But, as to persons not so belonging, it would be of the most dangerous consequence to suppose that the courts of either of them would assume the liberty to hold such marriages a nullity merely because their own jurisprudence would not in a local celebration of marriage therein uphold it." This position has been expressly disavowed by the English courts. In Brook *v.* Brook it was held that an Englishman's marriage with his deceased wife's sister during a residence in Denmark where the union is lawful is invalid in England. In Hyde *v.* Hyde in the English divorce court it was held that a marriage contracted in a country where polygamy is lawful between a man and a woman who profess a faith which allows polygamy is not a marriage as understood in Christendom; and, although it was a valid marriage by the *lex loci*, and at the time when it was contracted both the man and the woman were single and competent to contract marriage, the court will not recognize it as a valid marriage in a matrimonial suit. The difference in the law of divorce in different countries produces many complications of this kind. It appears that a divorce of an English marriage abroad for cause not recognized in England as ground for a divorce will be upheld in England if the parties were domiciled at the time of the divorce in the foreign state; otherwise not. Compare also the French rule as to marriages of French subjects in foreign countries. The too frequent consequence of these variances is that the same persons are held married in one country and unmarried in another, while their children are legitimate in one country and illegitimate in another. There is no subject in relation to which the establishment of a common code for all civilized nations is more urgently required.

Besides true marriage, with which we have been exclusively dealing hitherto, inferior forms of union have from time to time been recognized, and may be briefly noticed here. These have all but disappeared from modern society, depending as they do on matrimonial restrictions now obsolete.

The institution of slavery is a fruitful source of this kind of debased matrimony. In Roman law no slave could contract marriage whether with another slave or a free person. The union of male and female slaves (*contubernium*) was recognized for various purposes; a free woman entering into a union with a slave incurred under the S.C. Claudianum the forfeiture of her own liberty; but the bondwoman might be the concubine of a freeman. In the United States, where slavery was said to be regulated by the principle of the civil law, the marriage of slaves was so far recognized that on emancipation complete matrimony took effect and the children became legitimate without any new ceremony. Such at least is the purport of the more recent decisions.

In Roman law no legal marriage could be contracted unless there was *connubium* between the parties. Originally there was no connubium between plebs and patricians, and the privilege was conceded after a long struggle by the Lex Canuleia. In later times Latini and Peregrini were excluded from connubium except where the right had been expressly conferred. The great matrimonial law of the early empire (Lex Julia et Papia Poppæa) introduced restrictions depending on the condition of the parties which later legislation extended and perpetuated. Senators under that law were forbidden to marry freedwomen or women of inferior rank, and the husband of a freedwoman becoming a senator was set free from his marriage. In the canon law [1] new restrictions were developed. Persons who

[1] The restrictions are enumerated in the following lines:—
Error, Conditio, Votum, Cognatio, Crimen,
Cultus Disparitas, Vis, Ordo, Ligamen, Honestas,
Ætas, Affinis, si Clandestinus et Impos,
Raptave sit mulier nec parti reddita tutæ.

bound themselves not to marry were deemed incapable of marrying. The order of the clergy were forbidden to marry. And disparity of faith was recognized by the early church as a bar to matrimony, *e.g.*, between Christians and pagans, and between orthodox and heretics (see *Dictionary of Christian Antiquities*, art. "Marriage").

CONCUBINAGE, which such restrictions tended to develop, is noticed under a separate heading (*q.v.*). It might be described as marriage which has no consequences, or only slight and peculiar consequences, in legal *status*. In the left-handed or "morganatic"[1] marriages of the German royal families we have the nearest approach ever made by concubinage to true marriage, the children being legitimate, but neither they nor the wife acquiring any right to the rank or fortune of the husband. Under the Royal Marriage Act in England a union of this kind has no matrimonial effect whatever.

Differences of religion are no longer regarded in Christian countries as hindrances to marriage, except possibly in some branches of the Greek Church. But the marriage of persons of different religions frequently requires the intervention of the law as to the faith of the children, more particularly in Europe as between Catholics and Protestants. In some countries the clergy make it a condition of such marriages that the children shall be educated in the Catholic faith. English law gives the father an indefeasible right to dictate the faith of his children, no matter what engagements he may have entered into (see INFANT). The practice on this point varies in Europe—the question being ignored in French law, Germany following in some parts the same rule as England, in others giving effect to ante-nuptial stipulations. In Ireland mixed marriages (*i.e.*, between Catholic and Protestant) were by 19 Geo. II. c. 13 null and void if celebrated by a Catholic priest. This Act is repealed by 33 & 34 Vict. c. 110, which permits mixed marriages to be validly celebrated by an Episcopalian or Roman Catholic clergyman, subject to conditions set forth in section 38. (E. R.)

MARRYAT, FREDERICK (1792–1848), has never been surpassed as a writer of tales of nautical adventure. His own life supplied him with abundant raw materials for his art. The son of a wealthy London gentleman (who sat in parliament for several years for the boroughs of Horsham and Sandwich, and was a writer of verses and political pamphlets), he distinguished himself as a boy by frequently running away towards sea; and at last, at the age of fourteen, he was allowed to enter the navy. His first service was under Lord Cochrane in the famous "Impérieuse," and no midshipman ever had a livelier apprenticeship to the sea. "The cruises of the 'Impérieuse' were," he says, "periods of continual excitement, from the hour in which she hove up her anchor till she dropped it again in port; the day that passed without a shot being fired in anger was with us a blank day." During his two and a half years of service under the daring and active Cochrane, the young midshipman witnessed more than fifty engagements, many of them extremely brilliant, and had experience of every description of service, fighting duels with fairly matched ships of war, engaging gunboats, engaging batteries, storming forts, capturing and cutting out merchantmen. Before the general peace of 1815 he had added considerably to this experience of active service, and gained a wide knowledge of conditions of life on board ship under various commanders. He frequently received honourable mention for his behaviour in action, and in 1818 he received the medal of the Humane Society for "at least a dozen" gallant rescues. He commanded with distinction in the Burmese war of 1824-25. And Marryat's honours were not confined to gallant exploits; he was the inventor of a code of signals, obtained some celebrity as a caricaturist, and was elected an F.R.S.

Marryat brought ripe experience and unimpaired vivacity to his work when he commenced novelist. His first production was *Frank Mildmay, or the Naval Officer*, published in 1829, and his second, published nine months later, *The King's Own*. "I think," Washington Irving wrote to him soon after, "the chivalry of the ocean quite a new region of fiction and romance, and to my taste one of the most captivating that could be explored." This was the general feeling. The freshness of the new field opened up to the imagination, so full of vivid lights and shadows, light-hearted fun, grinding hardship, stirring adventure, heroic action, warm friendships, bitter hatreds, was felt all the more keenly from its contrast with the world of the historical romancer and the fashionable novelist, to which the mind of the general reader was at that date given over. The novels of the sea captain at once won public favour. His first attempt was somewhat severely criticized from an artistic point of view. It was without form, though the reverse of void; he had packed into it matter enough for half a dozen novels. Marryat was accused also of gratifying private grudges by introducing real personages too thinly disguised. He admitted the justice of these criticisms, and rapidly learnt the mechanical part of his new business without losing any of the vivacious charm of his style. *The King's Own* was a vast improvement, in point of construction, upon *Frank Mildmay*; and he went on, through a quick succession of tales, *Newton Forster*, *Peter Simple*, *Jacob Faithful*, *The Pacha of Many Tales*, *Japhet in Search of a Father*, *Mr Midshipman Easy*, *The Pirate and the Three Cutters*, till he reached his high-water mark of constructive skill in *Snarley-yow, or the Dog Fiend* (1837). If he never surpassed this in story-telling art, humorous portraiture, and richness of incident, the records of circulating libraries and the pencilled comments of their subscribers show that his subsequent works —he produced twenty-four in all during his twenty years of authorship—were no less capable of riveting the attention, especially of youthful readers. The following is the list, with the dates of publication:—*The Phantom Ship* (1839), *A Diary in America* (1839), *Olla Podrida* (1840), *Poor Jack* (1840), *Masterman Ready* (1841), *Joseph Rushbrook* (1841), *Percival Keene* (1842), *Monsieur Violet* (1842), *The Settlers in Canada* (1843), *The Privateer's Man* (1844), *The Mission, or Scenes in Africa* (1845), *The Children of the New Forest* (1847), *The Little Savage* (1847), and *Valerie*, not completed by Marryat (1849). Captain Marryat retired from the naval service in 1830, and thereafter worked as hard at literature as any professional man of letters, making special historical and geographical studies for several of the works in the above list. He edited the *Metropolitan Magazine* for four years (1832–36). Marryat's novels were in the first flush of their success when Dickens was a youth, and they have an interest in the history of literature as forming an important link between Smollett and Fielding and the author of *Sketches by Boz*. He died in 1848. There is a biography by his daughter, Florence Marryat.

MARS was a Roman deity whose name has passed into later literature as that of the war god. There grew in Rome a tendency, fostered by Greek influence, to consider Jupiter as the one great god, and the other deities as representing special sides of his character. Mars then was identified with the Greek ARES (*q.v.*), and was regarded as almost the same in nature with the warlike element in Jupiter as Feretrius and Triumphator. In the actual worship of the Romans Mars bears a very different character, which, however, had almost disappeared from the mind of the people before Augustus built in the Forum his temple to Mars Ultor, the avenger of the murder of Julius Cæsar.

Father Mars, Marspiter, Maspiter, Mavors, or Maurs, was the great god of one of the races that composed the Roman state. He is the god of heaven, the giver of light, the opener of the new year; he hurls the thunder and sends

[1] Said to be so called because the wife's rights were limited to the *Morgengabe* (donum matutinale). The common law in Germany permits them to the royal houses and the higher nobility, and the law of Prussia to the lower nobility also. Inequality of condition (Unebenbürtigkeit) is not necessary to a marriage of this kind, which may be made between persons of equal rank, *e.g.*, with the object of not prejudicing the children of a first marriage by allowing full rights to the offspring of a second. A woman of high rank may make a morganatic alliance with a man of inferior position.

the rain. In cases of drought the *lapis manalis*, which was kept in his temple on the Appian Way, was carried through the city by the *pontifices*. The first month of the old Roman year was the month of Mars, still called March. On the first day the god had been born; and on the same day various annual ceremonies both political and religious took place; and the holy fire was renewed in the temple of Vesta. When Mamurius Veturius, *i.e.*, Mars of the Year (*vetus*, Greek Ϝέτος), was beaten out of the city on March 14, the intention was originally to symbolize the driving away of the old year. The spear sacred to Mars was in its original sense doubtless the lightning, and his sacred shield was, like the ægis of Zeus and Athene, the storm shield, *i.e.*, the thundercloud. The Sabine words Marmar and Mamers (akin to μαρμαίρω) are evidently names of the heaven-god. The wolf which was sacred to Mars may be compared with the wolves of Zeus Lycaios, and the horse, the sacrifice of Mars, is the horse of the sun, which the Greeks also sacrificed to Helios.

As heaven-god and sender of rain, Mars is the giver of fertility and increase. Hence in some of the oldest cults he is the god of the land, of agriculture, and of the flocks. As he was powerful to send fertility, so he could cause also drought, sterility, and all evil; and propitiatory ceremonies, such as the Ambarvalia, were consecrated to him. The Arval brothers invoked Mars to assist them and to avert pestilence. In the Robigalia a sheep and a reddish dog were sacrificed by the flamen of Mars to avert mildew from the crops. The sacrifice of the "October horse" in the Campus Martius, whose head the people of the Subura and the Sacra Via struggled for in order to hang it up in their own precincts, had also a naturalistic and apotropaic character. In times of calamity there was an old Italian custom of dedicating to Mars a *ver sacrum*. Everything born in this spring was the property of the god; the animals were sacrificed, the young men when they grew up were sent out of the country. Mars seems also to have had some relation to the religious ceremony of marriage. Along with Juno, the goddess of women and of childbirth, he was worshipped by the Roman matrons on June 1 and at the Matronalia on March 1. As god of the land and giver of increase, Mars was also the god of death and the dead; he was one of the deities invoked by Decius when devoting himself to death. He was likewise the giver of oracles: like Zeus he revealed his will to men by certain signs. His ancient oracle at Tiora Matiene near Cære resembled in character the oracle of Zeus at Dodona, in so far as revelation took place by the medium of sacred birds and trees. Woodpeckers were the sacred birds of Mars, and the noise which they made tapping on the trees was one of the simplest methods of revelation. Picus, the woodpecker, was a name or form of Mars, and was ultimately individualized as a local hero, an early king of Latium, and son of the god. Faunus, the favouring deity, son of Picus, is pre-eminently the god of prophecy; he also is closely related to the original Italian character of Mars, which he retained far more truly than the great Roman god.

Although the worship of Mars was known both in Latium and in Etruria, it was probably of Sabine origin. Quirinus, an undoubtedly Sabine word, is merely a name of Mars, which never acquired complete individuality; the feeling always remained alive in Rome that Mars and Quirinus were one, although they had separate priests. It is in accordance with the Sabine character that the warlike element should have been very strong in their conception of deity; and thus the Sabine Mars became in the Roman pantheon the deity of war. Besides the ceremonies round the altar of Mars in the Campus Martius, the oldest cults of the god in Rome are the Sabine worship of Quirinus on the Quirinal and the Latin worship of the holy spear of Mars in the temple of Vesta. There likewise grew at an early time a cultus of the god on the Palatine, said to have been founded by Numa, and twelve Salii of the Palatine existed alongside of the twelve Quirinal Salii. The Palatine Salii performed one of the most remarkable ceremonies in the Roman worship of Mars. For many days, beginning from March 1, they danced in armour through certain parts of the city, clashing their lances on their shields, and repeated the prescribed song. The shields which they carried were the twelve sacred *ancilia* preserved on the Palatine. One of these, it was said, fell from heaven in the time of Numa, and the king, in order to preserve safely this pledge of victory for the state, had eleven others exactly like it made by Mamurius Veturius. The song of the Salii, besides mentioning all the gods of the city, referred to Mamurius, whose name is only a form of Mamers.

Next to Jupiter, Mars was the chief protecting god of the Roman state. Quirinus Mars was the father of the twin-founders of the city, and his sacred wolf was the emblem of the city and the foster-mother of the twins. The Campus Martius outside the city was dedicated to the god from a very early time; there the young men practised their warlike exercises; there the horse races, *equiria*, in honour of Mars (February 27) and the sacrifice of the "October horse" took place. There also was held the census every fifth year, followed by the purificatory ceremonial for the whole city, which was dedicated to Mars. When war broke out, the Roman general clashed the shield and spear in the temple of Mars and invoked the god; the spoils of victory belonged to him after Jupiter Feretrius.

There was an ancient temple of Mars outside the Porta Capena on the Appian Way; and on the ides of July, in commemoration of the battle of Lake Regillus, the knights had a procession

> "From Castor in the Forum,
> To Mars without the wall."

As the god of war, who marched with his people to battle, Mars was Gradivus; such at least was the later explanation of an old religious name. Inuus Lupercus, the averter, to whom the Lupercalia was dedicated, was probably a local form of Mars; his character as protector of the Palatine city, and the warlike element in him, resemble Mars (see LUPERCALIA). Silvanus is also closely related to the agricultural god Mars, who is sometimes called Mars Silvanus. A goddess named Nerio or Neriene is sometimes mentioned as wife of Mars. There was also a goddess Bellona, whose name marks her strictly as the goddess of war; she is called the sister or daughter or wife of Mars. Quirinus, on the Quirinal, had a festival called Quirinalia, on the 17th of February.

See Preller, *Röm. Mythol.*, and the other books on Roman religion; Marquardt on religious antiquities; Unger, "Lupercalia," *Rhein. Mus.*, 1881; Jordan, *Stadt Rom*; Roscher, *Apollo und Mars*; and on the Etruscan Mars, Müller, *Etrusker*, ed. Deecke, ii. 57 and 169.

MARSALA, a seaport on the west coast of Sicily, in the province of Trapani, 20 miles south of Trapani, to the north of the river Marsala, with a station on the railway between Trapani and Palermo. A flourishing and well-built town, with wide paved streets, it possesses a castle, a cathedral, a theatre, cavalry barracks (now occupied by Government offices), an academy of science and literature, and a public library. The Corinthian columns of the cathedral were originally intended for the cathedral at Canterbury, and owe their present destination to the wreck of the vessel which was conveying them to England. After the destruction of its harbour in the latter part of the 16th century as a precaution against its occupation by the Turkish pirates, the commercial importance of Marsala remained in abeyance till the construction of the new port to the south of the town. The sea-wall for this was begun in 1818; but it was not till 1835–36 that the pier was constructed. A great part of the surface of 44 acres constituting the port is now silted up; new works, however, on an extensive scale, are being undertaken. The wine trade, which forms the staple, was commenced in the end of the last century by Woodhouse & Co.; and the wines first got into favour by being supplied to the English fleet in 1802. They are for the most part white, and are usually "fortified." The number of seagoing vessels that entered at Marsala in 1863 was 149, with a burden of 9791 tons; in 1880 there were 249 vessels of 16,645 tons. From 31,350 in 1861 the population of the commune had increased by 1881 to 40,251; that of the town was 14,105 in 1871, or, with the suburbs of Porta Garibaldi, Porta Mazzara, and Porta Trapani, 17,666.

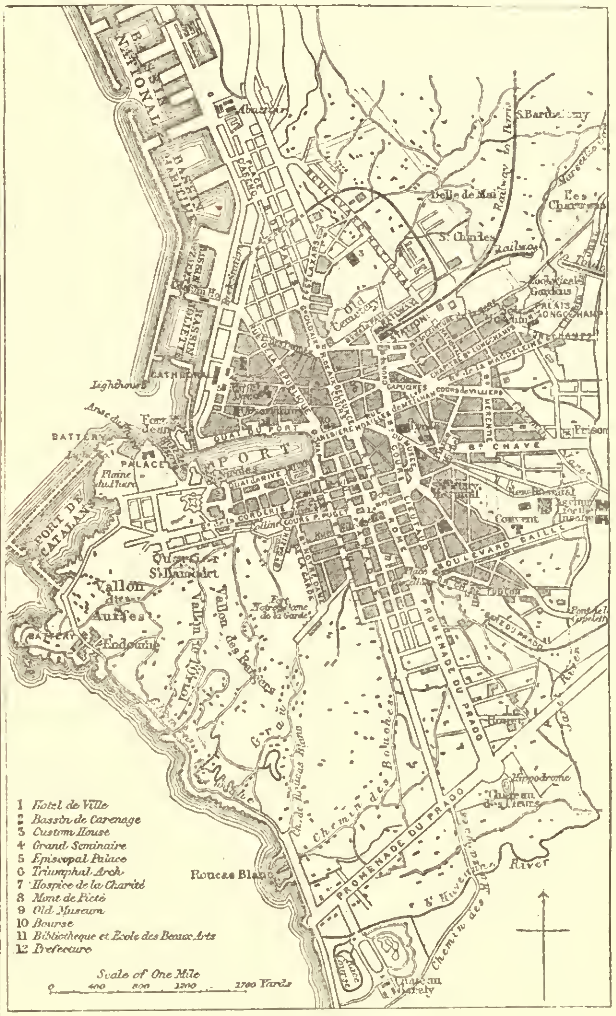
On the small island of San Pantaleone, about 6 miles north of Marsala, lay the Carthaginian stronghold of Motya (Ital., *Mozia*).[1] After the destruction of this settlement by Dionysius in 397 B.C. the defeated party established a new colony on the neighbouring promontory of Lilybæum. It was there that in 276 B.C. the Carthaginians held out successfully against Pyrrhus, who had already driven them from the rest of Sicily; and it was only after a siege of ten years that in the first Punic War they were obliged to surrender the fortress to the Romans. Under its new possessors Lilybæum continued to flourish and became the residence of one of the two quæstors of Sicily. It was still an important city under the later empire, and when occupied first by the Goths and then by the Vandals. The Arabs called it Mersá 'Aly, "port of 'Aly," and Edrisi (12th century) describes it as a considerable town, which, having been ruined, had been restored by Roger I. It was at Marsala that Garibaldi began his Sicilian campaign in 1860.

MARSDEN, WILLIAM (1754–1836), an eminent Oriental scholar, was the son of a Dublin merchant, and was born in 1754. After studying at Trinity College, he obtained an appointment in the civil service of the East India Company, and set sail for Bencoolen, Sumatra, in 1771. There he soon rose to the office of principal secretary to the Government, and was at the same time intent on acquiring that intimacy with the Malay language, and that knowledge of the country, which were afterwards the sources of his literary reputation. Returning to England in 1779 with a pension, he retired into literary seclusion, and in 1782 produced *The History of Sumatra*. Marsden was appointed in 1795 second secretary and afterwards first secretary to the admiralty. In 1807 he retired again into private life, and, devoting himself to study, published in 1812 his *Grammar and Dictionary of the Malay Language*, and in 1817 his translation of the *Travels of Marco Polo*. A pension of £1500, which he had received on his retirement from office, he voluntarily resigned in 1831 for the behoof of the public. In 1834 he presented his rich collection of Oriental coins to the British Museum, and his library of books and Oriental MSS. to King's College, London. He died of apoplexy in October 1836.

Marsden's other works are—*Numismata Orientalia*, London, 1823–25; *Catalogue of Dictionaries, Vocabularies, Grammars, and Alphabets*, 1796; and several papers on Eastern topics in the *Philosophical Transactions* and the *Archæologia*. His name will also be remembered in connexion with African philology, as he had—the first in England, and, it would appear, independently of Lichtenstein and Vater—drawn attention to the affinity of the Congo and Mozambique languages with those spoken by the Kaffre race. See Tuckey's *Narrative of an Expedition to explore the River Zaire*, London, 1818, p. 386 *sq.*

MARSEILLES (Fr. *Marseille*), the third largest city of France, and the chief commercial port of the Mediterranean, in 43° 17′ N. lat. and 5° 22′ E. long., is the chief town of the department of Bouches du Rhône, headquarters of the 15th army corps, the seat of a bishop, and of numerous commercial and scientific institutions. The population (1881) is 360,099.

The old harbour of Marseilles opens on the west to the Gulf of Lyons; and the famous Rue de la Cannebière, leading east-north-east from the inner end of the harbour, and continued by the Rue de Noailles, the Allées de Meilhan, and the Boulevard de Longchamps, to the Palais des Arts, forms the first main artery of the town. A second great artery, at right angles to the first, connects the Aix gate and its triumphal arch with the grand Promenade du Prado, by the Cours Belsunce and the Rue de Rome. North of the old harbour, between the Aix gate and the sea, lies the old town of Marseilles. The finest streets, the Rue St Ferréol, the Rue Paradis, and the Rue de Breteuil, are to the south of the Rue Cannebière,



Plan of Marseilles.

running parallel with the Rue de Rome, between it and the foot of the hill upon which is Notre Dame de la Garde. From La Cannebière to La Joliette, the centre of the new docks, runs the broad Rue de la République, lined with fine buildings, and opening a line through the oldest part of the town. The entrance to the old harbour is defended by Fort St Jean on the north and Fort St Nicolas on the south. Behind the latter is the Anse (Creek) de la Réserve. Beyond this again, situated in succession along the shore, come the old imperial palace, the Anse du Pharo, the military exercising ground, and the Anse des Catalans. The new parts of the town extend in this direction to the Vallon d'Endoume behind Fort St Nicolas. To the old harbour, which covered only 70 acres, the basin of La

[1] The ruins of Motya were excavated by Schliemann in 1876. See *Academy*, March 1876, p. 288.

Joliette (55 acres) was added in 1853. Communicating with the old harbour by a channel which passes behind Fort St Jean, this dock opens on the south into the outer harbour, opposite the palace and the Anse du Pharo; it is separated from the roadstead on the west by a simple jetty. A series of similar basins have since been added along the shore to the north, viz., the Lazaret or "Bassin des Docks" (37 acres), that of Arenc (59 acres), the "Bassin National," twice as large as the preceding, and the graving dock of 20 acres; a fine revolving bridge, worked by steam, separates the graving dock from the rest. Farther out, the Château d'If and the islets of Pomègue and Ratonneau, where vessels formerly did quarantine, have 45 acres of harbour accommodation. The port of Marseilles has in all an area of 422 acres, but there are only 4½ miles of quays, an amount of accommodation quite inadequate for the enormous traffic, now amounting to more than 3,400,000 tons. Protected on the east by Cape Croisette, and on the west by Cape Couronne, the roadstead of Marseilles and its approaches are lighted by six lighthouses, of which the most distant (130 feet high) is 8 miles south-west of the town, on the Planier rock. The docks along the Lazaret basin cover an area of 45 acres, and the company to which they belong also holds a large area of ground for their enlargement, and has exclusive rights over 1½ to 2 miles of quays. The warehouses occupy 27 acres of floor space on their several stories, and the 200,000 tons of goods for which they afford storage are easily manipulated by powerful hydraulic machinery wrought by steam. From the harbour station at the docks the railway is carried up to the principal station, "Gare St Charles," which commands the town. The Toulon line goes round the zoological gardens, and the whole upper part of Marseilles, and sends a branch to the Prado station. There is a fourth station to the south of the old harbour near the custom-house, and at the foot of the steps of St Victor; it is proposed to join it by a tunnel to the Marseille-Prado station. The large steam vessels for trading with Algiers, the Levant, and the further East lie in La Joliette, but the old harbour still displays the ancient characteristics of Marseilles. The old-fashioned Mediterranean traders with their lateen sails are crowded together in the Rive Neuve Canal to the south, while the sailing vessels of heavy tonnage are moored to the quay by their sterns. At the end of the old harbour opens out La Cannebière, so called from former rope-walks, of which it occupies the site; it is now the liveliest part of the town, where the principal cafés, shops, hotels, naval and commercial agencies, as well as the Bourse, are found.

Despite its antiquity, Marseilles has no ancient monuments. The old cathedral, which superseded a temple of Diana, itself preceded, it is said, by an altar of Baal, has given place to a modern structure, of which the exterior only is completely finished. It is a Byzantine basilica, in the form of a Latin cross, 460 feet long, built in grey Florentine stone blended with white stone from the neighbourhood of Arles. Near the cathedral stands the bishop's palace. The cathedral is situated at the entrance of the harbours, but a more distant church has superior attractions for the sailors,—the celebrated Notre Dame de la Garde, the steeple of which, surmounted by a gilded statue of the Virgin, 30 feet in height, rises 150 feet above the summit of the hill on which it stands, commanding a view of the whole port and town, as well as of the surrounding mountains and the neighbouring sea. The present chapel of Notre Dame de la Garde occupies the site of one built in 1214. Like the new cathedral it is in the Byzantine style, and constructed of the richest materials.

Descending from Notre Dame by steps, with shops on both sides containing objects of devotion, such as medals and chaplets, and passing the Promenade Pierre Puget, which affords another fine view of the sea, we reach the church of St Victor, close by Fort St Nicolas. Originally an abbey founded about 410 by St Cassian, it was afterwards destroyed by the Saracens, but rebuilt in the 11th century; destroyed a second time, it was finally restored by Pope Urban V., a former abbot, who surrounded it in 1350 with high square crenellated towers. Tradition relates that St Lazarus inhabited the catacombs under St Victor; and the black Virgin, still preserved there, is popularly attributed to St Luke. The spire of the ancient church des Accoules marks the centre of Old Marseilles. At its foot are a "Calvary" and a curious chapel of modern construction in rock work. Notre Dame du Mont Carmel, also in the old town, occupies the place of what was the citadel of the Massaliots when they were besieged by Julius Cæsar. The new Hôtel de la Préfecture, at the end of the Rue St Ferréol, the Palais de Justice, and the Bourse, are all buildings of the last twenty years. The first is a palatial edifice 300 feet long and 260 wide, adorned with statues and bas reliefs; it has a fine staircase and large reception rooms, decorated with paintings. Before the Palais de Justice stands a statue of Berryer. The pediment and peristyle are decorated with bas reliefs by Guillaume. The outer hall is surrounded by beautiful pillars of red marble. The Bourse has in the vestibule a bas relief representing Marseilles receiving the productions of all parts of the world, and allegorical statues of Marseilles and France. The hall is larger than even that of the Bourse at Paris. The hall of the Chamber of Commerce, at whose cost the whole edifice was built, is remarkable for the magnificence of its mural paintings and gildings. The Hôtel de Ville, an old and unimportant building, stands on the quay to the north of the old harbour. The Palais des Arts de Longchamps, completed in 1870, is a work of consummate taste; it is built at the terminus of the Canal de Marseille, that great work which has metamorphosed the town and its surroundings by bringing into it the waters of the Durance. This canal, which leaves the river opposite Pertuis, has a length of 94 miles, of which more than 15 are underground. It crosses the valley of the Arc, between Aix and Rognac, by the magnificent aqueduct of Roquefavour, comparable with the noblest works of ancient or modern times. The canal then purifies its waters, charged with ooze, in the basins of Réaltort, sets in motion seventy-two mills, which it supplies with upwards of 1200 horse-power, carrying about 200 cubic feet of water per second to the district of Marseilles. Right and left of the Château d'Eau, which occupies the centre of the Palais de Longchamps, and is 128 feet in height, are the picture gallery, a fine collection of ancient and modern works, and the natural history museum, remarkable for its conchological department and the interesting collection of ammonites. Behind are extensive zoological gardens, with the astronomical observatory, one of the most important in France. The museum of antiquities is established in the Palais Borély, in a fine park, recently purchased by the town, at the end of the Prado, and approached by the two finest promenades of the city. It includes a Phœnician collection (containing the remains that support the hypothesis of the Phœnician origin of Marseilles), an Egyptian collection, numerous Greek, Latin, and Christian inscriptions in stone, &c. A building within the city, recently finished, 177 feet by 64, with an imposing façade, contains the school of art and a valuable library. The triumphal arch of Aix, originally dedicated to the victors of the Trocadero, was in 1830 appropriated to the conquests of the empire.

Marseilles contains large hospitals. The Hôtel Dieu in the old town was founded in 1188, and rebuilt in 1593; it has 450 beds. The Hospice de la Charité, in the same neighbourhood, accommodates 600 patients, while at the opposite extremity of the town, near the Prado station, are the modern Hôpital de la Conception (with 800 beds), the military hospital, and the lunatic asylum.

The scientific institutions of the town are also numerous, including a faculty of science, an astronomical observatory, a preparatory school of medicine and pharmacy, a musical conservatoire, a school of art, a lyceum, and many private institutions. The principal learned societies are the academy of science, letters, and art, the medical association, and the geographical, statistical, agricultural, and horticultural societies.

The mean temperature of Marseilles is 58° Fahr.; frost is rare, and snow almost unknown. The heat of summer is tempered during the day by the cooling sea breeze. The most disagreeable wind is the mistral, a violent and cold north-west wind, which blows on an average one hundred and thirty-eight times a year, but has at least the advantage of restoring salubrity to the frequently unhealthy shores of the Mediterranean. The sirocco, a south-east wind, blows some sixty times a year; though hot and parching in summer, it softens the winter climate. The east-south-east wind is cold and damp, and brings rain. The Canal de la Durance has greatly modified the climate of Marseilles and its neighbourhood, for by restoring vegetation it has increased the fogs and rains; there is now an annual rainfall of nearly 24 inches.

Marseilles is at once the largest commercial port of France and a manufacturing town, working up the raw materials brought in by sea from every part of the world. The leading industry is that of soap-making, which occupies sixty factories with 1200 artisans, and annually produces 65,000 tons, valued at £2,000,000 sterling. With this manufacture are connected oil and chemical works; in the former, which employ 2000 to 2500 workmen, 55,000 tons of different oils are produced yearly. The chemical works comprise a dozen mills, manufacturing chiefly the salts of soda and concentrated acids. Two thousand operatives are there employed, and the value of their annual production is estimated at £320,000. There are also three sugar-refineries, producing 65,000 tons of loaf-sugar, of which more than half is re-exported. Sulphur from Sicily too is refined and converted into sticks or flowers of sulphur, to the value of £80,000. Petroleum refining occupies 100 workmen. Metallurgy is another great industry; a large quantity of ore, imported from Elba, Spain, and Algeria, is smelted in the blast furnaces of St Louis in the suburbs. The Mediterranean iron-works and yards, together with other private companies, have large workshops for the construction or repair of marine steam-engines and every branch of iron shipbuilding, employing several thousand workmen. Marseilles is a great centre for the extraction of silver from lead ore; 16,000 tons of lead and 25 tons of fine silver are separated annually. There are 64 flour-mills with 300 sets of stones, and 100 factories prepare semolina and other cereal pastes, while 34 tanyards dress 500,000 sheep skins and 335,000 goat skins. To this list of industries must be added the manufactories of matches, candles, and wax-lights, with brass foundries, glass-works, and manufactures of coral, and of Oriental hosiery.

The port of Marseilles is the centre of numerous lines of steamers. The French company of mail steam packets (*Messageries Maritimes*) despatch their boats regularly to Italy, Egypt, Réunion, India, China, and the far East, as well as to Greece, Turkey, the Black Sea, Smyrna, and Syria. The Transatlantic Company runs its vessels to Algiers, Tunis, Malta, and the coast of Italy, and has also a regular line between Marseilles and New York. Many private companies have services to Corsica, Algiers, the coast of Languedoc and of Spain, and the Italian Riviera. Other lines connect Marseilles with Brazil and La Plata, Havre, and London. Landward there are two lines of railway to Aix, and a third to Toulon. A navigable canal is greatly needed to connect the port directly with the Rhone, in order to avoid the difficulties of egress from the river and to make Marseilles the natural outlet of the rich Rhone basin. The countries with which the greatest traffic is maintained are Algeria, Spain, Italy, Turkey, and the Russian ports on the Black Sea; next in order come England, Austria, the western coast of Africa, Réunion, the Cape, British India, Brazil, the Antilles, China, and Senegambia. From the Black Sea, Turkey, and Algeria come the cereals which form the chief imports in point of bulk; from Italy, Spain, the Levant, China, and Japan the silk, which is the import of greatest value (£4,000,000 yearly). Then follow ores and metals, iron, cast iron, lead, and copper; also wood, raw material for oil manufacture, raw sugar, cattle, wool and cotton, rice, and various dry vegetable foods, petroleum, cocoa, gums, pepper, and other spices, wines and brandies, coal, skins, cod-fish, cheese, and sponges. The principal exports in respect of value are silk, woollen, and cotton fabrics, refined sugars, wines and spirits; those of greatest bulk are cereals in the form of grain or flour, coal, building materials, oil-cakes, iron and other manufactures in metal, wines and spirits, oils, glass and crystal, lead, and coffee.

Of the seagoing tonnage, one-third is under the French flag, but the coasting trade, carried on by French sailors alone, is almost half as large as the ocean trade. The shipowners of the port possess almost seven hundred vessels, without counting the hundreds of fishing boats which ply along the coast.

History.—The Greek colony of Massalia (in Latin, *Massilia*) was founded by the enterprising mariners of Phocæa in Asia Minor, about 600 B.C. The settlement of the Greeks in waters which the Carthaginians jealously reserved for their own commerce was not effected without a naval conflict; it is, indeed, not improbable that the Phœnicians were settled at Marseilles before the Greek period, and that the very name of the town is the Phœnician מְזֻל, "settlement." Whether the judges (שפטים, "suffetes") of the Phœnician sacrificial tablet of Marseilles were the rulers of a city older than the advent of the Phœnicians, or were a sort of consuls for Punic residents in the Greek period, is disputed. The fall of the Ionic cities before the Persians probably sent new settlers to the Ligurian coast and cut off the remote city of Massalia from close connexion with the mother country. Isolated amidst alien populations, the Massaliots made their way by great prudence in dealing with the inland tribes, by the vigilant administration of their oligarchical government, and by frugality and temperance united to remarkable commercial and naval enterprise. Their colonies spread east and west along the coast from Monaco to Cape St Martin in Spain, carrying with them the worship of Artemis; the inland trade, in which wine was an important element, can be traced by finds of Massalian coins right across Gaul and through the Alps as far as Tyrol. The Massaliot Pytheas (330–320 B.C.) passed the pillars of Hercules and visited the coasts of Gaul, Britain, and Germany. The great rival of Massalian trade was Carthage, and in the Punic wars the city took the side of Rome, and was rewarded by Roman assistance in the subjugation of the native tribes of the Ligurian mountains. In the war of Cæsar and Pompey the aristocratic town took the side of the latter, and made a courageous but vain resistance to Cæsar. In memory of its ancient services the city, "without which," as Cicero says, "Rome had never triumphed over the Transalpine nations," was still left as a *civitas libera*, but her power was broken and most of her dependencies taken from her. From this time Massalia has little place in Roman history; it became for a time an important school of letters and medicine, but its commercial and intellectual importance gradually declined into insignificance. The town appears to have been Christianized before the end of the 3d century, and its reputation partly revived through the names of Gennadius and Cassian, which give it prominence in the history of Semi-Pelagianism and the foundation of Western monachism.

After the ravages of successive streams of invaders, Marseilles was repeopled in the 10th century under the protection of its viscounts. In 1112 the town bought up their rights, and was formed into a republic, governed by a podestat, who was appointed for life, and exercised his office in conjunction with 3 notables, and a municipal council, composed of 80 citizens, 3 clerics, and 6 principal tradesmen. During the rest of the Middle Ages, however, the higher town was governed by the bishop, and had its harbour at the creek of La Joliette. The southern suburb was governed by the abbot of St Victor, and owned the Port des Catalans. Situated between the two, the lower town, the republic, retained the old harbour, and was the most powerful of the three divisions. The period of the crusades brought great prosperity to Marseilles. The activity of its shipbuilding, the magnitude of its fleet, the importance of its commerce and manufactures, all increased at once. The count of Provence, Raymond Bérenger, Charles of Anjou, and afterwards Alphonso of Aragon, successively attempted to make themselves masters of the town; it suffered at different times from incendiarism, pillage, and massacre during the 13th and 14th centuries, and in the beginning of the 15th. King René, who had made it his winter residence, however, caused trade, arts, and manufactures again to flourish. Under Francis I., the disaffected constable de Bourbon vainly besieged the town with the imperial forces in 1524. During the wars of religion, Marseilles took an active part against the Protestants, and long refused to acknowledge Henry IV. The loss of the ancient liberties of the town brought on new disturbances under the Fronde, which Louis XIV. came in person to suppress. He took the town by storm, and had Fort St Nicolas constructed. Marseilles repeatedly suffered from the plague, and an epidemic raged from May 1720 to May 1721 with a severity for which it is almost impossible to find a parallel; Bishop Belsunce, Chevalier Rose, and others immortalized themselves by their courage and devotion.

During the Revolution the people rose against the aristocracy, who up to that time had governed the commune. In the Terror they rebelled against the convention, but were promptly subdued by General Carteaux. The wars of the empire, by dealing a severe blow to their maritime commerce, excited the hatred of the inhabitants against Napoleon, who accordingly hailed with enthusiasm the return of the Bourbons and the defeat of Waterloo. The news of the latter provoked a bloody reaction in the town against those suspected of imperialism. Since 1815 the prosperity of the city has received a considerable impulse from the conquest of Algeria and the opening of the Suez Canal. The completion of the canal of the Durance has covered with verdure the formerly arid country surrounding the town, and the openings made in the old part of Marseilles have improved its sanitary condition. (G. ME.)

MARSH, George Perkins, LL.D. (1801-1882), American diplomatist and philologist, was born at Woodstock, Vermont, March 17, 1801, graduated at Dartmouth College in 1820, and practised law at Burlington, Vermont, devoting himself also with ardour to philological studies. In 1835 he was elected to the State legislature, and in 1842 he became a member of Congress. In 1849 he was appointed United States minister to Turkey, and in 1852 discharged also a special mission to Greece, returning to Vermont in 1853. In 1861 he became United States minister to Italy, and died in that office at Vallombrosa, July 24, 1882.

His chief published works are a *Compendious Grammar of the Old Northern or Icelandic Language*, 1838, compiled and translated from the grammar of Rask; *The Camel, his Organization, Habits, and Uses*, 1856; *Lectures on the English Language*, 1861; *The Origin and History of the English Language*, 1862; *Man and Nature*, 1864. The last-named work, largely rewritten, was issued under the title *The Earth as Modified by Human Action* in 1874.

MARSHAL (from Old High German *marah*, horse, and *scalc*, care-taker), in its original signification a servant of the royal *manège*, was afterwards a title given in different countries to the holder of various high offices, military and civil. In the time of Philip Augustus the commander of the French forces was called the marshal of France. Under Francis I. the marshals of France became two in number, under Henry III. four, and in the time of Louis XIV. their number was raised to twenty. In England the marshal was a high officer of state as far back as the 12th century. In the end of the 12th and first half of the 13th century the office was conferred on the earls of Pembroke, from whom it passed by female descent to the family of Bigod, earl of Norfolk. The dignity of earl-marshal was afterwards held successively by the Mowbrays, dukes of Norfolk, the Howards, dukes of Norfolk, and the earls of Arundel and Norwich. Under a grant by Charles II. to Henry Howard, earl of Norwich, it has descended to and continues in the line of the existing dukes of Norfolk. The marshal was in feudal times (in conjunction with the constable, a still higher officer) the judge in the court of chivalry, which had cognizance of questions of honour and dignity; and, when the king headed his army in person, it was the marshal who selected the proper spot for the encampment of each noble. The constable's powers and duties were superseded in the reign of Henry VIII.; but the earl-marshal is still the head of the Heralds' College, and appoints the officers of arms. In Scotland (an orthography resembling the French maréchal being adopted) the office of marischal, probably introduced under David I., became from the 14th century hereditary in the family of Keith. The Scottish marischal became an earl under the designation of "earl-marischal" in 1458. Marischal College in Aberdeen was founded and endowed by the munificence of George, 5th earl-marischal. The dignity came to an end by the attainder of George, 10th earl-marischal, in 1716. The military title of field-marshal was at first borrowed by the Germans from the French *maréchal de champs*; and in the Thirty Years' War it meant much what quartermaster-general does now. It was not till last century that the word rose in dignity so as to signify the highest military dignity except that of commander-in-chief. It was adopted into the British military system from Germany,—the first field-marshals being John, duke of Argyll, and George, earl of Orkney, made so by George II. in 1736.

MARSHALL, John (1755-1835), chief justice of the United States, was born in Fauquier county, Virginia, on September 24, 1755. As lieutenant and captain he served in the revolutionary army from 1775 to 1780. In 1781 he began the practice of the law, and two years later removed to Richmond. At various times from 1782 to 1798 he was elected a member of the Virginia legislature, in 1788 a member of the Virginia convention for the ratification of the constitution; in 1797 he was envoy-extraordinary to France, and in 1799 a member of Congress; in 1800 he became secretary of state; and on January 31, 1801, he was appointed to the chief justiceship, which position he held until his death on the 6th of July 1835. Marshall as a lawyer soon rose to the first rank at the Virginia bar, and acquired also a national reputation. In the Virginia convention of 1788 his influence was second only to that of Madison in securing the adoption of the constitution. But, unlike Madison, he continued, under the constitution, to support the administration of Washington and Federalist measures in general. It was as chief justice of the supreme court of the United States, however, that Marshall won lasting fame. His reports, filling about thirty volumes, form a work which time will only render more valued. In the expounding of public law, whether international or State law, his talents found their freest scope. In these departments of jurisprudence general principles rather than authority must be sought by the judge, and in their application Marshall has had no equal upon the American bench. It is the peculiar function of the supreme court of the United States to interpret the constitution and to guard it from the encroachments of both national and State legislation. To this duty Marshall brought his great and just powers of reasoning, as well as those broad views of government which, during the thirty-four years of his judicial career, gave to the constitution the liberal powers which were necessary to its durability. "The constitution," says Judge Story, "since its adoption, owes more to him than to any other single mind for its true interpretation and vindication." See biography by Henry Flanders in his *Lives of the Chief Justices*, vol. ii.

MARSHALL ISLANDS. See Micronesia.

MARSHALLTOWN, the county seat of Marshall County, Iowa, United States, is situated on the Iowa river at the junction of several railways, and in the midst of a grain and stock producing region. Among its numerous industries are sugar-refining, waggon-making, and the manufacture of barbed steel wire for fencing purposes. The population was 3218 in 1870 and 6240 in 1880, and has since increased rapidly.

MARSHMAN, Joshua (1768-1837), a Baptist missionary and Oriental scholar, was born on April 20, 1768, at Westbury Leigh, in Wiltshire, where he received a somewhat defective school education, and afterwards followed the occupation of a weaver until 1794, when he removed to Bristol to take charge of a small school there. Meanwhile he had been diligent in the cultivation of his talents, which were naturally good; and he was already a man of considerable acquirements when in 1799 he was sent by the Baptist Missionary Society to join their establishment at Serampore. Here, in addition to the discharge of his more special duties, he engaged with success in the study of Bengali and Sanskrit, and afterwards of Chinese, and accomplished numerous literary tasks, the more important of which are mentioned below. He received the degree of D.D. from Brown University, U.S.A., in 1811. His death took place at Serampore on December 5, 1837.

Dr Marshman translated into Chinese the book of Genesis, the Gospels, and the Epistles of Paul to the Romans and the Corinthians; in 1811 he published *The Works of Confucius, containing the Original Text, with a Translation*, and in 1814 his *Clavis Sinica*. He was also the author of *Elements of Chinese Grammar, with Preliminary Dissertation on the Characters and Colloquial Mediums of the Chinese*, and was associated with Carey in the preparation of a

Sanskrit grammar and of a Bengali-English dictionary. See J. C. Marshman's *Life and Times of Carey, Marshman, and Ward* (2 vols., 1859).

MARSIGLI (Latinized MARSILIUS), LUIGI FERDINAND, soldier and savant, was born at Bologna, July 10, 1658, and died in the same city, November 1, 1730. After a considerable course of study in mathematics, natural history, and anatomy, he visited Constantinople, and on his return to Christendom offered his services to the emperor Leopold, then at war with the Turks (1682). Wounded and captured in an action on the river Raab, he was sold to a pasha and accompanied him to the siege of Vienna; but in 1684 his friends purchased his release, and at the close of the war he was appointed commissioner for fixing the new Dalmatian boundary. In 1703 he was second in command to the count of Arco when Alt-Breisach was surrendered to the duke of Burgundy; and, though popular opinion acquitted him of blame, Marsigli was cashiered when Arco was condemned to death. Devoting himself to scientific pursuits, he visited Switzerland, and spent a considerable time at Paris and Marseilles. He went to Rome in 1709 at the request of Clement XI., but soon returned to Marseilles to prosecute his investigations into the physical nature of the sea. In 1712 he presented his scientific collections to his native city, and thus gave rise to the Bologna Institute of Science and Art; and about the same time he established a press, including founts of Oriental characters, for printing the publications of the society.

Marsigli's own works were valuable contributions to knowledge, brought out in very handsome style. Best known are his curious physical history of the sea (Italian, Venice, 1711; French, Amsterdam, 1725), with a very laudatory preface by Boerhaave; *L'état militaire de l'Empire Ottoman* (Amsterdam, 1732); and *Danubius Pannonico-Mysicus* (Hague, 1726). This last, of which only three hundred and seventy-five copies were printed, consists of six huge folio volumes illustrated by nearly three hundred maps and engravings, and furnishes an exceedingly elaborate account of the course of the Danube, of the towns and antiquities along its banks, of its birds, beasts, fishes, &c. See Fontenelle's *éloge* in *Mém. de l'Acad. des Sciences*, Paris, 1730; Quincy, *Vie de Mons. le Comte de Marsigli*, Zurich, 1741.

MARSTON, JOHN, was one of the most vigorous satirists and dramatists of the Shakespearean age. He was probably some ten years younger than Shakespeare He has been identified with a gentleman commoner of Brasenose College, Oxford, who entered in 1591, and was admitted B.A. in 1593 as the eldest son of an esquire. If this is the same John Marston that was buried in the Temple Church in 1634, under a tombstone *Oblivioni sacrum*, the identification of him with the poet is most probably right, for one of Marston's most singular poems is a prayer to Oblivion—

"Let others pray
For ever their fair poems flourish may;
But as for me, hungry Oblivion,
Devour me quick."

In the superfluity of learned allusions and Latin quotations in his plays Marston proclaims the fact that he was a university man. He entered the field of letters in 1598, as a satirist, with a *Scourge of Villany*. He was professedly an imitator of Juvenal, but he wrote rather in the spirit of Skelton, and speedily earned something like Skelton's reputation as a coarse ribald buffoon of astonishing energy, girding at the grossest vices of the time in "plain naked words stript from their shirts." There was more of the good-natured chuckling buffoon than of the cynic in Marston's satire, though he did profess unmeasured scorn for the vices and fopperies of his age. The coarse energy of his invective pours out as if he loved strong language more than he hated the subjects of his ridicule. Shakespeare's *Venus and Adonis* was one of Marston's first butts; in his *Pygmalion's Image* (1598) the wooing of Adonis by the queen of love is very roughly but very cleverly parodied. The freshness and vigour of Marston's vein brought him at once into notice. He is mentioned (misspelt as Maxton or Mastone) in Henslowe's *Diary*, in 1599, as "the new poet" receiving payment as part author of a play; and in the same year he was probably ridiculed by Ben Jonson as "Carlo Buffone" in *Every Man out of his Humour*. He and Dekker had a famous quarrel with Jonson arising out of the latter's attack upon them in the *Poetaster* (see DEKKER). The literary enemies were reconciled; Marston forswore literary quarrels, dedicated a play to Jonson in terms of high eulogy, and was conjoined with Jonson and Chapman in the play of *Eastward Ho!* some political allusions in which nearly cost the authors their ears. Marston wrote comparatively few plays, published in quick succession at the following dates:—*Antonio and Mellida* (1602); *Antonio's Revenge* (1602); *The Malcontent* (1604, his first and most powerful play); *The Dutch Courtesan* (1605); *Parasitaster* (1606); *Sophonisba* (1606); *What You Will* (1607). Marston then apparently left off play writing; if he lived till 1634, there is no explanation of his sudden stoppage. There is very little constructive skill in his plays; the plots are uninteresting. He does little more than send a procession of puppets across the stage, one or more of which "gird at" the others—very "loose libertines" and very contemptible some of them—in the author's own rough vein of satire. One scene in *Antonio and Mellida* was much admired by Charles Lamb, and either suggested or was suggested by one of the most powerful situations in *King Lear*. But the passage taken out of the body of the play gives a very misleading idea of its general tenor, or of the general cast of Marston's dramatic work.

MARSYAS was a Phrygian god, whose name has passed into Greek mythology. It is hardly possible to discover the real basis of the legends, as their original form has been so much altered. Marsyas was the god of a small river which rose in a cave in the agora of Celænæ, and flows into the Mæander. In this cave was hung a hide, which according to the story was the skin of Marsyas suspended there by Apollo. When Athene threw away her flute, Marsyas found it, a subject represented by the sculptor Myron. Proud of his skill, Marsyas challenged Apollo with his lyre. Midas the Phrygian king, appointed judge in the contest, preferred the flute-player, and got his ass's ears in reward for his stupidity. The contest and the punishment of Marsyas, who was flayed alive by Apollo, were frequent subjects for Greek art, both vase-painting and sculpture. There can be little doubt that this account has been very much altered from its native Phrygian form by the Attic comic poets, with whom Marsyas was a favourite character. With regard to the Phrygian god it is difficult to say more than that he and Silenus and Midas are associated in legend with Dionysus, and that he must therefore belong to the cycle of legends of Cybele (see Preller, *Gr. Mythol.*, i. 508). The flute was the favourite instrument in the worship of the goddess. Sacrifices were offered by the people of Celænæ to Marsyas, and he helped them against the Galatians (Paus., x. 30). A statue of Marsyas was erected in the Roman Forum and in other towns, and is said to have been a symbol of liberty.

MARTEN,[1] the name of a group of animals constituting

[1] By all old authors of authority, as Ray, Pennant, Shaw, and Fleming, the word is written "Martin," but this form of spelling is now generally reserved by way of distinction for the bird (see MARTIN). The word, as applied to the animal here described, occurs in most Germanic and Romanic languages:—German, *marder*; Dutch, *marter*; Swedish, *mard*; Danish, *maar*; English, *marteron*, *martern*, *marten*, *martin*, and *martlett*; French, *marte* and *martre*; Italian, *martora* and *martorella*; Spanish and Portuguese, *marta*. Its earliest known use is in the form *martes* (Martial, *Ep.* x. 37), but it can scarcely be an old Latin word, as it is not found in Pliny or other classical writers,

a small but well-defined section of the family *Mustelidæ*, belonging to the Arctoid or Bear-like division of the order *Carnivora* (see MAMMALIA, pp. 439, 440 of the present volume).

The genus *Mustela*, as restricted by Cuvier (*Règne Animal*, 1817), contains a very natural assemblage of animals commonly called Martens, Sables, Polecats, Stoats, Ermines, and Weasels, all closely allied in structure and habits. A structural division, however, occurs between the two first-named and all the others, especially shown in the presence of an additional small premolar tooth on each side of each jaw; and, availing himself of this and some other minor characters, Cuvier divided the genus into two subgenera, for the first of which he retained the name of *Mustela*, and to the second assigned that of *Putorius*. Three years later Nilsson (*Skand. Fauna*, 1820) definitely constituted the two groups into genera, applying to the first the name of *Martes*, by which the animals composing it had been generally designated by the Latin-writing zoologists of the preceding century, and keeping *Mustela* for the more typical Weasels and their immediate allies. Later zoologists have been divided between the nomenclature of Cuvier, which has the priority, and that of Nilsson, which on other grounds is preferable. Those who adopt the latter affirm that Cuvier's names, being only used by him in a subgeneric sense, and not binomially, need not be applied generically; but this is contrary to the practice usually followed in such cases. Others avoid the difficulty by not breaking up the genus at all, and so apply the term *Mustela* to all the species. The result is that the generic name of the Martens in modern zoological works oscillates between *Martes* and *Mustela*, according to the views of the writer.

The following characters apply to the restricted group of Martens proper, by whatever name they are called. Body long, slender, and very flexible, though less so than in the true Weasels. Head somewhat triangular; muzzle pointed, the nose extending a little beyond the lips; eyes large and prominent; ears conspicuous, broad, somewhat triangular, rounded at the ends, furred outside and in; limbs short; feet rounded; toes short, five on each foot, all with short, compressed, curved, sharp-pointed claws. Soles densely furred between the naked pads. Tail moderately long, more or less bushy. Outer fur long, strong, and glossy; a very abundant soft under fur.

Vertebræ: C 7, D 14, L 6, S 3, C 18–23. Skull elongated and depressed. Facial portion moderate and rather compressed. Zygomata arched and wide but slender. Postorbital processes small. Auditory bullæ large, but not very globose. Mandible with a strong triangular vertical coronoid process and a well-developed angular process.

Dentition: $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $p\,\frac{4}{4}$, $m\,\frac{1}{2}$; total 38. Upper incisors in a straight transverse line, rather long and compressed; first and second subequal, third considerably larger. Lower incisors very small, especially the first, and crowded together, the second placed rather behind the others. Canines long and sharp-pointed. Upper premolars: first very small, with simple crown and one root; second and third nearly equal in size and two-rooted, with simple compressed sharp-pointed crowns, with very slightly developed accessory cusps; fourth (the sectorial) with blade consisting chiefly of the central and posterior cusps, the anterior being rudimentary, inner tubercle small and confined to the anterior part of the tooth. True molar tubercular, about twice as wide transversely as in the antero-posterior direction, having an outer, more elevated, but smaller portion, bearing three blunt tubercles; to the inner side of this the crown is contracted, and its surface deeply hollowed; it then expands again into a broad low lobe, with the central part elevated, and a raised, even, semicircular, slightly crenated internal border. Lower premolars: first very small, simple, and one-rooted; second, third, and fourth increasing slightly in size, with high compressed pointed crowns and posterior accessory cusps, best marked in the third. First molar (sectorial) with well-marked bilobed blade,—heel scarcely more than one-third of the length of the tooth, and a very small inner tubercle. Second molar small, single-rooted, with a low, flattened, subcircular or oval tubercular crown.

In geographical distribution the Martens are limited to the northern hemisphere, ranging throughout the greater part of the northern temperate regions of both Old and New Worlds, as far north as conditions of existence suited to their habits are met with, and southwards in America to 35° N. lat., while in Asia one species is met with as far as the island of Java.

The various species appear to be very similar in their habits. They live in woods and rocky places, and are thoroughly arboreal, spending most of their time in trees, although descending to the ground in quest of prey. They climb with great facility, and are agile and graceful in their movements. Some species are said occasionally to resort to berries and other fruit for food, but as a rule they are strictly carnivorous, feeding chiefly on birds and their eggs, small mammals, as squirrels, hares, rabbits, and moles, but chiefly mice of various kinds, of which they destroy great numbers, and occasionally snakes, lizards, and frogs. In proportion to their size they are among the most bloodthirsty of animals, though less so than the true Weasels. The female usually makes her nest of moss, dried leaves, and grass in the hollow of a tree, but sometimes in a hole among rocks or ruined buildings, and produces several young at a birth, usually from four to six. Though wild and untameable to a great degree if captured when fully grown, when taken young they are very docile, and have frequently been made pets of, not having the strong unpleasant odour of the smaller *Mustelidæ*. The common European Marten appears to have been partially domesticated by the Greeks and Romans, and to have been used to keep houses clear from rats and mice before cats were introduced.[1] In the same way, according to Hodgson, an allied species, the Yellow-bellied Weasel (*Mustela kathiah*), "is exceedingly prized by the Nepalese for its service in ridding houses of rats. It is easily tamed; and such is the dread of it common to all murine animals that not one will approach a house where it is domiciled." It is, however, to the great value attached to the pelts of these animals that their importance to man is chiefly due. Though all yield fur of serviceable quality, the commercial value varies immensely, not only according to the particular species from which it is obtained, but according to individual variation, depending upon age, sex, season, and other trifling circumstances. The skins from northern regions are more full and of a finer colour and gloss than those from more temperate climates, as are those of animals killed in winter compared to the same individuals in the summer season. The caprices of fashion have, moreover, set wholly factitious values upon slight shades of colour, recognized and named by experienced furriers, but not indicating any specific or other distinctions

and Martial often introduced foreign words into his Latin. Its etymology has been connected with the German "martern," to torment. A second Romanic name for the same animal is *fuina*, in French *fouine* (see E. Von Marten's "Ueber Thiernamen," in *Der Zoologische Garten*, vol. xi., 1870). The term "Marten Cat," often used, is a misnomer, for though somewhat Cat-like in size, general appearance, and habits, its true affinities are not with the *Felidæ*, but, as stated above, with the Bears.

[1] See Rolleston, "On the Domestic Cats, *Felis domesticus* and *Mustela foina*, of Ancient and Modern Times," *Journal of Anatomy and Physiology*, vol. ii. p. 47, 1868.

of which zoologists have any cognizance. Enormous numbers of animals are annually caught, chiefly in traps, to supply the demand of the fur trade, Siberia and North America being the principal localities from which they are obtained.

With the exception of the Pekan (*M. pennanti*) all the Martens are so much alike in size, general colouring, and cranial and dental characters that the discrimination of the species, and assignment of the proper geographical distribution to each, has been a subject which has sorely perplexed the ingenuity and patience of zoologists. The following description by Dr Elliott Coues of the external characters of the American Pine Marten (*M. americana*) will apply almost equally well to most of the others. "It is almost impossible to describe the colour of the Pine Marten, except in general terms, without going into the details of the endless diversities occasioned by age, sex, season, or other incidents. The animal is 'brown,' of a shade from orange or tawny to quite blackish; the tail and feet are ordinarily the darkest, the head lightest, often quite whitish; the ears are usually rimmed with whitish; on the throat there is usually a large tawny-yellowish or orange-brown patch, from the chin to the fore legs, sometimes entire, sometimes broken into a number of smaller, irregular blotches, sometimes wanting, sometimes prolonged on the whole under surface, when the animal is bicolor like a Stoat in summer. The general 'brown' has a greyish cast, as far as the under fur is concerned, and is overlaid with rich lustrous blackish-brown in places where the long bristly hairs prevail. The claws are whitish; the naked nose pad and whiskers are black. The tail occasionally shows interspersed white hairs, or a white tip."

The species generally recognized as distinct are the following, the first five belonging to the Old and the last two to the New World.

1. *Mustela foina*, Erxleben; the Beech Marten, Stone Marten, or White-breasted Marten.—Distinguished from the following by the greater breadth of the skull, and some minute but constant dental characters, by the dull greyish-brown colour of the fur of the upper parts, and the pure white of the throat and breast. It inhabits the greater part of the Continent of Europe, but is more southern than the next in its distribution, not being found in Sweden or Norway, nor, according to the recent investigations of Mr Alston, in the British Isles, although included in their fauna by all earlier writers.

2. *M. martes*, Linn; *Martes sylvatica*, Nilsson; *M. abietum*, Fleming; the Pine Marten (see figure).—Outer fur rich dark brown; under fur reddish-grey, with clear yellow tips; breast spot usually yellow, varying from bright orange to pale cream-colour or yellowish-white. Length of head and body 16 to 18 inches; of tail (including the hair) 9 to 12 inches. This species is extensively distributed throughout northern Europe and Asia, and was formerly

European Pine Marten (*Mustela martes*). From life.

common in most parts of Great Britain and Ireland. Though commonly called "Pine Marten," it does not appear to have any special preference for coniferous trees, except that, inasmuch as they constitute the greater proportion of the forests of the countries which it inhabits, it is more often met with in them than in any other. With regard to its recent occurrence in the British Isles, Mr Alston writes in *Proc. of Zool. Society of London*, 1879:—

"Although greatly reduced in numbers by persecution, it still maintains its ground in the wilder districts of Scotland, the north of England, Wales, and Ireland; and occasionally specimens are killed in counties where the species was thought to have been long extinct. In Scotland it is still found, though comparatively rarely, in the Lews and in most of the Highland mainland counties, being perhaps most abundant in Sutherland and Ross-shire, especially in the deer forests. In the Lowlands a Marten is now a very great rarity; but a fine example was killed in Ayrshire in the winter of 1875–76. In the north of England Mr W. A. Durnford says the species is 'still plentiful' in the wilder parts of Cumberland, Westmoreland, and Lancashire, and in Lincolnshire several have been recorded, the latest killed in 1865, by Mr Cordeaux.[1] In Norfolk one was shot last year; and I have myself examined a fine example which was shot in Hertfordshire, within 20 miles of London, in December 1872. In Dorsetshire the last is said to have been killed in 1804; but a specimen occurred in Hampshire about forty years ago, and another in Surrey in 1847. In Ireland the following counties were enumerated by Thompson as habitats of this species: Donegal, Londonderry, Antrim, Down, Armagh, Fermanagh, Longford, Galway, Tipperary, Cork, and Kerry. The *Cat-crann* is probably now a rarer animal in Ireland than it was when Thompson wrote; but it still exists in various districts, especially in County Kerry, whence the society has received several living examples; and Professor A. Leith Adams states that it has been seen of late years even in county Dublin."

3. *M. zibellina*, Linnæus; the Sable (German, *Zobel* and *Zebel*; Swedish, *sabel*; Russian, *sobel*, a word probably of Turanian origin).—Closely resembling the last, if indeed differing from it except in the quality of the fur, which is the most highly valued of that of all the group. Found chiefly in eastern Siberia.

4. *M. flavigula*, Boddaert; the Indian Marten.—Inhabits the southern slopes of the Himalayas, the Nilgiri Hills, the interior of Ceylon, the Malay Peninsula, and Java.

5. *M. melampus*, Wagner.—Japan.

6. *M. americana*, Turton; the North-American Sable or Marten.—A species so closely allied to the European Pine Marten and Asiatic Sable that it is very difficult to assign constant distinguishing characters between them. The importance of the fur of this animal as an article of commerce may be judged of from the fact that 15,000 skins were sold in one year by the Hudson's Bay Company as long ago as 1743, and the more recent annual imports into Great Britain have exceeded 100,000. It is ordinarily caught in wooden traps of very simple construction, being little enclosures of stakes or brush in which the bait is placed upon a trigger, with a short upright stick supporting a log of wood, which falls upon its victim on the slightest disturbance. A line of such traps, several to a mile, often extends many miles. The bait is any kind of meat, a mouse, squirrel, piece of fish, or bird's head. It is principally trapped during the colder months, from October to April, when the fur is in good condition, as it is nearly valueless during the shedding in summer. Dr Coues tells us that, notwithstanding the persistent and uninterrupted destruction to which the American Sable is subjected, it does not appear to diminish materially in numbers in unsettled parts of the country. It holds its own partly in consequence of its shyness, which keeps it away from the abodes of men, and partly because it is so prolific, bringing forth six to eight young at a litter. Its home is sometimes a den under ground or beneath rocks, but oftener the hollow of a tree, and it is said frequently to take forcible possession of a squirrel's nest, driving off or devouring the rightful proprietor.

7. *M. pennanti*, Erxleben; the Pekan or Pennant's Marten, also called Fisher Marten, though there appears to be nothing in its habits to justify the appellation. This is the largest species of the group, the head and body measuring from 24 to 30 inches, and the tail 14 to 18 inches. It is also more robust in form than the others, its general aspect being more that of a Fox than a Weasel; in fact its usual name among the American hunters is "Black Fox." Its general colour is blackish, lighter by mixture of brown or grey on the head and upper fore part of the body, with no light patch on the throat, and unlike the other Martens generally darker below than above. It was generally distributed in wooded districts throughout the greater part of North America, as far north as Great Slave Lake, lat. 63° N., and Alaska, and extending south to the parallel of 35°; but at the present time it is almost exterminated in the settled parts of the United States east of the Mississippi.

See Elliott Coues, *Fur-bearing Animals, a Monograph of North American Mustelidæ*, 1877; E. R. Alston, "On the British Martens," *Proceedings of the Zoological Society of London*, 1879, p. 468. (W. H. F.)

MARTIAL (M. VALERIUS MARTIALIS) is a writer to whose merits it is difficult to do justice in the present day. His faults are of the most glaring kind; they are exhibited without the least concealment; and they are of the sort of which modern feeling is most intolerant. Living as he did under perhaps the worst of the many bad emperors who ruled the world in the 1st century, he addresses him and his favourites with the most servile flattery in his lifetime, reviles him immediately after his death (xii. 6), and offers equally fulsome incense at the shrine of his successor. No writer of equal genius has ever shown such an absence of dignity and independence of character in his relation to his richer friends and patrons. He is not ashamed

[1] The *Zoologist* for June 1882 records the recent capture of a Marten in a trap near Bardney in Lincolnshire.

to be dependent on them for gifts of money, for his dinner, and even for his dress. We cannot feel sure that even what seem his sincerest tributes of regard may not be prompted by the hope of payment. Further, there is no book in any literature which, both in expression and in the things treated of, sins so flagrantly against all instincts of propriety. A certain proportion of the epigrams in every book—perhaps one-fifth or one-sixth (in some books the proportion is much larger)—can be read by no class of readers with any other feelings than those of extreme distaste.

These faults are so unmistakable and undeniable that many readers of ancient literature have formed their whole estimate of Martial from them, and have declined to make any further acquaintance with him. Even those who greatly admire his genius, who find the freshest interest in his representation of Roman life and his sketches of manners and character, and who, after admitting the unfavourable first impression which he is bound to make, believe that they still can discern sufficient indications of the better nature which made him a popular and likeable man in his day, do not attempt to palliate his faults, though they may partially account for them by reference to the morals of his age and the circumstances of his life. The time when "the last of the Flavian line was tearing in pieces the half-lifeless world, and Rome was a bondslave to a bald Nero,"[1] was one when literature had either to be silent or to be servile. Martial was essentially a man of letters; there was no other métier for which he was fitted; he was bound either to gain favour by his writings or to starve. Tacitus and Juvenal might have chosen the latter alternative, but they were fortunately spared the necessity of making the choice by the possession of independent means. Even Statius, the contemporary of Martial, whose writings are in other respects irreproachable, is nearly as fulsome in his adulation as Martial. The relation of client to patron had been recognized as an honourable one by the best Roman traditions. No blame had attached to Virgil or Horace on account of the favours which they received from Augustus and Mæcenas, or of the return which they made for these favours in their verse. That old honourable relationship had, however, greatly changed its character between the era of Augustus and that of Domitian. Men of good birth and education, and sometimes even of high official position (Juv., i. 117), were not ashamed to gain or increase their living by the acceptance of money doles to provide their daily meal. "Atria magna colam" is the resource of a man who was too lazy or too incompetent to become an advocate, and who thought himself too much of a gentleman to adopt any mechanical trade. Martial was merely following a general fashion in paying his court to "a lord." "Rex" is the common term used for a patron. He made the best of the custom. In his earlier career he used to accompany his patrons to their villas at Baiæ or Tibur, and to attend their morning levées. Later on he went to his own small country house, near Nomentum, and sent a poem, or a small volume of his poems, as his representative, at the early visit. If his patron was courteous and liberal, he became his friend and entertained him with his wit and social vivacity. If he was mean and exacting, he found in him a subject for his epigrams. The fault of grossness Martial shares with nearly all ancient and many modern writers who treat of life from the baser or more ridiculous side. That he offends worse than perhaps any of them is to be explained, not, apparently, on the ground that he was more of a libertine in his life, but on the ground that he had to amuse a public which had become more corrupt than in any other civilized era. Although there is the most cynical effrontery and want of self-respect in Martial's use of language, there is not much trace of the satyr in him,—much less, many readers will think, than in Juvenal. Neither is it at all true, as is said by historians of Roman literature (W. S. Teuffel, vol. ii. 317, 5), that his epigrams mostly deal with this side of life. At least four-fifths of them are unexceptionable in subject and treatment.

Our knowledge of Martial's life is derived almost entirely from himself. His writings do not, like those of Horace, supply materials for a continuous biography, nor do they lay bare every secret of his heart with the self-absorption of Catullus. But, as he writes frankly about everything that interested him, he has not only painted a very life-like picture, or rather drawn a multitude of very life-like sketches of Roman society in his time, but he has clearly marked his own position in and his own relation to that society. His criticism of men and manners enables us to judge of the standard which he applied to life, of the things which he liked and disliked, and of his own temper and disposition. Reference to public events enables us approximately to fix the date of the publication of the different books of epigrams, and from these dates to determine those of various important events in his life. Thus, as in book x., which was published in 97 or perhaps 98 A.D., he is found celebrating his fifty-seventh birthday (x. 24), the date of his birth may be assigned to the year 40 or 41. The place of his birth was Bilbilis, or Augusta Bilbilis, in Spain, in a "barren and rugged country" near the sources of the Tagus. His name seems to imply that he was born with the rights of Roman citizenship, but he speaks of himself as "sprung from the Celts and Iberians, and a countryman of the Tagus"; and, in contrasting his own masculine appearance with that of an effeminate Greek, he draws especial attention to "his stiff Spanish hair"—

"Hispanis ego contumax capillis" (x. 65).

In an epigram written nearly thirty years after his removal to Rome he piously commends the soul of a little child, Erotion, to whom he was much attached, to his parents Fronto and Flaccilla, who had gone before to the world of shades (v. 34). Their position in life seems to be indicated by such references to his former home as the phrase "saturæ sordida rura casæ" (x. 96). His home was evidently one of rude comfort and plenty, sufficiently in the country to afford him the amusements of hunting and fishing, which he often recalls with a keen sense of pleasure, and sufficiently near the town to afford him the companionship of many comrades, the few survivors of whom he looks forward to meet again after his five and thirty years absence (x. 104). The memories of this old home, of Bilbilis on its mountain site, of the shallow, rapid Salo flowing round the base of the hill ("flectu tenui sed inquieto"), of "Gaius hoary with snow and sacred Vadavero with its broken cliffs," of the ilex-grove of Burado (iv. 55) "which even the laziest traveller walks through," and of other spots the rough names and local associations of which he delights to introduce into his verse, attest the enjoyment which he had in his early life, and were among the influences which kept his spirit thoroughly alive in the midst of the deadening routine of social life in Rome. But his Spanish home could impart, not only the vigorous vitality which was one condition of his success as a wit and poet, but the education which made him so accomplished a writer. The literary distinction obtained by the Senecas, by Lucan, by Quintilian, who belonged to a somewhat older generation, and by his friends and contemporaries Licinianus of Bilbilis, Decianus of Emerita, and

[1] Cum iam semianimum laceraret Flavius orbem
Ultimus, et calvo serviret Roma Neroni.—Juv., iv. 37.

Canius of Gades, proves how eagerly the novel impulse of letters was received in Spain in the first century of the empire, just as a similar impulse had been received in Cisalpine Gaul in the first half of the first century before our era. The success of his countrymen may have been the motive which induced Martial's parents to prepare him for a literary career,—

"At me litterulas stulti docuere parentes" (ix. 73, 7),

and which induced Martial himself to remove to Rome when he had completed his education. This he must have done some time before the fall, in 65 A.D., of Seneca and Lucan, who were probably his earliest patrons. He speaks of the halls of the Pisos and of Seneca as having been opened to him when he first went to Rome (iv. 40); and in epigrams, addressed to his widow nearly thirty years after the death of Lucan, he speaks of him with grateful admiration, and applies to her the word "Regina," "his lady patroness."

Of the details of his life for the first twenty years or so after he came to Rome we do not know much. He published some juvenile poems of which he thought very little in his maturer years, and he laughs at a foolish bookseller who would not allow them to die a natural death (i. 113). Martial had neither youthful passion nor youthful enthusiasm to make him precociously a poet. His faculty ripened with experience and with the knowledge of that social life which was both his theme and his inspiration; and many of his best epigrams are among those written in his last years. From many answers which he makes to the remonstrances of friends,—among others to those of Quintilian,—it may be inferred that he was urged to practise at the bar, but that he preferred his own lazy Bohemian kind of life to more settled and remunerative modes of industry. He made many influential friends and patrons, and secured the favour both of Titus and Domitian. From them he obtained various privileges, among others the "semestris tribunatus," which conferred on him equestrian rank. He failed, however, in his application to the latter for more substantial advantages, although he commemorates the glory of having been invited to dinner by him, and also the fact that he procured the privilege of citizenship for many persons in whose behalf he appealed to him. The earliest of his extant works, that known by the name of *Liber Spectaculorum*, was first published at the opening of the Colosseum in the reign of Titus; but the book as it now stands was given to the world in or about the first year of Domitian, *i.e.*, about 81 A.D. The favour of the emperor procured him the countenance of some of the worst creatures at the imperial court,—among them of the notorious Crispinus, of Parthenius, Earinus, Regulus, and probably of Paris, the supposed author of Juvenal's exile, on whose death Martial afterwards wrote a eulogistic epitaph. The two books numbered xiii. and xiv., and known by the name of *Xenia* and *Apophoreta*,—inscriptions of two lines for presents,—were published between 81 and 86 A.D. In that last year he gave to the world the first two of the twelve books on which his reputation rests. From that time till his return to Spain in 98 A.D. he published a volume almost every year. The first nine books and the first edition of book x. appeared in the reign of Domitian; and book xi. at the end of 96 A.D., shortly after the accession of Nerva. A revised edition of book x., that which we now possess, appeared in 98 A.D., about the time of the entrance of Trajan into Rome. The last book was written after three years' absence in Spain, shortly before his death, which happened about the year 102 or 103 A.D.

These twelve books bring Martial's ordinary mode of life between the age of five-and-forty and sixty very fully before us. His regular home for five-and-thirty years was Rome. He lived at first up three pair of stairs ("et scalis habito tribus sed altis," i. 117), and his rooms overlooked the laurels in front of the portico of Agrippa. He had a small and not very valuable country house near Nomentum, in the Sabine territory, to which he occasionally retired as a refuge from the bores and noises of the city (ii. 38, xii. 57). In his later years he had a small house on the Quirinal, near the temple of Quirinus. At the time when his third book was brought out he had retired for a short time to Cisalpine Gaul, in weariness, as he tells us, of his unremunerative attendance on the levées of the great—

"Non poterat vanæ tædia ferre togæ" (iii. 4).

For a time he seems to have felt the charm of the new scenes which he visited, and in a later book (iv. 25) he contemplates, probably with a reminiscence of Horace (*Od.* ii. 6), the prospect of retiring to the neighbourhood of Aquileia and the Timavus in his old age. But the spell exercised over him by Rome and Roman society was too great to permit of a prolonged absence; and even the epigrams sent from Forum Corneli and the Æmilian Way ring much more of the Roman Forum, and of the streets, baths, porticos, and clubs of Rome, than of the places from which they are dated. So too his motive for his final departure from Rome in 98 A.D. was a weariness of the burdens imposed on him by his social position, and, apparently, the difficulties of meeting the ordinary expenses of living in the metropolis (x. 96); and he looks forward, with a kind of "nostalgia," to a return to the scenes familiar to his youth. The well-known epigram addressed to Juvenal (xii. 18) shows that for a time his ideal was realized; but the more trustworthy evidence of the prose epistle prefixed to book xii. proves that his contentment was of very short duration, and that he could not live happily away from the literary and social pleasures of Rome ("bibliothecas, theatra, convictus"), which supplied both the impulse to his genius and the material on which it could exercise itself. The one consolation of his exile was the society of a lady, Marcella, of whom he writes rather as if she were his patroness,—and it seems to have been a necessity of his being to have always a patron or patroness,—than his wife or mistress. His delight in her society arose from his finding in her one who, though born and bred in this remote province, yet by her natural grace and accomplishment revived for him the charm of Rome.

During his life there, although he never rose to a position of real independence, and had always a hard struggle with poverty, he seems to have known everybody, especially every one of any eminence at the bar or in literature. In addition to Lucan and Quintilian, he numbered among his friends or more intimate acquaintances Silius Italicus, Juvenal, the younger Pliny; and we find a number of other names, such as those of Julius Martialis, Faustinus, Bassus, Decianus, Melior, Stella, &c., of men holding a high social, legal, or literary position, whose society and patronage he enjoyed. The silence which he and Statius, although authors writing at the same time, having common friends, and treating sometimes of the same subjects, maintain in regard to one another may be explained by mutual dislike or want of sympathy. Martial, in many places, shows an undisguised contempt for the artificial kind of epic on which Statius's reputation chiefly rests; and it seems quite natural that the respectable author of the *Thebaid* and the *Silvæ* should feel little admiration for either the life or the works of the Bohemian epigrammatist.

The personal faults of Martial, which deny to his writings, notwithstanding their vivacity, truth, and brilliancy, a place among the best poetry of antiquity, have been sufficiently indicated. It remains to ask, What were those qualities of nature and intellect which enable us to read his best work—even the great body of his work—with the freshest sense of pleasure in the present day?

He had the keenest capacity for enjoyment, the keenest curiosity and power of observation. The ordinary spectacle of Roman life, as it passed before his eyes, was thus vividly apprehended and reproduced by him in all its details; and the many varieties of character which an over-ripe and decaying civilization produces were quickly seized and graphically sketched. He had also a very just discernment. It is rare to find any one endowed with so quick a perception of the ridiculous who is so little of a caricaturist. He was himself singularly free from cant, pedantry, or affectation of any kind. Though tolerant of most vices, he has a hearty scorn of hypocrisy,—of the combination of outward austerity with secret profligacy,—of the man who, while he wears

"Fuscos colores, galbinos habet mores."[1]

There are few better satirists of social and literary pretenders either in ancient or modern times. Living in a very artificial age, he was quite natural, hating pomp and show, and desiring to secure in life only what really gave him pleasure. To live one's own life heartily from day to day without looking before or after, and to be one's self without trying to be that for which nature did not intend him, is the sum of his philosophy. It is the philosophy of a man who has passed the middle of life, who has outlived any illusions he may ever have had, and who is quite content that whatever remains to him in the future should be like his present. Further, while tolerant of much that is bad and base,—the characters of Crispinus and Regulus, for instance,—he shows himself genuinely grateful for kindness and appreciative of excellence. He has no bitterness, malice, or envy in his composition. He professes to avoid personalities in his satire;—"Ludimus innocui" is the character he claims for it. Pliny, in ths short tribute which he pays to him on hearing of his death, says, "He had as much candour as wit and pungency in his writings" (*Ep.* iii. 21).

Honour and sincerity (*fides* and *simplicitas*) are the qualities which he most admires in his friends. Though many of his epigrams indicate a cynical disbelief in the character of women, yet others prove that he could respect and almost reverence a refined and courteous lady. His own life in Rome afforded him no experience of domestic virtue; but his epigrams show that, even in the age which is known to modern readers chiefly from the *Satires* of Juvenal, that virtue was recognized as the purest source of happiness. The tenderest element in Martial's nature seems, however, to have been his affection for children and for his dependants. The pathos with which he has recorded their premature death, combined with his fresh enjoyment of outward nature, give to many of his pieces a rank among the serious poetry of the world—"inter sanctiora carmina,"—to use a phrase of his own.

The permanent literary interest of Martial's epigrams arises not so much from their verbal point or brilliancy, though in these respects they are unsurpassed, as from the amount of human life and character which they contain. There is no truer painter of social manners in antiquity. He enables us better than any other writer to revive the outward spectacle of the imperial Rome which we see in its ruins, and to repeople its streets, shops, porticos, baths, and amphitheatres. If Juvenal enforces the lesson of that time, and has penetrated more deeply into the heart of society, Martial has sketched its external aspect with a much fairer pencil and from a much more intimate contact with it. It is from the immediate impressions and comments of the epigrammatist that the satirist has taken the suggestion of many of his more elaborate pictures and more stern denunciations. But it is not only the peculiarities of Roman customs that live in the writings of Martial. His page, to use his own phrase, "has the true relish of human life" in every age—"hominem pagina nostra sapit." He was to Rome in the decay of its ancient virtue and patriotism what Menander was to Athens in its decline. They were both men of cosmopolitan rather than of a national type, and had a closer affinity to the life of Paris or London in the 18th century than to that of Rome in the days of the Scipios or of Athens in the age of Pericles. The form of epigram was fitted to the critical temper of Rome as the comedy of manners was fitted to the dramatic genius of Greece. Martial professes to be of the school of Catullus, Pedo, and Marsus, and admits his inferiority only to the first. But, though he is a poet of a less pure and genuine inspiration, he is a greater epigrammatist even than his master. He has indeed made that form of art peculiarly his own. He has applied it to the representation of a very much greater number of situations, incidents, and characters, and he has done this with the greatest clearness, terseness, and vivacity of style, and with a masterly command over all his metres, except the pure hexameter, in which no other writer has been able to treat the familiar matters of the day with the light touch of Horace. Martial, except where he is flattering the emperor,—and then we may sometimes suspect an undercurrent of irony,—is one of the most natural and sensible as he is one of the wittiest and most brilliant of writers. He fails, perhaps, more often in his wit than in his sense. He is full of the happiest phrases, which express admirably for all times, without over-subtlety and without triteness, the judgment and impressions of life formed by direct contact with it, and taken neither from books nor from the opinions of other men, of a thorough man of the world, who had yet some feelings and sensibilities to which men of the world are generally strangers. He wrote naturally because he was completely in harmony with the life of his age. As this is the explanation of his grave offences, it should also be recognized as contributing to his merits as a writer.

Owing probably to the reasons which have excluded his writings from school education, little has been done for the criticism or explanation of Martial for about two centuries. There is a good edition of the text by Schneidewin in the Teubner series of classics. For English readers the *Selected Epigrams of Martial*, by H. H. Stephenson, and the *Martialis Epigrammata Selecta*, by Messrs Paley and Stone, may be recommended as a good introduction to the study of this poet. An edition of book i., with a Latin commentary by J. Flach, has lately appeared at Tübingen. Further information about him may be obtained in a work by A. Brandt, *De Martialis poetæ vita et scriptis* (Berlin, 1853), and in Friedländer's *Sittengeschichte Roms*; and an excellent criticism on his writings is to be found among the prose works of Lessing. (W. Y. S.)

MARTIAL LAW. See Military Law.

MARTIGUES, chief place of a canton in the department of Bouches-du-Rhône, France, stands on the southern shore of the lagoon of Berre, and at the eastern extremity of that of Caronte, by which the former is connected with the Mediterranean. Divided into three quarters by canals with numerous bridges, the place has sometimes been called the Venice of Provence. It has a harbour of 10 acres, an iron foundry, workshops for maritime constructions, oil manufactures, and chemical works; the principal industry, however, consists in the preparation of "boutargue," which is obtained from the roes of the grey mullet caught in the lagoons, and rivals Russian caviare. The population in 1876 was 8053.

[1] "Whose dress is of a dull colour, his morals a pale green."

Built in 1232 by Raymond Bérenger, count of Provence, Martigues was made a viscountship by Joanna I., queen of Naples. Henry IV. made it a principality, in favour of a princess of the house of Luxembourg. It afterwards passed into the hands of the duke of Villars.

MARTIN[1] (French, *Martinet*), the *Hirundo urbica* of Linnæus and *Chelidon urbica* of modern ornithologists, a bird very well known throughout Europe, including even Lapland, where it is abundant, retiring in winter to the south of Africa.[2] It also inhabits the western part of Asia, and appears from time to time in large flocks in India; but the boundaries of its range and those of at least one of its Eastern congeners cannot as yet be laid down. The Martin (or House-Martin, as it is often called, to distinguish it from the Sand-Martin presently to be mentioned) commonly reaches its summer-quarters a few days later than the SWALLOW (*q.v.*), whose habits its own so much resemble that heedless persons often disregard the very perceptible differences between them, the Martin's white rump and lower parts being conspicuous as it flies or clings to its "loved mansionry" attached to our houses, for, as Shakespeare wrote—

> "No jutty, frieze,
> Buttress, nor coign of vantage, but this bird
> Hath made his pendent bed and procreant cradle."
> —*Macbeth*, act i. sc. 6.

This nest, made of the same material as the Swallow's, is, however, a far more difficult structure to rear, and a week or more is often occupied in laying its foundations—the builders clinging to the wall while depositing the mud of which it is composed. But, the base once securely fixed, the superstructure is often quickly added till the whole takes the shape of the half or quarter of a hemisphere, and a lining of soft feathers, mixed with a few bents or straws, fits it for its purpose. The Martin sets about building very soon after its return, and a nest that has outlasted the winter's storms is almost at once reoccupied; though if a new nest be needed its construction often involves great delay, for any excess of wet or drought retards the operation, and the work is generally placed in such an exposed situation that heavy driving rains will frequently wash away the half-dried walls. However, the bird mostly perseveres against these and other untowardnesses, contriving in the course of the summer to raise a second or, rarely, a third brood of offspring—though it is certain that the latest broods often die in the nest—apparently through failure of food. Yet what seem to be adults of this species are observed in England every year so late as November, and there are several instances of its appearance within a few days of the winter solstice; but it is to be remarked that these late birds are almost certainly strangers, and not natives of the locality in which they are seen.

The Sand-Martin, *Hirundo riparia* of Linnæus and *Cotile riparia* of modern writers, differs much in appearance and habits from the former. Its smaller size, mouse-coloured upper surface, and jerking flight ought to render it easily recognizable from the other British *Hirundinidæ*; but through carelessness it is seldom discriminated, and, being the first of the Family to return to its northern home, the "early Swallow" of newspaper-writers would seem to be nearly always of this species. Instead of the clay-built nest of the House-Martin, this bird bores, with a degree of regularity and an amount of labour rarely excelled in its Class, horizontal galleries in a natural or artificial escarpment. When beginning its excavation, it clings to the face of the bank, and with its bill loosens the earth, working from the centre outwards, assuming all sorts of positions—as often as not hanging head downwards. The form of the boring and its length depend much on the nature of the soil; but the tunnel may extend to 4, 6, or even 9 feet. The gallery seems intended to be straight, but inequalities of the ground, and especially the meeting with stones, often cause it to take a sinuous course. At the end is formed a convenient chamber lined with a few grass stalks and feathers, the latter always beautifully arranged, and upon them the eggs are laid. The Sand-Martin has several broods in the year, and is much more regular than other *Hirundinidæ* in its departure for the south. The kind of soil needed for its nesting-habits makes it a somewhat local bird; but no species of the Order *Passeres* has a geographical range that can compare with this. In Europe it is found nearly to the North Cape, and thence to the Sea of Okhotsk. In winter it visits many parts of India, and South Africa to the Transvaal territory. In America its range is even more extraordinary, extending (due regard being of course had to the season of the year) from Melville Island to Caiçara in Brazil, and from Newfoundland to Alaska.

The Purple Martin of America,[3] *Hirundo* or *Progne purpurea*, requires some remarks as being such a favourite bird in Canada and in the United States. Naturally breeding in hollow trees, it readily adapts itself to the nest-boxes which are very commonly set up for its accommodation; but its numbers are in some years and places subject to diminution in a manner which has not yet been satisfactorily explained. The limits of its range in winter are not determined, chiefly owing to the differences of opinion as to the validity of certain supposed kindred species found in South America; but according to some authorities it reaches the border of Patagonia, while in summer it is known to inhabit lands within the Arctic Circle. The male is almost wholly of a glossy steel-blue, while the female is much duller in colour above, and beneath of a brownish-grey.

Birds that may be called Martins[4] occur almost all over the world except in New Zealand, which is not regularly inhabited by any member of the Family. The ordinary Martin of Australia is the *Hirundo* or *Hylochelidon nigricans* of most ornithologists, and another and more beautiful form is the Ariel or Fairy-Martin of the same country, *Hirundo* or *Lagenoplastes ariel*. This last builds of mud a bottle-shaped nest, as does also the Rock-Martin of Europe, *Hirundo* or *Biblis rupestris*; but space fails wherein to tell more of these interesting birds. (A. N.)

MARTIN, ST, bishop of Tours, was born of heathen parents at Sabaria (*Stein am Anger*) in Pannonia, about the year 316. When ten years of age he became a catechumen, and at fifteen, contrary to his own inclination, he entered the army. It was while he was stationed at Amiens that he divided his cloak with the beggar, and on the following night had the vision of Christ making known to his angels this act of charity to Himself on the part of "Martinus, still a catechumen." Soon afterwards he received baptism, and, two years later, having been permitted to leave the army, he joined Hilary of Poitiers, who wished to make him a deacon, but at his own request ordained him to the humbler office of an exorcist. In the course of the years that followed he undertook a journey to Pannonia for the purpose of converting his parents, and was successful in bringing his mother within the pale of

[1] The older English form, Martlet (French, *Martelet*), is, except in heralds' language, almost obsolete, and when used is now applied in some places to the SWIFT (*q.v.*).

[2] Since the publication of the account of this species in Yarrell's *British Birds* (ed. 4, ii. p. 354), Mr Gurney has informed the writer of a specimen obtained out of a migratory flock flying very high on the Qua'qua' river, lat. 19° 10′ S., by the expedition of Messrs Jameson and Ayres, 23d October 1880.

[3] In 1840 an example is said to have been killed at Kingstown in Ireland, the skin of which is in the Dublin Museum of Science and Art.

[4] The *Martin* of French colonists (in the Old World) is an *Acridotheres*, one of the STARLINGS (*q.v.*).

the church. For some time, doubtless during the Arian troubles, he lived, along with a presbyter friend, an ascetic life on the desert island of Gallinaria near Genoa; in 360 he was again with Hilary at Poitiers, and founded in the neighbourhood the monasterium Locociagense (Licugé). Here his miracles, which included more than one case of restoring the dead to life, were very numerous, and made him so famous that in 371 the people of Tours insisted on having him for their bishop. In this capacity he was extremely zealous and energetic in seeking to extirpate idolatry from his diocese and from France, and by example as well as by precept he did much for the spread of the monastic system. To obtain the privacy that he required for the maintenance of his personal religion, he established the monastery of Marmoutier-les-Tours (Martini monasterium) on the banks of the Loire. At Treves, in 385, he was importunate in his entreaties that the lives of the Priscillianist heretics should be given them, and he ever afterwards refused to hold ecclesiastical fellowship with those bishops who had sanctioned their execution. He died at Candes about the year 400, and is commemorated by the Roman Church on November 11 (duplex). He is the patron saint of France, and of the cities of Mainz and Würzburg. The *Life* by his disciple Sulpicius Severus is practically the only source we have for his biography, but it is full of legendary matter and chronological inaccuracies. The feast of St Martin (Martinmas) took the place of an old pagan festival, and inherited some of its usages (such as the Martinsmännchen, Martinsfeuer, Martinshorn, and the like, in various parts of Germany); by this circumstance is most probably to be explained the fact that he is regarded as the patron of drinking and jovial meetings, as well as of reformed drunkards.

MARTIN I., pope, succeeded Theodore I., in June or July 649. He had previously acted as papal apocrisiarius at Constantinople, and was held in high repute for learning and virtue. Almost his first official act was to summon a synod (the first Lateran) for dealing with the Monothelite heresy. It met in the Lateran church, was attended by one hundred and five bishops (chiefly from Italy, Sicily, and Sardinia, a few being from Africa and other quarters), held five sessions or "secretarii" from the 5th to the 31st of October 649, and in twenty canons condemned the Monothelite heresy, its authors, and the writings by which it had been promulgated. In this condemnation were included, not only the "Ecthesis" or exposition of faith of the patriarch Sergius for which the emperor Heraclius had stood sponsor, but also the "Typus" of Paul, the successor of Sergius, which had the support of the reigning emperor (Constans II.). Martin was very energetic in publishing the decrees of his Lateran synod in an encyclical, and Constans replied by enjoining his exarch to seize the pope, should he persist in this line of conduct, and send him prisoner to Constantinople. These orders were found impossible of execution for a considerable space of time, but at last Martin was arrested in the Lateran (June 15, 653), hurried out of Rome, and conveyed first to Naxos and subsequently to Constantinople (September 17, 654). After suffering an exhausting imprisonment and many public indignities, he was ultimately banished to Cherson, where he arrived on March 26, 655, and died on the 16th of September following. His successor was Eugenius I. A full account of the events of his pontificate will be found in Hefele's *Conciliengeschichte*, vol. iii., 1877.

MARTIN II. See Marinus I.

MARTIN III. See Marinus II.

MARTIN IV., pope from 1281 to 1285, was the successor of Nicholas III. He was a native of Touraine, born about 1210, and his proper name was Simon de Brion. After holding various offices at Rouen and Tours, he was made chancellor of France by Louis IX. in 1260, and cardinal by Urban IV. in 1261. He acted as legate for this pope and also for his successor Clement IV. in the negotiations for the assumption of the crown of Sicily by Charles of Anjou, and he is supposed also to have stimulated the ambition of Philip III. for the imperial dignity in 1273. After the death of Nicholas III. (August 1280) Charles of Anjou was able to secure the election of Cardinal Simon by the conclave at Viterbo (February 22, 1281). The Romans declined to receive him within their walls, and he was crowned at Orvieto. At the instance of Charles, whose tool he had become, he in November 1281 excommunicated the emperor Michael Palæologus, who stood in the way of the French projects against Greece, —an act by which the union of the Eastern and Western churches was rendered impossible. For three years after the Sicilian Vespers in 1282 all the spiritual and material resources at his command were in vain employed on behalf of his patron against Peter of Aragon. He died at Perugia on March 25, 1285, and was succeeded by Honorius IV.

MARTIN V. (Otto di Colonna), pope from 1417 to 1431, was elected on St Martin's day at Constance by a conclave consisting of twenty-three cardinals and thirty delegates of the council, which after deposing John XXIII. had long experienced much perplexity from the conflicting claims of Gregory XII. and Benedict XIII. The son of Agapito Colonna and Catarina Conti, born about 1368, he belonged to one of the oldest and most distinguished families of Rome, became apostolic protonotary under Urban VI., was created cardinal-deacon by Innocent VII., and in 1410 was the delegate of Alexander V. to hear the appeal which had been taken in that year to the papal see by John Huss. He was justly esteemed for his moderation, learning, uprightness, and business capacity, but he failed to achieve, as he might have done, the honour of being a reforming pope. His first act after his election was to publish a brief confirming all the regulations made by his predecessors with regard to the papal chancery,—regulations which had long been the subject of just complaint. When the "nations" of the council pressed their plans for reform, Martin submitted a counter scheme, and ultimately entered into negotiations for separate concordats, for the most part vague and illusory, with Germany, England, and France. He left Constance at the close of the council (May 1418), but travelled slowly through Italy, lingered at Florence, and did not venture to enter Rome until September 1420, when his first task was to seek to restore it to the prosperity and order to which it had become a stranger. In accordance with the decree of Constance, confirmed by himself, ordering that councils should be held every five years, he in 1423 summoned the council which met at Pavia and afterwards at Siena; it was somewhat poorly attended, and this circumstance gave the pope a pretext for dissolving it as soon as it had come to the resolution that "internal church union by reform ought to take precedence of external union." It was prorogued for seven years, and then met at Basel; shortly after its opening Martin died of apoplexy, on February 20, 1431. His successor was Eugenius IV.

MARTIN, John (1789-1854), a popular English painter, was born at Haydon Bridge, near Hexham, on the 19th of July 1789. On account of his early interest in art he was apprenticed by his father to a coachbuilder to learn heraldic painting, but owing to a quarrel the indentures were cancelled, and he was placed under Bonifacio Musso, an Italian artist, father of the well-known enamel painter Charles Musso. With his master Martin removed to London in 1806, where he married at the age of nineteen, and led a struggling life, supporting himself by giving drawing lessons, and by painting in water colours, and on china and glass. His leisure was occupied in the study of perspective and architecture. His first picture, Sadak in Search of the Waters of Oblivion, was executed in a month. It was exhibited in the Royal Academy of 1812, and sold for fifty guineas. It was followed by the Expulsion (1813), Paradise (1813), Clytie (1814), and Joshua (1815). In 1821 appeared the famous Belshazzar's Feast, which excited much favourable and hostile comment, and was awarded a prize of £200 at the British Institution, where the Joshua had previously carried off a premium of £100. Then came the Destruction of Herculaneum (1822), the Creation (1824), the Eve of the Deluge (1841), and a long series of other Biblical and imaginative subjects, many of which are widely known through engravings. In 1832–33 Martin received £2000 for drawing and engraving a fine series of designs to Milton, and along with Westall he produced a set of Bible illustrations. He was also much occupied with schemes for the improvement of London, and published various pamphlets and plans dealing with the metropolitan water supply, sewage, dock, and railway systems. During the last four years of his life he was engaged upon his large subjects of the Judgment, the Day of Wrath, and the Plains of Heaven. He was attacked with paralysis while painting, and died in the Isle of Man on the 17th of February 1854.

The bold originality of Martin's productions startled and attracted the public, but they are without the qualities of solid execution and truth to nature upon which a lasting fame in the arts must be built. His figures are badly drawn, his colouring is hot and unpleasant. To most of his professional brethren his works seemed theatrical and tricky; and the best lay critics of his time, like Charles Lamb, were disposed to deny that they evinced true imaginative power. His popularity may be said to have culminated in 1828, the year of his Fall of Nineveh; since then it has been gradually declining.

MARTINA FRANCA, a city of Italy in the province of Lecce, 18 miles north of Taranto, on a hill near the sources of the Tara. It was a fief of the Caraccioli family, and dates from a comparatively modern epoch. The ducal palace is one of the finest buildings of its kind in the south of Italy, somewhat similar in style of architecture to the Palazzo Pamfili in Naples. The population of the city was 13,088 in 1861; that of the commune has increased from 16,637 in that year to 19,257 in 1881.

MARTINEAU, Harriet (1802–1876), English woman of letters, was born at Norwich, where her father was a manufacturer. The family was of Huguenot extraction, but had adopted Unitarian views. Her education, which included Latin and French, as well as domestic accomplishments, was received partly at home, and partly under a Mr Perry, to whose lessons in logical English composition she ascribed something of her later clearness of thought and statement. The atmosphere of her home was industrious, intellectual, and austere; she herself was clever, weakly, and unhappy, and was, moreover, already growing deaf. At the age of fifteen the state of her health and temper led to a prolonged visit to her father's sister, Mrs Kentish, who kept a school at Bristol. Here, in the companionship of amiable and talented people, her life became happier. Here, also, she fell under the influence of the Unitarian minister, Dr Carpenter, from whose instructions, she says, she derived "an abominable spiritual rigidity and a truly respectable force of conscience strangely mingled together." From 1819 to 1830 she again resided chiefly at Norwich. The first part of this period was mainly spent in quiet and almost secret study and in needlework. About her twentieth year her deafness became confirmed, and she habitually from that time used an ear trumpet. In 1821 she began to write anonymously for the *Monthly Repository*, a Unitarian periodical, and was assured by her brother that authorship was her proper career. A little later she published *Devotional Exercises and Addresses, Prayers, and Hymns.*

In 1826 her father died, leaving a bare maintenance to his wife and daughters. His death had been preceded by that of his eldest son, and was shortly followed by that of the young man to whom Harriet was engaged. Mrs Martineau and her daughters soon after lost all their means by the failure of the house where their money was placed. Harriet had to earn her living, and, being precluded by her deafness from teaching, took up authorship in earnest and toiled with incredible industry. She reviewed for the *Repository* at the rate of £15 a year, wrote stories (afterwards collected as *Traditions of Palestine*), gained in one year (1830) three essay-prizes of the Unitarian Association, and eked out her income by needlework. In 1831 she was seeking a publisher for a series of tales designed as *Illustrations of Political Economy.* After many failures she accepted very disadvantageous terms, and the first number appeared amidst gloomy prognostications from the publisher. The sale, however, was immediate and enormous, the demand increased with each new number, and from that time her literary success was secured. In 1832 she moved to London; she at once became the fashion, and her acquaintance was eagerly sought. Till 1834 she continued to be occupied with her political economy series and with a supplemental series of *Illustrations of Taxation.* Four stories dealing with the poor-law came out about the same time. These tales, direct, lucid, written without any appearance of effort, and yet practically effective, display the characteristic qualities of their author's style. In 1834, when the whole series was complete, Miss Martineau paid a long visit to America. Here her open adhesion to the Abolitionist party, then small and very unpopular, gave great offence, which was deepened by the publication, soon after her return, of *Society in America* and a *Retrospect of Western Travel.* An article in the *Westminister Review*, "The Martyr Age of the United States," introduced English readers almost for the first time to the struggles of the Abolitionists. In these American writings Miss Martineau shows less than her usual calmness and judicial common sense, but it will scarcely be denied that there was some ground for her vehemence. The American books were followed by a novel, *Deerbrook*,—a story of middle class country life, lacking the delicate humour of Miss Austen or the touch of farce that enlivens Miss Edgeworth's tales, but delightfully clear in style, wholesome in spirit, and well sustained in point of interest. To the same period belong two or three little handbooks, forming parts of a *Guide to Service.* The veracity of her *Maid of all Work* led to a widespread belief, which she regarded with some complacency, that she had once been a maid of all work herself.

In 1839, during a visit to the Continent, Miss Martineau's health, which had long been bad, broke down entirely. She retired to solitary lodgings in Tynemouth, and remained a prisoner to her couch till 1844. She was still busy, and, besides a novel (*The Hour and the Man*), published some tales for children, and *Life in the Sick-room.* These volumes contain some of her best work, and possess a charm of tender feeling to balance the somewhat cold rationality that predominates in most of Miss Martineau's writing. During this illness she for a second time declined a pension on the civil list, fearing to compromise her political independence. Her letter on the subject was published, and some of her friends raised a small annuity for her soon after.

In 1844 Miss Martineau underwent a course of mesmerism, and in a few months was restored to health. Her recovery excited much discussion and controversy.

She herself felt no doubt either of its reality or of its being due to mesmerism, and not unnaturally resented the incredulity of others. She eventually published an account of her case in sixteen *Letters on Mesmerism*, a proceeding which caused great offence to some members of her family. On finding herself set free from the bondage of ill-health, she removed to Ambleside, where she built herself the house in which the greater part of her after life was spent. In 1845 she published three volumes of *Forest and Game Law Tales*, in which the method of her political economy series was again applied. In 1846 she made an Eastern tour with some friends. She was abroad for eight months, visiting Egypt, Palestine, and Syria, and on her return published *Eastern Life*. The tendency of this work is to display humanity passing through one after another of the world's historic religions, the conception of the Deity and of Divine government becoming at each step more and more abstract and indefinite. The ultimate goal Miss Martineau believed to be a philosophic atheism, but this belief she did not expressly declare in *Eastern Life*, considering it to be outside the province of that book. She published about this time *Household Education*, expounding the modern theory, in which freedom and rationality, rather than command and obedience, are regarded as the most effectual instruments of education. Her practical interest in all schemes of instruction led her to start a series of lectures, addressed at first to the school children of Ambleside, but afterwards extended, at their own desire, to their elders. The subjects of these lectures were sanitary principles and practice, the histories of England and North America, and the scenes of her Eastern travels. At the request of Mr Charles Knight she wrote for him, in 1849, *The History of the Thirty Years' Peace*,—a characteristic instance of Miss Martineau's remarkable powers of labour. "From the first opening of the books to study for the history to the depositing of the MS. of the first volume at press was," she says, "exactly six months. The second volume took six months to do."

In 1851 Miss Martineau edited a volume of *Letters on the Laws of Man's Nature and Development*. Its form is that of a correspondence between herself and Mr H. G. Atkinson (in which the latter has much the larger share), and it expounds that doctrine of philosophical atheism to which Miss Martineau had, in *Eastern Life*, depicted the course of human belief as tending. The existence of a first cause is not denied, but is declared unknowable, and the authors, while regarded by others as denying it, certainly considered themselves to be affirming the doctrine of man's moral obligation. Mr Atkinson was a zealous exponent of mesmerism, and the prominence given to the topics of mesmerism and clairvoyance no doubt tended to heighten the disapprobation with which the book was received. The reviewers were almost unanimous in condemnation, and the publication caused a lasting division between Miss Martineau and some of her friends.

The new philosophical bent of her studies directed Miss Martineau's attention to the works of Comte, and she undertook a condensed English version of the *Philosophie Positive*. It appeared in 1853, and to most readers is more useful and intelligible than the original. She had begun in the previous year to write articles, chiefly biographical, for the *Daily News*. Among these were the *Letters from Ireland*, written during a visit to that country in the summer of 1852. She also wrote a considerable number of essays upon different manufactures for *Household Words*, and another series for the same periodical upon the treatment of blindness, deafness, idiotcy, &c., besides a *Guide to Windermere*, followed afterwards by a *Complete Guide to the Lakes*. She had been for many years a contributor to the *Westminster Review*, and was one of the little band of supporters whose pecuniary assistance, in 1854, prevented its extinction or forced sale. In the early part of 1855 Miss Martineau found herself suffering from heart disease. Having always felt it one of her duties to write her autobiography, and believing the time before her to be but brief, she now at once set about this task, and on its completion caused the book to be printed that it might be ready for speedy publication at her death. But her life, which she supposed to be so near its close, was prolonged for other twenty years, her death not taking place until 1876.

These years were by no means idle. She continued to contribute to the *Daily News*, for which she wrote in all more than 1600 articles, and to the *Westminster Review*, as well as to other papers, and her biographical sketches were collected and reprinted from the *Daily News* in a volume which has justly become one of the best-known of her works. In point of style it is probably the most excellent of them all. The form and method leave nothing to be desired, and the perception of character is shrewd, sincere, and, roughly speaking, reliable. But in reading the book we feel that the biographies, divided by the editor into groups of royal, political, &c., fall far more naturally into two larger classes,—the biographies of persons whom Miss Martineau liked, and the biographies of persons whom she disliked. All are doubtless in a sense true, as all photographs are true, but the difference between a flattering and an unflattering photograph is considerable.

She also produced two books on the government of India, and was continually occupied in promoting schemes of reform and benevolence. Her poorer neighbours owed much to her kindly and enlightened efforts, and her servants found in her a friend as well as a mistress. Her long and busy life bears the consistent impress of two leading characteristics,—industry and sincerity. Her work was invariably sound, and its motive invariably respectable. The verdict which she records on herself in the autobiographical sketch left to be published by the *Daily News* is probably very near to that which will be recorded by future judgment. She says,—"Her original power was nothing more than was due to earnestness and intellectual clearness within a certain range. With small imaginative and suggestive powers, and therefore nothing approaching to genius, she could see clearly what she did see, and give a clear expression to what she had to say. In short, she could popularize while she could neither discover nor invent." Her judgment on large questions was clear and sound, and was always the judgment of a mind naturally progressive and Protestant. Mentally she was a true daughter of her Huguenot ancestors. But it is impossible to read her autobiography without suspecting that she was subject to considerable prejudices, especially in her judgment of persons, and that her temper, particularly in earlier life, was unamiable, hard, and unforgiving. She seems, indeed, to have possessed the sort of disposition which shows to much greater advantage in its relation to juniors, inferiors, and dependants than in its relations to elders and superiors, and which therefore appears more amiable in the closing than in the opening years of life. Her autobiography reveals also a weakness which was perhaps unavoidable. The publication of her political economy tales brought her into great and sudden notice; many persons of high position, official and otherwise, desired to enlist her advocacy on the part of their particular projects. She found her help much courted, and much help eagerly proffered to her. Her deafness, which suffered her to hear only what was directly addressed to herself, assisted to make her a central figure, and to induce the belief that hers was one of the most potent if not actually the most potent voice in English politics. Her deafness was in another direction probably advantageous. It led her to find solitude easier than most companionship, and saved her from many distractions of attention. It may indeed fairly be surmised that but for her deafness she could never have found time to achieve the amazing quantity of work that she did, while the courageous, cheerful, and unobtrusive spirit in which she bore her infirmity remains an example and an encouragement to all her fellow-sufferers. (C. BL.)

MARTINI, Giovanni Battista (1706-1784), the most learned musician of the 18th century, was born at Bologna on April 25, 1706. His father, Antonio Maria Martini, a violinist, taught him very early the elements of music, and to play the violin; at a later period he learned singing and harpsichord playing from Padre Pradieri, and counterpoint from Antonio Riccieri. Having received his education in classics from the fathers of the oratory of San Filippo Neri, he afterwards entered upon a noviciate at the Franciscan monastery at Lago, at the close of which he was received into that order on September

11, 1722. Continuing his studies in the theory and practice of music with great zeal, he in 1725, though only nineteen years of age, received the appointment of chapel-master in the Franciscan church at Bologna, where his compositions soon attracted much attention. At the invitation of amateurs and professional friends he now opened a school of musical composition at which in the course of his long life several celebrated musicians were trained, including Paolucci, Sabbatini, Ruttini, Zanotti, Sarti, Ottani, and Stanislas Mattei; as a teacher he consistently declared his preference for the traditions of the old Roman school of musical composition (see MUSIC). Padre Martini was a zealous and indefatigable collector of musical literature, and is alleged to have been the possessor of the most extensive musical library ever formed. After a lingering illness he died at Bologna on August 4, 1784. His *Elogio* was published by Pietro della Valle at Bologna in the same year.

The greater number of Martini's sacred compositions remain unprinted. The Liceo of Bologna possesses the MSS. of two oratorios; and a requiem, with some other pieces of church music, are now in Vienna. *Litaniæ atque antiphonæ finales B. V. Mariæ* were published at Bologna in 1734, as also twelve *Sonate d'intavolatura*; six *Sonate per l'organo ed il cembalo* in 1747; and *Duetti da Camera* in 1763. Martini's most important works are his *Storia della Musica* (Bologna, 1757–81) and his *Saggio di Contrapunto* (Bologna, 1774–75). The former, of which the three published volumes relate wholly to ancient music, and thus represent a mere fragment of the author's vast plan, exhibits immense reading and industry, but it is written in a dry and unattractive style, and is overloaded with matter which cannot be regarded as historical. At the beginning and end of each chapter occur puzzle-canons, some of which are exceedingly difficult; Cherubini solved the whole of them. The *Saggio* is a very learned and valuable work, containing an important collection of examples from the best masters of the old Italian and Spanish schools, with excellent explanatory notes. It treats chiefly of the tonalities of the plain chant, and of counterpoints constructed upon them. Besides being the author of several controversial works, Martini drew up a *Dictionary of Ancient Musical Terms*, which appeared in the second volume of G. B. Doni's *Works*; he also published a treatise on *The Theory of Numbers as applied to Music.*

MARTINI, SIMONE (1283–1344), called also Simone di Martino, and more commonly, but not correctly, Simon Memmi,[1] was born in 1283. He followed the manner of painting proper to his native Siena, as improved by Duccio, which is essentially different from the style of Giotto and his school, and the idea that Simone was himself a pupil of Giotto is therefore wide of the mark. The Sienese style is less natural, dignified, and reserved than the Florentine; it has less unity of impression, has more tendency to pietism, and is marked by exaggerations which are partly related to the obsolescent Byzantine manner, and partly seem to forebode certain peculiarities of the fully developed art which we find prevalent in Michelangelo. Simone, in especial, tended to an excessive and rather affected tenderness in his female figures; he was more successful in single figures and in portraits than in large compositions of incident. He finished with scrupulous minuteness, and was elaborate in decorations of patterning, gilding, &c.

The first known fresco of Simone is the vast one which he executed in the hall of the Palazzo Pubblico in Siena,—the Madonna Enthroned, with the Infant, and a number of angels and saints; its date is 1315, at which early period of his life he was already an artist of repute throughout Italy. In S. Lorenzo Maggiore of Naples he painted a life-sized picture of King Robert crowned by his brother, Lewis, bishop of Toulouse; this also is extant, but much damaged. In 1320 he painted for the high altar of the church of St Catharine in Pisa the Virgin and Child between six saints; above are archangels, apostles, and other figures. The compartmented portions of this work are now dispersed, some of them being in the academy of Siena. Towards 1321 he executed for the church of St Dominic in Orvieto a picture of the bishop of Savona kneeling before the Madonna attended by saints, now in the Fabricceria of the cathedral. Certain frescos in Assisi in the chapel of St Martin, representing the life of that saint, ascribed by Vasari to Puccio Capanna, are now, upon strong internal evidence, assigned to Simone. He painted also, in the south transept of the lower church of the same edifice, figures of the Virgin and eight saints. In 1328 he produced for the Sala del Consilio in Siena a work of a very different character—a striking equestrian portrait of the victorious general Guidoriccio Fogliani de' Ricci.

Simone had married in 1324 Giovanna, the daughter of Memmo (Guglielmo) di Filippuccio. Her brother, named Lippo Memmi, was also a painter, and was frequently associated with Simone in his work; and this is the only reason why Simone has come down to us with the family-name Memmi. They painted together in 1333 the Annunciation which is now in the Uffizi gallery. Simone kept a bottega (or shop), undertaking any ornamental work commissioned of him, and his gains were large. In 1339 he settled at the papal court in Avignon, where he made the acquaintance of Petrarch and Laura; and he painted for the poet a portrait of his lady, which has not come down to us; it gave occasion for two of Petrarch's sonnets, in which Simone is highly eulogized. He also illuminated for the poet a copy of the Comment of Servius upon Virgil, now preserved in the Ambrosian library of Milan. He was largely employed in the decorations of the papal buildings in Avignon, and several of his works still remain—in the cathedral, in the hall of the consistory, and, in the two chapels of the palace, the stories of the Baptist, and of Stephen and other saints. One of his latest productions (1342) is the picture of Christ Found by his Parents in the Temple, now in the Liverpool Gallery. Simone died in Avignon in July 1344.

From this account of Simone's principal works it will be perceived that those with which his name and fame are most generally identified are no longer regarded as his. These are the compositions, in the Campo Santo of Pisa, from the legend of S. Ranieri, and the Assumption of the Virgin; and the great frescos in the Cappellone degli Spagnuoli, in S. Maria Novella, Florence, representing the Triumph of Religion through the work of the Dominican order, &c. Some of the works in question can be proved to have been done many years after Simone's death, and the others belong to a different school and style of art.

MARTINIQUE, one of the West India islands, belonging to the chain of the Lesser Antilles, and constituting a French colony, lies 33 miles south of Dominica and 22 north of Saint Lucia, between 14° 23′ and 14° 52′ N. lat. and 63° 6′ and 63° 31′ W. long. The greatest length is 43 miles, the mean width 19; and the surface comprises 244,090 acres, or 380 square miles. A cluster of volcanic mountains in the north, a similar group in the south, and a line of lower heights between them, form the backbone of the island, which culminates in the north-west in Mont Pelée (4430 feet), and has altogether a much more irregular and strongly marked relief than it presents to the eye,—the deep ravines and precipitous escarpments with which it abounds being reduced in appearance to gentle undulations by the drapery of the forests. Of the numerous streams which traverse the few miles of country between the watershed and the sea, about seventy or eighty

[1] The ordinary account of this celebrated early Sienese painter is that given by Vasari, and since repeated in a variety of forms. Modern research shows that it is far from correct, the incidents being erroneous, and the paintings attributed to Simone in various principal instances not his. We follow the authority of Messrs Crowe and Cavalcaselle.

are of considerable size, and in the rainy season become deep and too often destructive torrents. The east coast of the island, exposed to the full sweep of the Atlantic, is a succession of inlets, headlands, islands, and rocks; the south coast is much more regular, but bold and steep; and the west alone presents, in the bay of Fort de France, a stretch of mangrove swamp. Of the total area, about 83,990 acres are under cultivation, 83,843 occupied by forest and savanna, and 68,837 by fallow. On an average, according to the returns for 1874-78 inclusive, 47,440 acres are devoted to the sugar crop, 1290 to coffee, 640 to cotton, and 1660 to cocoa. The mean annual temperature is 81° in the coast region,—the monthly mean for June being 83°, and that of January 77°. Of the annual rainfall of 87 inches, August has the heaviest share (11·3 inches), though the rainy season extends from June to October; March, the lowest, has 3·7. Martinique enjoys a remarkable immunity from hurricanes; half a century may pass without serious disaster from such a visitation. In 1878 there were 162,861 inhabitants (77,782 males, 85,079 females) in the island, which is thus nearly as densely peopled as Belgium. Since 1848 the increase amounts to about 42,800. Of the twenty-five communes, fourteen have more than 5000 inhabitants; the largest are Saint Pierre (23,909), Fort de France (15,414), Lamentin (13,409), and François (10,297). The great mass of the population consists of Creole negroes and half-castes of various grades, ranging from the "Saccatra," who has hardly retained any trace of Caucasian blood, to the so-called "Sangmêlé," with his mere suspicion of negro commixture. Marriage is frequently ignored, and of the births no less than 66 per cent. are illegitimate.

Fort de France, the chief town, a place of about 11,000 inhabitants, stands on a bay on the west coast. Since the earthquake of 1839 nearly all the houses are of wood, and have only one story; the streets are laid out with great regularity. An abundant supply of water was introduced in 1856. St Pierre, the commercial centre of the island, with about 20,000 inhabitants, lies farther north on the same coast. It consists of a lower and an upper town,—the one close and unhealthy, and the other for the most part well-ventilated and pleasant.

Martinique, also called Madiana or Mantinino, was discovered by Columbus 15th June 1502. It was at that time inhabited by Caribs (Galibis) who had expelled or incorporated an older stock. In 1635 a Norman captain, D'Enambuc, from St Christopher's, took possession of the island, and in 1637 his nephew Duparquet became captain-general of the colony, now numbering seven hundred men. In 1654 welcome was given to three hundred Jews expelled from Brazil, and by 1658 there were at least five thousand people exclusive of the Caribs, who were soon after exterminated. Purchased by the French Government from Duparquet's children for 120,000 livres, Martinique was assigned to the West India Company, but in 1674 it became part of the royal domain. The *habitants* (French landholders) at first devoted themselves to the cultivation of cotton and tobacco; but in 1650 sugar plantations were commenced, and in 1726 the coffee plant was introduced by Desclieux, who, when water ran short during his voyage to the island, shared his scanty allowance with his seedlings. Slave labour having been introduced, there were 72,000 blacks in the island by 1736. Martinique has several times been occupied by the English. Captured by Rodney in 1762, it was next year restored to the French; but after the conquest by Sir John Jervis and Sir Charles Grey in 1794 it was retained for eight years; and, seized again in 1809, it was not surrendered till 1814.

See Renouard, *Stat. de la Martinique*, 1822; Sidney Daney, *Hist. de la Martinique*, 1846; E. Rufz, *Études hist. et stat. sur la population de la Martinique*; Pardon, *La Martinique*, 1877; H. Rey, *Étude sur la col. de la Martinique*, 1881.

MARTINSBURG, a town of the United States, the capital of Berkeley county, West Virginia, lies on a plateau above the Tuscarora Creek, in the Shenandoah valley, 80 miles west of Washington. A station on the Baltimore and Ohio Railroad, and a terminus of the Cumberland Valley Railway, Martinsburg is the seat of extensive machine-shops belonging to the former company, which were sacked by the Confederates in 1861. The population, 4863 in 1870, was 6335 in 1880.

MARTIUS, Carl Friedrich Philipp von (1794–1868), a well-known German botanist and traveller in Brazil. He studied in the university of Erlangen, and on graduating M.D. in 1814 published as his thesis a critical catalogue of plants in the botanic garden of the university. He afterwards devoted himself to botanical study, and in 1817 he and Spix were sent to Brazil by the king of Bavaria. They travelled from Rio Janeiro through several of the southern and eastern provinces of Brazil, and ascended the river Amazon to Tabatinga, as well as some of its larger affluents. In 1820 they returned to Europe with rich collections of plants and animals, as also with stores of information on the geography, ethnology, and products of Brazil. In 1820 he was appointed conservator of the botanic garden at Munich, and in 1826 professor of botany in the university there, and held both offices till 1854, when he resigned them.

While a student Martius had published papers in various scientific periodicals, and he continued to do so during his whole life. After his return from Brazil he devoted his chief attention to the flora of that country, and in addition to numerous short papers he published the *Nova Genera et Species Plantarum Brasiliensium* (1823–32, 3 vols.) and *Icones selectæ Plantarum Cryptogamicarum Brasiliensium* (1827), both works being finely illustrated. An account of his travels in Brazil appeared in 3 vols. 4to, 1823–31, with an atlas of plates, and is regarded as one of the most valuable works of travel of the present century. Probably the work by which he is best known is his *Historia Palmarum* (1823–50) in 3 large folio volumes, of which one describes the palms discovered by himself in Brazil. In 1840 he began the *Flora Brasiliensis* with the assistance of the most distinguished European botanists, who undertook monographs of the various orders. Latterly Dr Eichler was associated with him in the editorship of this work, which is still going on, though over eighty parts have appeared. He also edited several works on the zoological collections made in Brazil by Spix, after the death of the latter in 1826. On the outbreak of potato disease in Europe he investigated the state of the diseased plants, and in 1842 published his observations. He also published independent works and short papers on the aborigines of Brazil, on their civil and social condition, on their past and probable future, on their diseases and medicines, and on the languages of the various tribes, especially the Tupi.

MARTOS, a town of Spain, in the province of Jaen, is situated on the slope of a steep hill, which is surmounted by a ruined castle, 16 miles west-south-west of Jaen. The streets are steep, narrow, crooked, and ill-paved; the public buildings are of the usual order, and present no feature calling for special remark. The surrounding district is specially productive of oil, and in the neighbourhood of the town are two sulphurous springs much resorted to in cases of cutaneous disease. Population in 1877, 14,654.

Martos perhaps stands on or near the site of the *Tucci* of Ptolemy. By Ferdinand III. it was taken from the Moors in 1225, and given to the knights of Calatrava; it was there that the brothers Carvajal, commanders of the order, were in 1410 executed by command of Ferdinand IV. after he had been "summoned" by them to a meeting at the Divine judgment seat. O'Donnell here gained a victory over the royalist troops in 1854.

MARTYN, Henry (1781–1812), a celebrated missionary, was born on February 18, 1781, at Truro, Cornwall. He came of a mining family, and his father John Martyn was a "captain" or mine-agent at Gwennap. He received his education at the grammar school of his native town under the famous Dr Cardew, entered St John's College, Cambridge, in the autumn of 1797, and in 1801, a month before he was twenty years old, was declared senior wrangler, obtaining soon after the first Smith's prize. In the following year he was chosen a fellow of his college. In the autumn of 1801 he was introduced to Charles Simeon, whose ardent disciple he soon became. It was his intention to devote himself to the bar, but in the October term of 1802 he chanced to hear Simeon speaking of the vast amount of good done in India by a single missionary, William Carey; some time afterwards he read the life of the devoted David Brainerd, the enthusiastic apostle of the Indians of North America, and, "filled with a holy emulation," resolved to devote his energies to the work of a Christian missionary. On October 22, 1803, he was ordained deacon at Ely, and afterwards priest, and served as Simeon's curate at the church of Holy Trinity, taking charge of the neighbouring parish of Lolworth. Still full of the thought of working in heathen lands, he designed to volunteer for the Church Missionary Society, but a sudden disaster in Cornwall deprived him and his unmarried sister of all the provision their father had made for them, and rendered it necessary that he should obtain a salary that would support her as well as himself. He accordingly applied for, and obtained, a chaplaincy under the East India Company. He left for India on July 5, 1805.

For some months he was chiefly located at Aldeen, near Serampore; in October 1806 he proceeded to Dinapore, where he laboured for a time amongst the Europeans, and soon found himself able to conduct divine worship among the natives in their own vernacular language, and to establish schools for their instruction. At the end of April 1809 he was ordered up to Cawnpore, where he made his first attempt to preach to the heathen in his own compound, and had to endure frequent interruptions "amidst groans, hissings, curses, blasphemies, and threatenings"; nevertheless he pursued his work among the hundreds who crowded round him, consoling himself that, if he should never see a native convert, God "might design by his patience and continuance in the work to encourage other missionaries." Meanwhile the great business of his life was being diligently carried on. Day after day he occupied himself with learning new languages, and had already, during his residence at Dinapore, been engaged in revising the sheets of his Hindustani version of the New Testament. He now translated the whole of the New Testament into Hindi also, and into Persian twice over. He translated the Psalms into Persian, the Gospels into Judæo-Persic, and the prayer book into Hindustani, in spite of the constant interruptions caused by excessive weakness of body, and "the pride, pedantry, and fury of his chief moonshee Sabat." Ordered by the doctors to take a sea voyage for his health, he got leave to go to Persia and correct his Persian New Testament, whence he made up his mind to go on to Arabia, and there compose an Arabic version. Accordingly, on October 1, 1810, having seen his work at Cawnpore crowned, on the previous day, by the opening of a church, he left for Calcutta, whence he departed on January 7, 1811, for Bombay, which he reached on his thirtieth birthday. From Bombay he set out for Bushire, bearing letters from Malcolm to men of position there, as also at Shiraz and Ispahan. After a killing journey from the coast he reached Shiraz, and was soon plunged into discussion with the disputants of all classes, "Sufi, Mohammedan, Jew, and Jewish-Mohammedan, even Armenian, all anxious to test their powers of argument with the first English priest who had visited them." Having made an unsuccessful journey to Tebriz to present the shah with his translation of the New Testament, he was seized with a fever, which so thoroughly prostrated his energies that, after a temporary recovery, he found it necessary to seek a change of climate. On September 12, 1812, he started with two Armenian servants, crossed the Araxes, rode from Tebriz to Erivan, from Erivan to Kars, from Kars to Erzeroum, from Erzeroum to Chiflik, urged on from place to place by his cruel Tartar guide, and, though the plague was raging at Tokat, he was compelled to stop there from utter prostration caused by fever. On the 6th of October he died, either from the plague or from the weakness of the disorders which harassed him from day to day.

By his valuable labours as a translator Martyn had placed portions of the Scriptures within the reach of all who could read over one-fourth of the habitable globe, and during his brief life he earned for himself a foremost place among modern missionaries. Macaulay's lines, written in 1818, testify to the impression made by his enthusiastic career of self-devotion.

See Sargent, *Memoir of the Rev. Henry Martyn, B.D.*, 1819; Wilberforce, *Journals and Letters of the Rev. Henry Martyn*, 1837; Kaye, *Christianity in India*, 1859; Yonge, *Pioneers and Founders*, 1874; and *The Church Quarterly* for October 1881.

MARTYROLOGY, a catalogue or list of martyrs, arranged according to the succession of their anniversaries, and sometimes including an account of their lives and sufferings. The corresponding word in the Greek Church is *Menologion* or *Analogion*; from the *Menologia* the *Synaxaria* are compiled. The custom of paying honour to the memory of those who had "witnessed the good confession" in perilous times established itself very early in the Christian church, and one particular manner of commemoration was formally recognized by at least one ecclesiastical synod before the end of the 4th century; in the 47th canon of the third synod of Carthage (397 A.D.) it is decreed "liceat legi Passiones Martyrum quum anniversarii eorum dies celebrantur." Apart from the still extant *Depositio Martyrum* contained in the work of the chronographer of 354, edited in 1850 by Mommsen, the oldest "martyrologies" of which anything is known are the ἀρχαίων μαρτυρίων συναγωγή, or collection of records of past persecutions, to which Eusebius more than once alludes as having been made by himself, and the treatise *On the Martyrs of Palestine*, by the same author, the full text of which has been preserved in an ancient Syriac version edited by Cureton. Next to the general martyrology of Eusebius, in chronological order, it has been usual to place the calendar of saints' days referred to in a letter, attributed to Jerome, which purports to be written in answer to bishops Chromatius and Heliodorus, who had asked him to search the archives of Eusebius with the view of enabling them to observe the saints' days with more regularity. This epistle is now admitted to be spurious; ultimately, however, a so-called *Martyrologium Hieronymianum* came into existence, but it is not so much a single martyrology as a rude patchwork derived from many ancient church calendars. In its present form it is a meagre list of names and places, but may be said to lie at the foundation of all subsequent Western calendars. Almost contemporary with its last recension is what is known as the *Parvum Martyrologium Romanum*, found by Ado of Vienne about 850; in it many of the dates are changed, and for the first time days are assigned to the chief characters of Scripture. To nearly the same date must be assigned the independent compilation of Bede, which has reached us, however, only as enlarged by subsequent editors. The 9th century was very fertile in martyrologies, among which may be mentioned that of Florus, subdeacon of Lyons (*c.* 830), who was the first editor of Bede, that of Hrabanus Maurus, an attempted further improvement on Bede and Florus, that of Ado, an enlargement of Florus, but based on the *Parvum Martyrologium Romanum*, that of Usuard of Paris, the epitomizer of Ado, and that of Notker of St Gall, based on Ado and Hrabanus. The *Martyrologium Romanum* was published by Baronius at the command of Pope Gregory XIII. in 1586; the enlarged edition by Rosweyd appeared at Antwerp in 1613. The Cistercian *Martyrology* appeared at Rome in 1733 and 1748. The best-known Greek *Menologion* is that prepared in the 9th century by command of the emperor Basilius Macedo; it was edited in 1727 by Cardinal Hannibal Urbini. An ancient Syriac martyrology, entitled "the names of our lords the martyrs and victors, with their days on which they won crowns," written in 412, has been edited, with an English translation, by Professor W. Wright, in the *Journal of Sacred*

Literature (1866). See *Catal. Syr. MSS. Br. Mus.*, ii. 632.

MARULLUS, Michael Tarchaniota (*ob.* 1500), one of the most brilliant scholars of the golden age of Florentine learning, was born at Constantinople, and at an early age, on the fall of his native city, was brought to Ancona in Italy, where he became the friend and pupil of Pontanus, with whom his name is associated by Ariosto (*Orl. Fur.*, xxxvii. 8). He was a soldier and a poet, and in the latter capacity published epigiams and *hymni naturales.*[1] Marullus took no part in the work of translation, then so favourite an exercise of scholars, but he was understood to be planning some great work when he perished, 10th April 1500, in the river Cecina near Volterra. Of other incidents in his life his feud with Politian and his marriage to the beautiful and learned Alexandra Scala, whom he praises in his poems, may be noticed. The name of Marullus is now perhaps most familiar from the brilliant emendations on Lucretius which he left unpublished, and which were used for the Juntine edition. See especially Munro's *Lucretius*, 2d ed., p. 6 *sq.*

MARUM (in Dutch Marwm), Martin Van (1750–1837), a distinguished Dutch man of science, born at Delft. Though his fame rests chiefly on his electrical researches, he took a prominent position in many departments of natural science. He graduated at Groningen in medicine and philosophy, and his numerous papers take up subjects connected with botany, chemistry, hygiene, natural history, and technology, as well as with his more special department, natural philosophy. In early life his father, who was a skilled mathematician, gave him a thorough training in the one really indispensable science. After his doctorate he for some time attached himself to the celebrated botanist Camper. He then commenced medical practice in Haarlem, but seems to have been too busy with original work to pay proper attention to his numerous patients. He devoted himself mainly to lecturing on physical subjects; and, after a brief interval, his extensive knowledge and methodical habits led to his being made secretary of the scientific society of his adopted city. For this post he was specially fitted; and, under his active guidance, the society was advanced to the position of one of the most noted in Europe. He soon became professor of physics, and was entrusted with the care of the celebrated Teyler collection (now the Musée Teyler). He caused to be constructed for this, by Cuthbertson, the gigantic electrical machine which, for a long period, was the most powerful in the world. He also effected great improvements in air-pumps and other pneumatic machines. Though his name is not associated with any discovery of the very first order, the number and variety of his researches (especially in connection with electricity) are remarkable. So also is the practical mode in which he regarded his results, always when at all possible from the technological point of view. The work by which he is best known is his *Treatise on Electricity* (Groningen, 1776), in which all that had then been discovered in that science was carefully methodized. Van Marum was a man of quiet but active disposition, and of simple habits and tastes, which probably conduced in no small measure to the extreme length and usefulness of his life.

MARUTSE-MABUNDA, a kingdom in South Africa, stretching from 18° to 14° 25′ S. lat. and from about 22° to 28° 25′ E. long., with an area estimated at 123,590 square miles. It all belongs to the basin of the Zambesi, and by far the greater proportion lies to the north of that river, which forms its south-eastern boundary from the mouth of the Linyanti to the mouth of the Kafue, a distance of about 350 miles. The kingdom thus includes the main part of the territory formerly subject to the Makololo empire, which broke up on the death of Sekeletu in 1864. Of country and people Dr Holub gives a very favourable report. Abundance of water, a fertile soil, and a genial climate render easy the work both of husbandry and cattle-breeding. The chief crop is Kaffre corn, red and white; the hemp-like kleen-korn or *rosa*, maize, water-melons, sugar-cane, ground-nuts, two kinds of beans, and *manza* are also cultivated. "September and October are the usual months for sowing; but gourds, leguminous plants, and tobacco are sown any time up to December, the growth of the two latter crops being so rapid that they often ripen by January, whilst Kaffre corn and maize are ready by February." Upwards of fifty kinds of wild fruit are used by the people as food. Salt has to be imported, and is consequently within the reach only of the wealthier classes. Besides the two great tribes which give their name to the kingdom, there are a large number of vassal tribes of numerical importance—Masupias, Matongas, Makalakas—all considered in the light of slaves by the rulers. The prevailing language is the Sesuto of the nearly extirpated Makololos. See Holub, *Seven Years in South Africa*, 1881.

MARVELL, Andrew (1621–1678), was born on March 31, 1621, at the parsonage of Winestead in Holderness. He was educated at Hull grammar school by his father, who had obtained high position in that town, until his admission to Trinity College, Cambridge, on December 14, 1633. There he became ensnared by the Jesuits, who at that time were keen to secure youths of promise at the universities, and by them, probably in the beginning of 1638, was taken to London; but he was recaptured by his father, and again received into Trinity on April 13 of the same year. He appears to have contributed to the *Musa Cantabrigiensis* in 1637; and beyond this nothing is known or even conjectured as to his college career. In 1640 his father was drowned under remarkable circumstances, an event which appears to have entirely unsettled him, for by an entry in the College Conclusion book, dated September 24, 1641, we find that he was adjudged by the seniority to have forfeited the benefits of the college. He used his liberty during the next four years to travel through the Continent, remaining abroad until 1646. It has been assumed that during this journey Marvell became acquainted with Milton, but a comparison of dates shows that this is an error. His first employment was in 1650, as tutor to Lord Fairfax's daughter. During his stay at Nunappleton were written the *Poems of the Country* and some of the *Poems of Imagination and Love.* In 1652 he was in communication with Milton, to whom he had probably been introduced by Fairfax, and was by him sent on February 21 to President Bradshaw with a letter urging his appointment as assistant Latin secretary to himself. The post was, however, otherwise filled up, and he was provided instead with another tutorship, that of Cromwell's nephew, Mr Dutton. This has been wrongly stated by several writers as not occurring until six years later. In 1657 the secretaryship again fell vacant, and was then conferred upon him, but he held office for a year only, and no record of his work appears in the calendar of state papers. Marvell accepted the Commonwealth as a practical fact, and the rule of Cromwell as the only guarantee for government at once tolerant and strong. But he never lost his belief in the monarchical theory. His line "'Tis godlike good to save a falling king" is well known; and throughout his most vehement invective against corruption there is a great tenderness and desire to spare the king.

[1] Two books of epigrams appeared first without date; an enlarged edition, with two additional books, published in 1497, contains also the so-called hymns.

The assistant secretaryship opened the way to public life, and in 1658 Marvell was elected member for Kingston-upon-Hull in Richard Cromwell's parliament. From 1663 to 1665 he acted as secretary to Lord Carlisle's embassy to Muscovy, Sweden, and Denmark; and this is the only official post he ever filled during the reign of Charles. With the exception of this and of shorter unexplained intervals of travel, Marvell was constant in his parliamentary attendance to the day of his death. He seldom spoke in the House, some five or six times in all, but his parliamentary influence is amply established by other evidence; and his correspondence with his constituents, from 1660 to 1678, forms a source of information all the more valuable because by a resolution passed at the Restoration the publication of the proceedings of the House without leave was forbidden. He made it a point of duty to write at each post—that is, every two or three days—both on local interests and on all matters of public interest. The discreet reserve of these letters, natural at a time when the post-office was a favourite source of information to the Government, contrasts curiously with the freedom of the few private letters which state opinions as well as facts. Marvell's constituents, in their turn, were not unmindful of their member. He makes frequent references to their presents, usually of Hull ale and of salmon, and he regularly drew from them the wages of a member, six and eightpence a day during session.

During these years Marvell wrote a good deal of verse, chiefly satire, often very coarse, but always vigorous and full of an honest hatred at corruption. He chose verse merely as being the usual vehicle of satire, and cared little about form. "He plucked a cudgell from the nearest hedgerow, careless if it became fuel after it had served his turn." It was very different with his prose satires. His peculiar talent was first displayed in the mock *King's Speech*, issued in 1675. This is written in a vein of genial banter, perhaps the greatest tribute to the influence which the bonhomie of Charles exercised even over such men as Marvell. But his tone soon changed, and *The Growth of Popery and Arbitrary Power*, published in the year of his death, is a grave indictment of the conduct of ministers of the crown, and, by implication, of Charles himself, since the Restoration. So shrewdly did this strike the conscience of the king that a proclamation, of which Marvell takes laughing notice, offered a large reward for the discovery of the author.

As a political pamphleteer Marvell holds a high place; as a satirist he stands still higher. Tolerance in religion was his creed, and this creed had been lately attacked by a clergyman seeking promotion, Dr Parker, afterwards bishop of Oxford, who asserted in their most extravagant form the claims of the civil magistrate over the consciences of subjects in matters of external religion. Marvell's reply, *The Rehearsal Transprosed*, is a masterpiece of prolonged banter. It contains passages of lofty indignation, hearty laughter, coarse vituperation; but the prevailing tone is that of grave and ironical banter. The effect, as witnessed to by Anthony Wood, Burnet, and other contemporary writers, was to set the whole public "from the king to the tradesman" in a laugh against Parker. This stung him to an ill-tempered rejoinder, affording Marvell a second opportunity, of which he availed himself so well that no more was heard from his opponent; and Swift was shortly afterwards able to say that people remembered Parker's book only by Marvell's answer. Marvell's second controversial work, *Mr Smirke, or the Divine in Mode*, was written in the same strain and under similar circumstances, and obtained a success fully equal to that of the *Rehearsal Transprosed*. It was a defence of Croft, bishop of Hereford, against a violent attack by Dr Turner, the High Church master of St John's, Cambridge. Prefixed to it was a "short historical essay concerning general councils," intended to show the folly of religious impositions. Several other writings, often ascribed to him, more especially the *Parliamenti Angliæ Declaratio*, *A Sensible Question and an Usefull Answer*, and the *Flagellum Parliamentarium*, were certainly not his.

As a humorist, then, and as a great "parliament man," no name is of more interest to a student of the reign of Charles II. than that of Marvell. But other qualities entitle him to still higher respect. To a personal charm so great, to wit so brilliant, to learning so extensive, and to sympathies so wide that he was at the same time dear to John Milton and courted by Charles II., he joined the rarest quality of that evil time, a robust and intrepid rectitude. In the very heyday of political infamy, at a time when he says passionately "we are all venal cowards except some few," and when opposition to the court was likely to be resented by personal violence of the brutalest kind, he, a needy man, obliged to accept wages from his constituents, tempted in winning phrases from royal lips by his old schoolfellow Danby, and with nothing to gain from the court by purity, kept his political virtue unspotted and unsuspected. The meaning of this fact can barely be felt by any one who has not read with minute care the annals of that time. When the grossest forms of self-indulgence were the ordinary habits of town life, Marvell was a temperate man, in spite of Aubrey's witness that he "kept bottles of wine at his lodgings and would drink liberally by himself to refresh his spirits and exalt his muse." Lastly, in the worst times of parliamentary violence, he stood forward throughout his career as the champion of moderate and tolerant measures. His person corresponded singularly with his mind, so far as can be judged from the portrait by Hannemann and from the few words of John Aubrey—"He was of a middling stature, pretty strong set, roundish faced, cherry cheeked, hazel eyed, brown haired. In his conversation he was modest and of very few words."

He died suddenly in 1678 on his return from Hull to take his seat in August. That he was poisoned, and at the instigation of the court, has been roundly asserted, naturally enough, though without the slightest foundation. The matter has been finally set at rest by a very interesting letter by Dr Samuel Gee in the *Athenæum* for March 7, 1874.

The following works may be consulted on Marvell:—*Life and Works*—(1) by Thomas Cooke, 2 vols., 1726 (there is a reprint by Thomas Davies in 1772); (2) by Captain Thomson, 3 vols. 4to, 1776; (3) by John Dove, 1832; (4) by Edwin Paxton Hood, 1853; and essays by Hartley Coleridge in *Lives of the Northern Worthies*, Henry Rogers in his collected *Essays*, and an anonymous author in the *Cornhill Magazine* for July 1869, and in the *Saturday Review* for April 26, 1873. All these authorities are mentioned, collated, and corrected in the very important and laborious work of Mr Grosart, whose book, in spite of its excessive mannerism and one or two curious inaccuracies, is indispensable to the student of Marvell's correspondence and career. (O. A.)

MARWAR. See JODHPUR.

MARY[1] (Μαρία, Μαριάμ), the mother of Jesus, at the time when the gospel history begins, had her home in

[1] The name (Heb. מִרְיָם), that of the sister of Moses and Aaron, is of uncertain etymology; many interpretations have been suggested, including "stella maris," which, though it has attained considerable currency through Jerome (the *Onomasticon*), may be at once dismissed. It seems to have been very common among the Jews in New Testament times; besides the subject of the present notice there are mentioned (1) "Mary (the wife) of Clopas," who was perhaps the mother of James "the little" (ὁ μικρός) and of Joses (see vol. xiii. pp. 552, 553); (2) Mary Magdalene, *i.e.*, of Magdala; (3) Mary of Bethany, sister of Martha and Lazarus; (4) Mary the mother of Mark (see MARK); and (5) Mary, an otherwise unknown benefactress of the apostle Paul (Rom. xvi. 6).

Galilee, at the village of Nazareth. Of her parentage nothing is recorded in any extant historical document of the 1st century, for the genealogy in Luke iii. (*cf.* i. 27) is manifestly that of Joseph. In early life she became the wife of JOSEPH (*q.v.*) and also the mother of our Lord (see JESUS[1]); that she afterwards had other children is a natural inference from Matt. i. 25, which the evangelists, who frequently allude to "the brethren of the Lord," are at no pains to obviate. The few incidents mentioned in Scripture regarding her show that she followed our Lord to the very close of His earthly career with unfailing motherliness, but the "Magnificat" assigned to her in Luke i. is the only passage which would distinctly imply on her part a high prophetic appreciation of His divine mission. She was present at the crucifixion, where she was commended by Jesus to the care of the apostle John, (John xix. 26, 27), Joseph having apparently died before this time. (It would be idle to inquire why "the brethren of the Lord," who, whatever their relationship to Mary, must at least have been nearer than John, were ignored in this arrangement.) Mary is mentioned in Acts i. 14 as having been among those who continued in prayer along with the apostles at Jerusalem during the interval between the ascension and pentecost. There is no allusion in the New Testament to the time or place of her death.

The subsequent growth of ecclesiastical tradition and belief regarding Mary will be traced most conveniently under the separate heads of (1) her perpetual virginity, (2) her absolute sinlessness, (3) her peculiar relation to the Godhead, which specially fits her for successful intercession on behalf of mankind.

Her Perpetual Virginity.—This doctrine, as has already been pointed out, was, to say the least, of no importance in the eyes of the evangelists, and so far as extant writings go there is no evidence of its having been anywhere taught within the pale of the catholic church of the first three centuries. On the contrary, to Tertullian the fact of Mary's marriage after the birth of Christ is a useful argument for the reality of the Incarnation against Gnostic notions, and Origen relies upon the references to the Lord's brethren as disproving the Docetism with which he had to contend. The ἀειπαρθενία, though very ancient, is in reality a doctrine of non-catholic origin, and first occurs in a work proscribed by the earliest papal *Index Librorum Prohibitorum* (attributed to Gelasius) as heretical,—the so-called *Protevangelium Jacobi*, written, it is generally admitted, within the 2d century. According to this very early source, which seems to have formed the basis of the later *Liber de Infantia Mariæ et Christi Salvatoris* and *Evangelium de Nativitate Mariæ*, the name of Mary's father was Joachim (in the *Liber de Infantia* a shepherd of the tribe of Judah, living in Jerusalem); he had long been married to Anna her mother, whose continued childlessness had become a cause of much humiliation and sorrow to them both. The birth of a daughter was at last angelically predicted to each parent separately. From her third to her twelfth year "Mary was in the temple as if she were a dove that dwelt there, and she received food from the hand of an angel." When she became of nubile age a guardian was sought for her by the priests among the widowers of Israel "lest she should defile the sanctuary of the Lord"; and Joseph, an elderly man with a family, was indicated for this charge by a miraculous token. Some time afterwards the annunciation took place; when the Virgin's pregnancy was discovered, Joseph and she were brought before the high priest, and, though asserting their innocence in all sincerity, were acquitted only after they had been tried with "the water of the ordeal of the Lord" (Numb. v. 11). Numerous details regarding the birth at Bethlehem are then given. The perpetual physical virginity of Mary, naively insisted upon in this apocryphon, is alluded to only with a half belief and a "some say" by Clement of Alexandria (*Strom.*, vii. 16), but became of much importance to the leaders of the church in the 4th century, as for example to Ambrose, who sees in Ezek. xliv. 1–3 a prophetic indication of so great a mystery.[2] Those who continued to believe that Mary, after the miraculous birth of Jesus, had become the mother of other children by Joseph came accordingly to be spoken of as her enemies,—Antidicomarianitæ (Epiphanius) or Antidicomaritæ (Augustine),—and the first-mentioned author devotes a whole chapter (chap. 78) of his great work upon heresies to their confutation. For holding the same view Bonosus of Sardica was condemned by the synod of Capua in 391. To Jerome the perpetual virginity not only of Mary but even of Joseph appeared of so much consequence that while a young man he wrote (387) the long and vehement tract *Against Helvidius*, in which he was the first to broach the theory (which has since gained wide currency) that the brethren of our Lord were children neither of Mary by her husband, nor of Joseph by a former marriage, but of another Mary, sister to the Virgin and wife of Clopas or Alphæus. At last the epithet of ἀεὶ παρθένος was authoritatively applied to the Virgin by the council of Chalcedon in 451, and the doctrine implied has ever since been an undisputed point of orthodoxy both in the Eastern and in the Western church, some even seeking to hold the Anglican Church committed to it on account of the general declaration (in the *Homilies*) of concurrence in the decisions of the first four general councils.

Her Absolute Sinlessness.—While much of the apocryphal literature of the early sects in which she is repeatedly spoken of as "undefiled before God" would seem to encourage some such doctrine as this, many passages from the acknowledged fathers of the church could be cited to show that it was originally quite unknown to catholicism. Even Augustine repeatedly asserts that she was born in original sin (*De Gen. ad lit.*, x. 18); and the *locus classicus* regarding her possible immunity from actual transgression, on which the subsequent doctrine of Lombardus and his commentators was based, is simply an extremely guarded passage (*De Nat. et Grat.*, chap. 36) in which, while contradicting the assertion of Pelagius that many had lived free from sin, he wishes exception to be made in favour of "the holy Virgin Mary, of whom out of honour to the Lord I wish no question to be made where sins are treated of,—for how do we know what mode of grace wholly to conquer sin may have been bestowed upon her who was found meet to conceive and bear Him of whom it is certain that He had no sin." A writer so late as Anselm (*Cur Deus Homo*, ii. 16) declares that "the Virgin herself whence He (Christ) was assumed was conceived in iniquity, and in sin did her mother conceive her, and with original sin was she born, because she too sinned in Adam in whom all sinned," and the same view was expressed by Damian. The growth of the modern Roman doctrine of the immaculate conception from the time in the 12th century when the canons of Lyons sought to institute a festival in honour of her "holy conception," and were remonstrated with by Bernard, has been already sketched elsewhere (see IMMACULATE CONCEPTION).

[1] Vol. xiii. 656 *sq.*, where (p. 659) sufficient reference is made to the coarse view of this event taken by the later hostile Judaism (a view supposed by some to be alluded to even in John viii. 41). We learn from Origen that the story about the soldier Panthera (Πανθήρα) was already upheld by Celsus. The Ebionites and other heretical sects, as is well known, maintained the paternity of Joseph.

[2] *De Inst. Virg.*, "quæ est hæc porta nisi Maria? . . . per quam Christus intravit in hunc mundum, quando virginali fusus est partu et genitalia virginitatis claustra non solvit."

The epithets applied to her in the Greek Church are such as ἀμόλυντος, πάναγνος, ἁγία; but in the East generally no clear distinction is drawn between immunity from actual sin and original sinlessness.

Her Peculiar Relation to the Godhead, which specially fits her for Successful Intercession on Behalf of Mankind.—It seems probable that the epithet θεοτόκος ("Mother of God") was first applied to Mary by theologians of Alexandria towards the close of the 3d century; but it does not occur in any genuine extant writing of that period, unless we are to assign an early date to the apocryphal *Transitus Mariæ*, in which the word is of frequent occurrence. In the 4th century it is met with frequently, being used by Eusebius, Athanasius, Didymus, and Gregory of Nazianzus,—the latter declaring that the man who believes not Mary to have been θεοτόκος has no part in God (*Orat.*, li. p. 738).[1] If, as is not unlikely, its use was first recommended by a desire to bring into prominence the divinity of the Incarnate Word, there can be no doubt that latterly the expression came to be valued as directly honourable to Mary herself and as corresponding to the greatly increased esteem in which she personally was held throughout the catholic world, so that, when Nestorius and others began to dispute its propriety in the following century, their temerity was resented, not as an attack upon the established orthodox doctrine of the Nicene creed, but as threatening a more vulnerable and more tender part of the popular faith. It is sufficient in illustration of the drift of theological opinion to refer to the first sermon of Proclus, preached on a certain festival of the Virgin (πανήγυρις παρθενική) at Constantinople about the year 430 or to that of Cyril of Alexandria delivered in the church of the Virgin Mary at the opening of the council of Ephesus in 431. In the former the orator speaks of "the holy Virgin and Mother of God" as "the spotless treasure-house of virginity, the spiritual paradise of the second Adam; the workshop in which the two natures were welded together . . . . the one bridge between God and men";[2] in the latter she is saluted as the "mother and virgin," "through whom (δι' ἧς) the Trinity is glorified and worshipped, the cross of the Saviour exalted and honoured, through whom heaven triumphs, the angels are made glad, devils driven forth, the tempter overcome, and the fallen creature raised up even to heaven." The response which such language found in the popular heart was sufficiently shown by the shouts of joy with which the Ephesian mob heard of the deposition of Nestorius, escorting his judges with torches and incense to their homes, and celebrating the occasion by a general illumination. The causes which in the course of the preceding century had led to this exaltation of the Mother of God in the esteem of the catholic world are not far to seek. On the one hand the solution of the Arian controversy, however correct it may have been theoretically, undoubtedly had the practical effect of relegating the God-man redeemer for ordinary minds into a far away region of "remote and awful Godhead," so that the need for a mediator to deal with the very Mediator could not fail to be felt. On the other hand, it must be accepted as a fact abundantly proved by history that the religious instincts of mankind are very ready to pay worship, in grosser or more refined forms, to the idea of womanhood; at all events many of those who became professing Christians at the political fall of paganism entered the church with such instincts (derived from the nature-religions in which they had been brought up) very fully developed. Probably it ought to be added that the comparative colourlessness with which the character of Mary is presented not only in the canonical gospels but even in the most copious of the apocrypha left greater scope for the untrammelled exercise of devout imagination than was possible in the case of Christ, in the circumstances of whose humiliation and in whose recorded utterances there were many things which the religious consciousness found difficulty in understanding or in adapting itself to. At all events, from the time of the council of Ephesus, to exhibit figures of the Virgin and Child became the approved expression of orthodoxy, and the relationship of motherhood in which Mary had been formally declared to stand to God[3] was instinctively felt to give the fullest and freest sanction of the church to that invocation of her aid which had previously been resorted to only hesitatingly and occasionally. Previously to the council of Ephesus, indeed, the practice had obtained complete recognition, so far as we know, in those circles only in which one or other of the numerous redactions of the *Transitus Mariæ* passed current.[4] There we read of Mary's prayer to Christ: "Do Thou bestow Thine aid upon every man calling upon, or praying to, or naming the name of Thine handmaid"; to which His answer is, "Every soul that calls upon thy name shall not be ashamed, but shall find mercy and support and confidence both in the world that now is and in that which is to come in the presence of My Father in the heavens." But Gregory of Nazianzus also, in his panegyric upon Justina, mentions with incidental approval that in her hour of peril she "implored Mary the Virgin to come to the aid of a virgin in her danger."[5] Of the growth of the Marian cultus, alike in the East and in the West, after the decision at Ephesus it would be impossible to trace the history, however slightly, within the limits of the present article. Justinian in one of his laws bespeaks her advocacy for the empire, and he inscribes the high altar in the new church of St Sophia with her name. Narses looks to her for directions on the field of battle. Heraclius bears her image on his banner. John of Damascus speaks of her as the sovereign lady to whom the whole creation has been made subject by her son. Peter Damian recognizes her as the most exalted of all creatures, and apostrophizes her as deified and endowed with all power in heaven and in earth, yet not forgetful of our race.[6] In a word, popular devotion gradually developed the entire system of doctrine and practice which Protestant controversialists are accustomed to call by the name of Mariolatry. With reference to this much-disputed phrase it is always to be kept in mind that the directly authoritative documents,

[1] See Gieseler (*KG.*, Bd. i. Abth. 1), who points out instances in which anti-Arianizing zeal went so far as to call David θεοπάτωρ, and James ἀδελφόθεος.

[2] Labbé, *Conc.*, vol. iii. p. 51. Considerable extracts are given by Augusti (*Denkw.* iii.); see also Milman (*Lat. Christ.*, i. 185), who characterizes much of it as a "wild labyrinth of untranslatable metaphor."

[3] The term θεοτόκος does not actually occur in the canons of Ephesus. It is found, however, in the creed of Chalcedon.

[4] It is true that Irenæus (*Hær.*, v. 19, 1) in the passage in which he draws his well-known parallel and contrast between the first and second Eve (comp. Justin, *Dial. c. Tryph.*, 100), to the effect that, "as the human race fell into bondage to death by a virgin, so is it rescued by a virgin," takes occasion to speak of Mary as the "advocata" of Eve; but it seems certain that this word is a translation of the Greek συνήγορος, and implies hostility and rebuke rather than advocacy.

[5] It is probable that the commemorations and invocations of the Virgin which occur in the present texts of the ancient liturgies of "St James" and "St Mark" are due to interpolation. In this connexion ought also to be noted the chapter in Epiphanius (*Hær.*, 79) against the "Collyridians," certain women in Thrace, Scythia, and Arabia, who were in the habit of worshipping the Virgin (ἀεὶ παρθένον) as a goddess, the offering of a cake (κολλυρίδα τινα) being one of the features of their worship. He rebukes them for offering the worship which was due to the Trinity alone; "let Mary be held in honour, but by no means worshipped." The cultus was probably a relic of heathenism; compare Jerem. xliv. 19.

[6] "Numquid quia ita deificata, ideo nostræ humanitatis oblita es? Nequaquam, Domina. . . . Data est tibi omnis potestas in cœlo et in terra. Nil tibi impossibile." Serm. de Nativ. Mariæ, ap. Gieseler, *KG.*, Bd. ii. Abth. 1.

alike of the Greek and of the Roman Church, distinguish formally between "latria" and "dulia," and declare that the "worship" to be paid to the mother of God must never exceed that superlative degree of "dulia" which is vaguely described as "hyperdulia." On the other hand, it must be remembered that the comparative reserve shown by the council of Trent in its decrees, and even in its catechism,[1] on this subject has not been observed by individual theologians, and in view of the fact of the canonization of some of these (such as Liguori),—a fact guaranteeing the absence of erroneous teaching from their writings,—it does not seem unfair to hold the Roman Church responsible for the natural interpretations and just inferences which may be drawn even from apparently exaggerated expressions in such works as the well-known *Glories of Mary* and others frequently quoted in controversial literature. A good résumé of recent Catholic developments of the cultus of Mary is to be found in Pusey's *Eirenicon*.

The following are the principal feasts of the Virgin in the order in which they occur in the ecclesiastical year. (1) That of the Presentation (*Præsentatio B. V. M.*, τὰ εἰσόδια τῆς θεοτόκου), to commemorate the beginning of her stay in the temple, as recorded in the *Protevangelium Jacobi* (see above). It is believed to have originated in the East sometime in the 8th century, the earliest allusion to it being made by George of Nicomedia (9th century); Manuel Comnenus made it universal for the Eastern empire, and in the modern Greek Church it is one of the five great festivals in honour of the Deipara. It was introduced into the Western Church late in the 14th century, and, after having been withdrawn from the calendar by Pius V., was restored by Sixtus V., the day observed both in East and West being November 21. It is not mentioned in the English calendar. (2) The Feast of the Conception (*Conceptio B. V. M.*, *Conceptio Immaculata B. V. M.*, σύλληψις τῆς ἁγίας Ἄννης), observed by the Roman Catholic Church on December 8, and by all the Eastern churches on December 9, has already been explained (see IMMACULATE CONCEPTION); in the Greek Church it only ranks as one of the middle festivals of Mary. (3) The Feast of the Purification (*Occursus*, *Obviatio*, *Præsentatio*, *Festum SS. Simeonis et Annæ*, *Purificatio*, *Candelaria*, ὑπαπαντή, ὑπαντή) is otherwise known as CANDLEMAS (*q.v.*). (4) The Feast of the Annunciation of the Virgin Mary (*Annunciatio*, Εὐαγγελισμός); see ANNUNCIATION. It may be mentioned that at the Toledan council in 656 it was decreed that this festival should be observed on December 18, in order to keep clear of Lent. (5) The Feast of the Visitation (*Visitatio B. V. M.*) was instituted by Urban VI., promulgated in 1389 by Boniface IX., and reappointed by the council of Basel in 1441 in commemoration of the visit paid by Mary to Elizabeth. It is observed on July 2, and has been retained in the English calendar. (6) The Feast of the Assumption (*Dormitio*, *Pausatio*, *Transitus*, *Depositio*, *Migratio*, *Assumptio*, κοίμησις, μετάστασις, ἀνάληψις) has reference to the apocryphal story related in several forms in various documents of the 4th century condemned by Pope Gelasius. Their general purport is that as the time drew nigh for "the most blessed Virgin" (who is also spoken of as "Holy Mary," "the queen of all the saints," "the holy spotless Mother of God") to leave the world, the apostles were miraculously assembled round her deathbed at Bethlehem on the Lord's day, whereupon Christ descended with a multitude of angels and received her soul. After "the spotless and precious body" had been laid in the tomb, "suddenly there shone round them (the apostles) a miraculous light," and it was taken up into heaven. The first Catholic writer who relates this story is Gregory of Tours (*c.* 590); Epiphanius two centuries earlier had declared that nothing was known as to the circumstances of Mary's death and burial; and one of the documents of the council of Ephesus implies a belief that she was buried in that city. The Sleep of the Theotokos is observed in the Greek Church as a great festival on August 15; the Armenian Church also commemorates it, but the Ethiopic Church celebrates her death and burial on two separate days. The earliest allusion to the existence of such a festival in the Western Church seems to be that found in the proceedings of the synod of Salzburg in 800; it is also spoken of in the thirty-sixth canon of the reforming synod of Mainz, held in 813. It was not, however, at that time universal, being mentioned as doubtful in the capitularies of Charlemagne. It ought to be observed that the doctrine of the bodily assumption of the Virgin into heaven, although extensively believed, and indeed flowing as natural theological consequence from that of her sinlessness, has never been declared to be "de fide" by the Church of Rome, and is still merely a "pia sententia." (7) The Nativity of Mary (*Nativitas*, γενέθλιον τῆς θεοτόκου), observed on September 8, is first mentioned in one of the homilies of Andrew of Crete (*c.* 750), and along with the feasts of the Purification, the Annunciation, and the Assumption, it was appointed to be observed by the synod of Salzburg in 800, but seems to have been quite unknown at that time in the Gallican Church, and even two centuries later it was by no means general in Italy. In the Roman Church a large number of minor festivals in honour of the Virgin are locally celebrated; and all the Saturdays of the year as well as the entire month of May are also regarded as sacred to her. (J. S. BL.)

[1] The points taught in the catechism are—that she is truly the Mother of God, and the second Eve, by whose means we have received blessing and life; that she is the Mother of Pity, and very specially our advocate; that her merits are highly exalted, and that her dispositions towards us are extremely gracious; that her images are of the utmost utility. In the *Missal* her intercessions (though alluded to in the canon and elsewhere) are seldom directly appealed to except in the Litany and in some of the later offices such as those for September 8, and for the Festival of the Seven Sorrows (decreed by Benedict XIII. in 1727). Noteworthy are the versicles in the office for December 8 (The Feast of the Immaculate Conception), "Tota pulchra es, Maria, et macula originalis non est in te," and "Gloriosa dicta sunt de te, Maria, quia fecit tibi magna qui potens est."

MARY I., queen of England (1516–1558), unpleasantly remembered as "the Bloody Mary" on account of the religious persecutions sanctioned under her reign, was a woman whose private history demands no less compassion than her policy as queen (if indeed it was her own) merits the condemnation of a more humane and tolerant age. She was the daughter of Henry VIII. and Catherine of Aragon, born in the earlier years of their married life, when as yet no cloud had darkened the prospect of Henry's reign. Her birth occurred at Greenwich on Monday the 18th February 1516, and she was baptized on the following Wednesday, Cardinal Wolsey standing as her godfather. She seems to have been a singularly precocious child, and is reported in July 1520, when she was little more than four years of age, as entertaining some visitors by a performance on the virginals. When she was little over nine she was addressed in a complimentary Latin oration by commissioners sent over from Flanders on commercial matters, and replied to them in the same language "with as much assurance and facility as if she had been twelve years old" (Gayangos, iii. pt. 1, 82). Her father, against whom it cannot be said that he depreciated learning, had taken care to give her an excellent education, and was proud of her achievements. About the same time that she replied to the commissioners in Latin he was arranging that she should learn Spanish, Italian, and French. A great part, however, of the credit of her early education was undoubtedly due to her mother, who not only consulted the Spanish scholar Vives upon the subject, but was herself Mary's first teacher in Latin. She was also well instructed in music, and among her principal recreations as she grew up was that of playing on the virginals and lute.

It was a misfortune that she shared with many other high-born ladies in those days that her prospects of life were made a matter of sordid bargaining from the first. Political alliances to be cemented by marriages between persons who were at the time mere infants—or perhaps, more shameful still, between a child and a superannuated debauchee—are among the most repulsive features of the times. Mary was little more than two years old when she was proposed in marriage to the dauphin, son of Francis I. Three years afterwards the French alliance was broken off, and she was affianced to her cousin the young emperor Charles V. by the treaty of Windsor. No one, perhaps, seriously expected either of these arrangements to endure; and, though we read in grave state papers of some curious compliments and love tokens (really the mere counters of diplomacy) professedly sent by the girl of nine to the powerful cousin whom she had never seen, not many years passed away before Charles released himself from this engagement and made a more convenient match. In 1526 a rearrangement was made of the royal household, and it was thought right to give Mary an establishment of her own along with a council on the borders of Wales, for the better government of the Marches. For some years she accordingly kept her court at Ludlow, while new arrangements were made for the disposal of her hand in connexion with the latest turn in the tortuous game of diplomacy. She was now proposed as a wife, not for the dauphin as before, but for his father Francis I., who had just been redeemed from captivity at Madrid, and who was only too glad of an alliance with England to mitigate the severe conditions imposed on him by the emperor. Wolsey, however, on this occasion, only made use of the princess as a bait to enhance the terms of the compact, and left Francis free in the end to marry the emperor's sister.

It was during this negotiation, as Henry afterwards pretended, that the question was first raised whether Henry's own marriage with Catherine was a lawful one. The bishop of Tarbes, who was one of the ambassadors sent over by Francis to ask the princess in marriage, had, it was said, started an objection that she might possibly be considered illegitimate on account of her mother having been once the wife of her father's brother. The statement was a mere pretence to shield the king when the unpopularity of the divorce became apparent. It is not only extremely improbable in itself, but is proved to be untrue by the strongest evidence, for we have pretty full contemporary records of the whole negotiation. On the contrary, it is quite clear that Henry, who had already for some time conceived the project of a divorce, kept the matter a dead secret, and was particularly anxious that the French ambassadors should not know it, while he used his daughter's hand as a bait for a new alliance. The alliance itself, however, was actually concluded by a treaty dated Westminster, the 30th April 1527, in which it was provided, as regards the Princess Mary, that she should be married either to Francis himself or to his second son Henry, duke of Orleans. But the real object was only to lay the foundation of a perfect mutual understanding between the two kings, which Wolsey soon after went into France to confirm.

During the next nine years the life of Mary, as well as that of her mother, was rendered miserable by the conduct of Henry VIII. in seeking a divorce. During the most of that period mother and daughter seem to have been kept apart, and, though sometimes living at no great distance from each other, were strictly forbidden to see each other. Of the two it may be that Queen Catherine had the hardest trial; but Mary's was scarcely less severe. Removed from court and treated as a bastard, she was, on the birth of Anne Boleyn's daughter, required to give up the dignity of princess and acknowledge the illegitimacy of her own birth. On her refusal her household was broken up, and she was sent to Hatfield to act as lady-in-waiting to her own infant sister. Nor was even this the worst of her trials; her very life was in danger from the hatred of Anne Boleyn. Her health, moreover, was indifferent, and even when she was seriously ill, although Henry sent his own physician Dr Buttes to attend her, he declined to let her mother visit her. So also at her mother's death in January 1536 she was forbidden to take a last farewell of her. But in May following another change occurred which seemed to promise some kind of relief. Anne Boleyn, the real cause of all her miseries, fell under the king's displeasure and was put to death. Mary was then urged to make a humble submission to her father as the means of recovering his favour, and, after a good deal of correspondence with the king's secretary Cromwell, she actually did so. The terms exacted of her were bitter in the extreme, but there was no chance of making life tolerable otherwise, if indeed she was permitted to live at all; and the poor friendless girl, absolutely at the mercy of a father who could brook no contradiction, at length subscribed an act of submission, acknowledging the king as supreme, repudiating the pope's authority, and confessing that the marriage between her father and mother "was by God's law and man's law incestuous and unlawful."

No act, perhaps, in the whole of Henry's reign gives us a more painful idea of his revolting despotism. Mary was a high-spirited girl, and undoubtedly popular. All Europe looked upon her at that time as the only legitimate child of her father, but her father himself compelled her to disown the title and pass an unjust stigma on her own birth and her mother's good name. Nevertheless Henry was now reconciled to her, and gave her a household in some degree suitable to her rank. During the rest of the reign we hear little about her except in connexion with a number of new marriage projects taken up and abandoned successively, one of which, to the count palatine Philip, duke of Bavaria, was specially repugnant to her in the matter of religion. Her privy purse expenses for nearly the whole of this period have been published, and show that Hatfield, Beaulieu or Newhall in Essex, Richmond, and Hunsdon were among her principal places of residence. Although she was still treated as of illegitimate birth, it was believed that the king, having obtained from parliament the extraordinary power to dispose of the crown by will, would restore her to her place in the succession, and three years before his death she was so restored by statute, but still under conditions to be regulated by her father's will.

Under the reign of her brother Edward VI. she was again subjected to severe trials, which at one time made her seriously meditate taking flight and escaping abroad. Edward himself indeed seems to have been personally not unkind to her, but the religious revolution in his reign assumed proportions such as it had not done before, and Mary, who had done sufficient violence to her own convictions in submitting to a despotic father, was not disposed to yield an equally tame obedience to authority exercised by a factious council in the name of a younger brother not yet come to years of discretion. Besides, the cause of the pope was naturally her own. In spite of the forced declaration formerly wrung from herself, no one really regarded her as a bastard, and the full recognition of her rights depended on the recognition of the pope as head of the church. Hence, when Edward's parliament passed an Act of Uniformity enjoining services in English and communion in both kinds, the law appeared to her totally void of authority, and she insisted on having mass in her own private chapel under the old form. When ordered to desist, she appealed for protection to the emperor Charles V., who, being her cousin, intervened for some time not ineffectually, threatening war with England if her religious liberty was interfered with. But Edward's court was composed of factions of which the most violent eventually carried the day. Lord Seymour, the admiral, was attainted of treason and beheaded in 1549. His brother, the Protector Somerset, met with the same fate in 1552. Dudley, duke of Northumberland, then became paramount in the privy council, and easily obtained the sanction of the young king to those schemes for altering the succession which led immediately after his death to the usurpation of Lady Jane Grey. Dudley had, in fact, overawed all the rest of the privy council, and when the event occurred he took such energetic measures to give effect to the scheme that Lady Jane was actually recognized as queen for some days, and Mary had even to fly from Hoddesden into Norfolk. But the country was really devoted to her cause, as indeed her right in law was unquestionable, and before many days she was royally received in London, and took up her abode within the Tower.

Her first acts at the beginning of her reign displayed a character very different from that which she still holds in popular estimation. Her clemency towards those who had taken up arms against her was altogether remarkable. She released from prison Lady Jane's father, Suffolk, and had difficulty even in signing the warrant for the execution of Northumberland. Lady Jane herself she fully meant to spare, and did spare till after Wyatt's formidable insurrection. Her conduct, indeed, was in every respect conciliatory and pacific, and so far as they depended on her personal character the prospects of the new reign might have appeared altogether favourable. But unfortunately her position was one of peculiar difficulty, and the policy on which she determined was far from judicious. Inexperienced in the art of governing, she had no trusty councillor but Gardiner; every other member of the council had been more or less implicated in the conspiracy against her. And though she valued Gardiner's advice she was naturally led to rely even more on that of her cousin, the emperor, who had been her mother's friend in adversity, and had done such material service to herself in the preceding reign. Following the emperor's guidance she determined almost from the first to make his son Philip her husband, though she was eleven years his senior. She was also strongly desirous of restoring the old religion and wiping out the stigma of illegitimacy passed upon her birth, so that she might not seem to reign by virtue of a mere parliamentary settlement.

Each of these different objects was attended by difficulties or objections peculiar to itself; but the marriage was the most unpopular of all. A restoration of the old religion threatened to deprive the new owners of abbey lands of their easy and comfortable acquisitions; and it was only with an express reservation of their interests that the thing was actually accomplished. A declaration of her own legitimacy necessarily cast a slur on that of her sister Elizabeth, and cut her off from the succession. But the marriage promised to throw England into the arms of Spain and place the resources of the kingdom at the command of the emperor's son. The Commons sent her a deputation to entreat that she would not marry a foreigner, and when her resolution was known insurrections broke out in different parts of the country. Suffolk, whose first rebellion had been pardoned, proclaimed Lady Jane Grey again in Leicestershire, while young Wyatt raised the county of Kent and actually besieged the queen in her own palace at Westminster. In the midst of the danger Mary showed great intrepidity, and the rebellion was presently quelled; after which, unhappily, she got leave to pursue her own course unchecked. She married Philip, restored the old religion, and got Cardinal Pole to come over and absolve the kingdom for its past disobedience to the Holy See.

But the misgivings of those who had disliked the Spanish match were more than sufficiently justified by the course of events. Mary yielded a loyal and womanly devotion to a husband who did not too greatly esteem the treasure of her person. Her health, which was feeble before, was bad for the remainder of her days, and she fell under a delusion at first that it was owing to an approaching confinement. Disappointment and vexation probably added to her helplessness. The resources of the kingdom were at Philip's command, and he even took ships of the English fleet to escort his father the emperor, on his abdication, to Spain. More extraordinary still, he ultimately succeeded in committing England to a war against France, when France had made an alliance with the pope against him as king of Spain; so the very marriage which was to confirm England in the old religion led to a war against the occupant of the see of Rome. And it was this war with France which produced the final calamity of the loss of Calais which sank so deeply into Mary's heart some months before she died.

The cruel persecution of the Protestants, which has cast so much infamy upon her reign, began about six months after her marriage; and it is not difficult to see that it was greatly due to the triumph of ideas imported from the land of the Inquisition. Rogers, the first of the martyrs, was burnt on the 4th February 1555. Hooper, bishop of Gloucester, had been condemned six days before, and suffered the same fate upon the 9th. From this time the persecution went on uninterrupted for more than three years, numbering among its victims Ridley, Latimer, and Cranmer. It seems to have been most severe in the eastern and southern parts of England, and the largest number of sufferers was naturally in the diocese of Bonner, bishop of London. From first to last nearly three hundred victims are computed to have perished at the stake; and their fate certainly created a revulsion against Rome that nothing else was likely to have effected. How far Mary herself—who during the most part of this time, if not the whole time, was living in the strictest seclusion, sick in body and mind, hysterical and helpless—was personally answerable for these things, it is difficult to say. To her, no doubt, the propagators of heresy were the enemies of mankind, and she had little cause to love them from her own experience. Yet perhaps she hardly realized the full horror of what was done under her sanction. But there can be little doubt what effect it had upon the people; and when Mary breathed her last, on the 17th November 1558, the event was hailed with joy as a national deliverance. (J. GA.)

MARY II. (1662–1694), queen of England, was the eldest daughter of James, duke of York (afterwards James II. of England), by his first wife Anne Hyde, and was born in London on April 30, 1662. Having been educated in the Protestant faith, she was married to William, prince of Orange, on November 4, 1677. After the events of 1688 she followed her husband to England, and was proclaimed by the convention joint sovereign with him on February 13, 1689. She died of small-pox on December 28, 1694 (o.s.). See Burnet's *Essay upon the Life of Queen Mary*, and the article WILLIAM III.

MARY (1542–1587), queen of Scots, daughter of King James V. and his wife Mary of Lorraine, was born in December 1542, a few days before the death of her father, heart-broken by the disgrace of his arms at Solway Moss, where the disaffected nobles had declined to encounter an enemy of inferior force in the cause of a king whose systematic policy had been directed against the privileges of their order, and whose representative on the occasion was an unpopular favourite appointed general in defiance of their ill-will. On the 9th of September following the ceremony of coronation was duly performed upon the infant. A scheme for her betrothal to Edward, prince of Wales, was defeated by the grasping greed of his father, whose obvious ambition to annex the crown of Scotland at once to that of England aroused instantly the general suspicion and indignation of Scottish patriotism. In 1548 the queen of six years old was betrothed to the dauphin Francis, and set sail for France, where she arrived on the 15th of August. The society in which the child was thenceforward reared is known to readers of Brantôme as well as that of imperial Rome at its worst is known to readers of Suetonius or Petronius,—as well as that of papal Rome at its worst is known to readers of the diary kept by the domestic chaplain of Pope Alexander VI. Only in their pages can a parallel be found to the gay and easy record which reveals without sign of shame or suspicion of offence the daily life of a court compared to which the court of King Charles II. is as the court of Queen Victoria to the society described by Grammont. Debauchery of all kinds, and murder in all forms, were the daily matter of excitement or of jest to the brilliant circle which revolved around Queen Catherine de' Medici. After ten years' training under the tutelage of the woman whose main instrument of policy was the corruption of her own children, the queen of Scots, aged fifteen years and five months, was married to the eldest and feeblest of the brood on April 24, 1558. On the 17th of November Elizabeth became queen of England, and the princes of Lorraine—Francis the great duke of Guise, and his brother the cardinal—induced their niece and her husband to assume, in addition to the arms of France and Scotland, the arms of a country over which they asserted the right of Mary Stuart to reign as legitimate heiress of Mary Tudor. Civil strife broke out in Scotland between John Knox and the queen-dowager,—between the self-styled "congregation of the Lord" and the adherents of the regent, whose French troops repelled the combined forces of the Scotch and their English allies from the beleaguered walls of Leith, little more than a month before the death of their mistress in the castle of Edinburgh, on the 10th of June 1560. On the 25th of August Protestantism was proclaimed and Catholicism suppressed in Scotland by a convention of states assembled without the assent of the absent queen. On the 5th of December Francis II. died; in August 1561 his widow left France for Scotland, having been refused a safe-conduct by Elizabeth on the ground of her own previous refusal to ratify the treaty made with England by her commissioners in the same month of the preceding year. She arrived nevertheless in safety at Leith, escorted by three of her uncles of the house of Lorraine, and bringing in her train her future biographer, Brantôme, and Chastelard, the first of all her voluntary victims. On the 21st of August she first met the only man able to withstand her; and their first passage of arms left, as he has recorded, upon the mind of John Knox an ineffaceable impression of her "proud mind, crafty wit, and indurate heart against God and His truth." And yet her acts of concession and conciliation were such as no fanatic on the opposite side could have approved. She assented, not only to the undisturbed maintenance of the new creed, but even to a scheme for the endowment of the Protestant ministry out of the confiscated lands of the Church. Her half-brother, Lord James Stuart, shared the duties of her chief counsellor with William Maitland of Lethington, the keenest and most liberal thinker in the country. By the influence of Lord James, in spite of the earnest opposition of Knox, permission was obtained for her to hear mass celebrated in her private chapel,—a licence to which, said the Reformer, he would have preferred the invasion of ten thousand Frenchmen. Through all the first troubles of her reign the young queen steered her skilful and dauntless way with the tact of a woman and the courage of a man. An insurrection in the north, headed by the earl of Huntly under pretext of rescuing from justice the life which his son had forfeited by his share in a homicidal brawl, was crushed at a blow by the Lord James against whose life, as well as against his sister's liberty, the conspiracy of the Gordons had been aimed, and on whom, after the father had fallen in fight and the son had expiated his double offence on the scaffold, the leading rebel's earldom of Murray was conferred by the gratitude of the queen. Exactly four months after the battle of Corrichie, and the subsequent execution of a criminal whom she is said to have "loved entirely," had put an end to the first insurrection raised against her, Pierre de Boscosel de Chastelard, who had returned to France with the other companions of her arrival, and in November 1562 had revisited Scotland, expiated with his head the offence or the misfortune of a second detection at night in her bed-chamber. In the same month, twenty-five years afterwards, the execution of his mistress, according to the verdict of her contemporaries in France, avenged the blood of a lover who had died without uttering a word to realize the apprehension which (according to Knox) had before his trial impelled her to desire her brother "that, as he loved her, he would slay Chastelard, and let him never speak word." And in the same month, two years from the date of Chastelard's execution, her first step was unconsciously taken on the road to Fotheringay, when she gave her heart at first sight to her kinsman Henry, Lord Darnley, son of Matthew Stuart, earl of Lennox, who had suffered an exile of twenty years in expiation of his intrigues with England, and had married the niece of King Henry VIII., daughter of his sister Margaret, the widow of James IV., by her second husband, the earl of Angus. Queen Elizabeth, with the almost incredible want of tact or instinctive delicacy which distinguished and disfigured her vigorous intelligence, had recently proposed as a suitor to the queen of Scots her own low-born favourite, Lord Robert Dudley, the widower if not the murderer of Amy Robsart; and she now protested against the project of marriage between Mary and Darnley. Mary, who had already married her kinsman in secret at Stirling Castle with Catholic rites celebrated in the apartment of David Rizzio, her secretary for correspondence with France, assured the English ambassador, in reply to the protest of his mistress, that the marriage would not take place for three months, when a dispensation from the pope would allow the cousins to be publicly united without offence to the church. On the 29th of July 1565 they were accordingly remarried at Holyrood. The hapless and worthless bridegroom had already incurred the hatred of two powerful enemies, the earls of Morton and Glencairn; but the former of these took part with the queen against the forces raised by Murray, Glencairn, and others, under the nominal leadership of Hamilton, duke of Chatelherault, on the double plea of danger to the new religion of the country, and of the illegal proceeding by which Darnley had been proclaimed king of Scots without the needful constitutional assent of the estates of the realm. Murray was cited to attend the "raid" or array levied by the king and queen, and was duly denounced by public blast of trumpet for his non-appearance. He entered Edinburgh with his forces, but failed to hold the town against the guns of the castle, and fell back upon Dumfries before the advance of the royal army, which was now joined by James Hepburn, earl of Bothwell, on his return from a three years' outlawed exile in France. He had been accused in 1562 of a plot to seize the queen and put her into the keeping of the earl of Arran, whose pretensions to her hand ended only when his insanity could no longer be concealed. Another new adherent was the son of the late earl of Huntly, to whom the forfeited honours of his house were restored a few months before the marriage of his sister to Bothwell. The queen now appealed to France for aid; but Castelnau, the French ambassador, replied to her passionate pleading by sober and earnest advice to make peace with the malcontents. This counsel was rejected, and in October 1565 the queen marched an army of 18,000 men against them from Edinburgh; their forces dispersed in face of superior numbers, and Murray, on seeking shelter in England, was received with contumely by Elizabeth, whose half-hearted help had failed to support his enterprise, and whose intercession for his return found at first no favour with the queen of Scots. But the conduct of the besotted boy on whom at their marriage she had bestowed the title of king began at once to justify the enterprise and to play into the hands of all his enemies alike. His father set him on to demand the crown matrimonial, which would at least have assured to him the rank and station of independent royalty for life. Rizzio, hitherto his friend and advocate, induced the queen to reply by a reasonable refusal to this hazardous and audacious request. Darnley at once threw himself into the arms of the party opposed to the policy of the queen and her secretary,—a policy which at that moment was doubly and trebly calculated to exasperate the fears of the religious and the pride of the patriotic. Mary was invited if not induced by the king of Spain to join his league for the suppression of Protestantism; while the actual or prospective endowment of Rizzio with Morton's office of chancellor, and the projected attainder of Murray and his allies, combined to inflame at once the anger and the apprehension of the Protestant nobles. According to one account, Darnley privately assured his uncle George Douglas of his wife's infidelity; he had himself, if he might be believed, discovered the secretary in the queen's apartment at midnight, under circumstances yet more unequivocally compromising than those which had brought Chastelard to the scaffold. Another version of the pitiful history represents Douglas as infusing suspicion of Rizzio into the empty mind of his nephew, and thus winning his consent to a deed already designed by others. A bond was drawn in which Darnley pledged himself to support the confederates who undertook to punish "certain privy persons" offensive to the state, "especially a stranger Italian called Davie"; another was subscribed by Darnley and the banished lords, then biding their time in Newcastle, which engaged him to procure their pardon and restoration, while pledging them to ensure to him the enjoyment of the title he coveted, with the consequent security of an undisputed succession to the crown, despite the counter claims of the house of Hamilton, in case his wife should die without issue,—a result which, intentionally or not, he and his fellow conspirators did all that brutality could have suggested to accelerate and secure. On the 9th of March the palace of Holyrood was invested by a troop under the command of Morton, while Rizzio was dragged by force out of the queen's presence and slain without trial in the heat of the moment. The parliament was discharged by proclamation issued in the name of Darnley as king; and in the evening of the next day the banished lords, whom it was to have condemned to outlawry, returned to Edinburgh. On the day following they were graciously received by the queen, who undertook to sign a bond for their security, but delayed the subscription till next morning under plea of sickness. During the night she escaped with Darnley, whom she had already seduced from the party of his accomplices, and arrived at Dunbar on the third morning after the slaughter of her favourite. From thence they returned to Edinburgh on the 28th of March, guarded by two thousand horsemen under the command of Bothwell, who had escaped from Holyrood on the night of the murder, to raise a force on the queen's behalf with his usual soldierly promptitude. The slayers of Rizzio fled to England, and were outlawed; Darnley was permitted to protest his innocence and denounce his accomplices; after which he became the scorn of all parties alike, and few men dared or cared to be seen in his company. On the 19th of June a son was born to his wife, and in the face of his previous protestations he was induced to acknowledge himself the father. But, as Murray and his partisans returned to favour and influence no longer incompatible with that of Bothwell and Huntly, he grew desperate enough with terror to dream of escape to France. This design was at once frustrated by the queen's resolution. She summoned him to declare his reasons for it in presence of the French ambassador and an assembly of the nobles; she besought him for God's sake to speak out, and not spare her; and at last he left her presence with an avowal that he had nothing to allege. The favour shown to Bothwell had not yet given occasion for scandal, though his character as an adventurous libertine was as notable as his reputation for military hardihood; but as the summer advanced his insolence increased with his influence at court and the general aversion of his rivals. He was richly endowed by Mary from the greater and lesser spoils of the church; and the three wardenships of the border, united for the first time in his person, gave the lord high admiral of Scotland a position of unequalled power. In the gallant discharge of its duties he was dangerously wounded by a leading outlaw, whom he slew in single combat; and while yet confined to Hermitage Castle he received a visit of two hours from the queen, who rode thither from Jedburgh and back through 20 miles of the wild borderland, where her person was in perpetual danger from the freebooters whom her father's policy had striven and had failed to extirpate. The result of this daring ride was a ten days' fever, after which she removed by short stages to Craigmillar, where a proposal for her divorce from Darnley was laid before her by Bothwell, Murray, Huntly, Argyle, and Lethington, who was chosen spokesman for the rest. She assented on condition that the divorce could be lawfully effected without impeachment of her son's legitimacy; whereupon Lethington undertook in the name of all present that she should be rid of her husband without any prejudice to the child,—at whose baptism a few days afterwards Bothwell took the place of the putative father, though Darnley was actually residing under the same roof, and it was not till after the ceremony that he was suddenly struck down by a sickness so violent as to excite suspicions of poison. He was removed to Glasgow, and left for the time in charge of his father; but on the news of his progress towards recovery a bond was drawn up for execution of the sentence of death which had secretly been pronounced against the twice-turned traitor who had earned his doom at all hands alike. On the 22d of the next month (January 1567) the queen visited her husband at Glasgow and proposed to remove him to Craigmillar Castle, where he would have the benefit of medicinal baths; but instead of this resort he was conveyed on the last day of the month to the lonely and squalid shelter of the residence which was soon to be made memorable by his murder. Between the ruins of two sacred buildings, with the town-wall to the south and a suburban hamlet known to ill fame as the Thieves' Row to the north of it, a lodging was prepared for the titular king of Scotland, and fitted up with tapestries taken from the Gordons after the battle of Corrichie. On the evening of Sunday, February 9, Mary took her last leave of the miserable boy who had so often and so mortally outraged her as consort and as queen. That night the whole city was shaken out of sleep by an explosion of gunpowder which shattered to fragments the building in which he should have slept and perished; and next morning the bodies of Darnley and a page were found strangled in a garden adjoining it, whither they had apparently escaped over a wall, to be despatched by the hands of Bothwell's attendant confederates.

Upon the view which may be taken of Mary's conduct during the next three months depends the whole debatable question of her character. According to the professed champions of that character, this conduct was a tissue of such dastardly imbecility, such heartless irresolution, and such brainless inconsistency as for ever to dispose of her time-honoured claim to the credit of intelligence and courage. It is certain that just three months and six days after the murder of her husband she became the wife of her husband's murderer. On the 11th of February she wrote to the bishop of Glasgow, her ambassador in France, a brief letter of simple eloquence, announcing her providential escape from a design upon her own as well as her husband's life. A reward of two thousand pounds was offered by proclamation for discovery of the murderer. Bothwell and others, his satellites or the queen's, were instantly placarded by name as the criminals. Voices were heard by night in the streets of Edinburgh calling down judgment on the assassins. Four days after the discovery of the bodies, Darnley was buried in the chapel of Holyrood with secrecy as remarkable as the solemnity with which Rizzio had been interred there less than a year before. On the Sunday following, Mary left Edinburgh for Seton Palace, 12 miles from the capital, where scandal asserted that she passed the time merrily in shooting-matches with Bothwell for her partner against Lords Seton and Huntly; other accounts represent Huntly and Bothwell as left at Holyrood in charge of the infant prince. Gracefully and respectfully, with statesmanlike yet feminine dexterity, the demands of Darnley's father for justice on the murderers of his son were accepted and eluded by his daughter-in-law. Bothwell, with a troop of fifty men, rode through Edinburgh defiantly denouncing vengeance on his concealed accusers. As weeks elapsed without action on the part of the royal widow, while the cry of blood was up throughout the country, raising echoes from England and abroad, the murmur of accusation began to rise against her also. Murray, with his sister's ready permission, withdrew to France. Already the report was abroad that the queen was bent on marriage with Bothwell, whose last year's marriage with the sister of Huntly would be dissolved, and the assent of his wife's brother purchased by the restitution of his forfeited estates. According to the *Memoirs* of Sir James Melville, both Lord Herries and himself resolved to appeal to the queen in terms of bold and earnest remonstrance against so desperate and scandalous a design; Herries, having been met with assurances of its unreality and professions of astonishment at the suggestion, instantly fled from court; Melville, evading the danger of a merely personal protest without backers to support him, laid before Mary a letter from a loyal Scot long resident in England, which urged upon her consideration and her conscience the danger and disgrace of such a project yet more freely than Herries had ventured to do by word of mouth; but the sole result was that it needed all the queen's courage and resolution to rescue him from the violence of the man for whom, she was reported to have said, she cared not if she lost France, England, and her own country, and would go with him to the world's end in a white petticoat before she would leave him. On the 28th of March the privy council, in which Bothwell himself sat, appointed the 12th of April as the day of his trial, Lennox, instead of the crown, being named as the accuser, and cited by royal letters to appear at "the humble request and petition of the said Earl Bothwell," who, on the day of the trial, had four thousand armed men behind him in the streets, while the castle was also at his command. Under these arrangements it was not thought wonderful that Lennox discreetly declined the danger of attendance, even with three thousand men ready to follow him, at the risk of desperate street fighting. He pleaded sickness, asked for more time, and demanded that the accused, instead of enjoying special favour, should share the treatment of other suspected criminals. But, as no particle of evidence on his side was advanced, the protest of his representative was rejected, and Bothwell, acquitted in default of witnesses against him, was free to challenge any persistent accuser to the ancient ordeal of battle. His wealth and power were enlarged by gift of the parliament which met on the 14th and rose on the 19th of April,—a date made notable by the subsequent supper at Ainslie's tavern, where Bothwell obtained the signatures of its leading members to a document affirming his innocence, and pledging the subscribers to maintain it against all challengers, to stand by him in all his quarrels, and finally to promote by all means in their power the marriage by which they recommended the queen to reward his services and benefit the country. On the second day following Mary went to visit her child at Stirling, where his guardian, the earl of Mar, refused to admit more than two women in her train. It was well known in Edinburgh that Bothwell had a body of men ready to intercept her on the way back, and carry her to Dunbar,—not, as was naturally inferred, without good assurance of her consent. On the 24th of April, as she approached Edinburgh, Bothwell accordingly met her at the head of eight hundred spearmen, assured her (as she afterwards averred) that she was in the utmost peril, and escorted her, together with Huntly, Lethington, and Melville, who were then in attendance, to Dunbar Castle. On the 3d of May Lady Jane Gordon, who had become countess of Bothwell on February 22d of the year preceding, obtained, on the ground of her husband's infidelities, a separation which, however, would not under the old laws of Catholic Scotland have left him free to marry again; on the 7th, accordingly, the necessary divorce was pronounced, after two days' session, by a clerical tribunal which ten days before had received from the queen a special commission to give judgment on a plea of somewhat apocryphal consanguinity alleged by Bothwell as the ground of an action for divorce against his wife. The fact was studiously evaded or concealed that a dispensation had been granted by the archbishop of St Andrews for this irregularity, which could only have arisen through some illicit connexion of the husband with a relative of the wife between whom and himself no affinity by blood or marriage could be proved. On the day when the first or Protestant divorce was pronounced, Mary and Bothwell returned to Edinburgh with every prepared appearance of a peaceful triumph. Lest her captivity should have been held to invalidate the late legal proceedings in her name, proclamation was made of forgiveness accorded by the queen to her captor in consideration of his past and future services, and her intention was announced to reward them by further promotion; and on the same day (May 12th) he was duly created duke of Orkney and Shetland. The duke, as a conscientious Protestant, refused to marry his mistress according to the rites of her church; and she, the chosen champion of its cause, agreed to be married to him, not merely by a Protestant, but by one who before his conversion had been a Catholic bishop, and should therefore have been more hateful and contemptible in her eyes than any ordinary heretic, had not religion as well as policy, faith as well as reason, been absorbed or superseded by some more mastering passion or emotion. This passion or emotion, according to those who deny her attachment to Bothwell, was simply terror,—the blind and irrational prostration of an abject spirit before the cruel force of circumstances and the crafty wickedness of men. Hitherto, according to all evidence, she had shown herself on all occasions, as on all subsequent occasions she indisputably showed herself, the most fearless, the most keen-sighted, the most ready-witted, the most high-gifted and high-spirited of women; gallant and generous, skilful and practical, never to be cowed by fortune, never to be cajoled by craft; neither more unselfish in her ends nor more unscrupulous in her practice than might have been expected from her training and her creed. But at the crowning moment of trial there are those who assert their belief that the woman who on her way to the field of Corrichie had uttered her wish to be a man, that she might know all the hardship and all the enjoyment of a soldier's life, riding forth "in jack and knapscull"—the woman who long afterwards was to hold her own for two days together without help of counsel against all the array of English law and English statesmanship, armed with irrefragable evidence and supported by the resentment of a nation—showed herself equally devoid of moral and of physical resolution; too senseless to realize the significance and too heartless to face the danger of a situation from which the simplest exercise of reason, principle, or courage must have rescued the most unsuspicious and inexperienced of honest women who was not helplessly deficient in self-reliance and self-respect. The famous correspondence produced next year in evidence against her at the conference of York may have been, as her partisans affirm, so craftily garbled and falsified by interpolation, suppression, perversion, or absolute forgery as to be all but historically worthless. Its acceptance or its rejection does not in any degree whatever affect, for better or for worse, the rational estimate of her character. The problem presented by the simple existence of the facts just summed up remains in either case absolutely the same.

That the coarse and imperious nature of the hardy and able ruffian who had now become openly her master should no less openly have shown itself even in the first moments of their inauspicious union is what any bystander of common insight must inevitably have foreseen. Tears, dejection, and passionate expressions of a despair "wishing only for death," bore fitful and variable witness to her first sense of a heavier yoke than yet had galled her spirit and her pride. At other times her affectionate gaiety would give evidence as trustworthy of a fearless and improvident satisfaction. They rode out in state together, and if he kept cap in hand as a subject she would snatch it from him and clap it on his head again; while in graver things she took all due or possible care to gratify his ambition, by the insertion of a clause in their contract of marriage which made their joint signature necessary to all documents of state issued under the sign-manual. She despatched to France a special envoy, the bishop of Dumblane, with instructions setting forth at length the unparalleled and hitherto ill-requited services and merits of Bothwell, and the necessity of compliance at once with his passion and with the unanimous counsel of the nation,—a people who would endure the rule of no foreign consort, and whom none of their own countrymen were so competent to control, alike by wisdom and by valour, as the incomparable subject of her choice. These personal merits and this political necessity were the only pleas advanced in a letter to her ambassador in England. But that neither plea would avail her for a moment in Scotland she had ominous evidence on the thirteenth day after her marriage, when no response was made to the usual form of proclamation for a raid or levy of forces under pretext of a campaign against the rievers of the border. On the 6th or 7th of June Mary and Bothwell took refuge in Borthwick Castle, twelve miles from the capital, where the fortress was in the keeping of an adherent whom the diplomacy of Sir James Melville had succeeded in detaching from his allegiance to Bothwell. The fugitives were pursued and beleaguered by the earl of Morton and Lord Hume, who declared their purpose to rescue the queen from the thraldom of her husband. He escaped, leaving her free to follow him or to join the party of her professed deliverers. But whatever cause she might have found since marriage to complain of his rigorous custody and domineering brutality was insufficient to break the ties by which he held her. Alone, in the disguise of a page, she slipped out of the castle at midnight, and rode off to meet him at a tower two miles distant, whence they fled together to Dunbar. The confederate lords on entering Edinburgh were welcomed by the citizens, and after three hours' persuasion Lethington, who had now joined them, prevailed on the captain of the castle to deliver it also into their hands. Proclamations were issued in which the crime of Bothwell was denounced, and the disgrace of the country, the thraldom of the queen, and the mortal peril of her infant son were set forth as reasons for summoning all the lieges of the chief cities of Scotland to rise in arms on three hours' notice and join the forces assembled against the one common enemy. News of his approach reached them on the night of June 14, and they marched before dawn with 2200 men to meet him near Musselburgh. Mary meanwhile had passed from Dunbar to Haddington, and thence to Seton, where 1600 men rallied to her side. On the 15th of June, one month from their marriage day, the queen and Bothwell, at the head of a force of fairly equal numbers but visibly inferior discipline, met the army of the confederates at Carberry Hill, some six miles from Edinburgh. Du Croc, the French ambassador, obtained permission through the influence of Maitland to convey to the queen the terms proposed by their leaders,—that she and Bothwell should part, or that he should meet in single combat a champion chosen from among their number. Bothwell offered to meet any man of sufficient quality; Mary would not assent. As the afternoon wore on their force began to melt away by desertion and to break up for lack of discipline. Again the trial by single combat was proposed, and thrice the proposal fell through, owing to objections on this side or on that. At last it was agreed that the queen should yield herself prisoner, and Bothwell be allowed to retire in safety to Dunbar with the few followers who remained to him. Mary took leave of her first and last master with passionate anguish and many parting kisses; but in face of his enemies, and in hearing of the cries which burst from the ranks, demanding her death by fire as a murderess and harlot, the whole heroic and passionate spirit of the woman represented by her admirers as a spiritless imbecile flamed out in responsive threats to have all the men hanged and crucified, in whose power she now stood helpless and alone. She grasped the hand of Lord Lindsay as he rode beside her, and swore "by this hand" she would "have his head for this." In Edinburgh she was received by a yelling mob, which flaunted before her at each turn a banner representing the corpse of Darnley with her child beside it invoking on his knees the retribution of Divine justice. From the violence of a multitude in which women of the worst class were more furious than the men she was sheltered in the house of the provost, where she repeatedly showed herself at the window, appealing aloud with dishevelled hair and dress to the mercy which no man could look upon her and refuse. At nine in the evening she was removed to Holyrood, and thence to the port of Leith, where she embarked under guard, with her attendants, for the island castle of Lochleven. On the 20th a silver casket containing letters and French verses, miscalled sonnets, in the handwriting of the queen, was taken from the person of a servant who had been sent by Bothwell to bring it from Edinburgh to Dunbar. Even in the existing versions of the letters, translated from the lost originals and retranslated from this translation of a text which was probably destroyed in 1603 by order of King James on his accession to the English throne,—even in these possibly disfigured versions, the fiery pathos of passion, the fierce and piteous fluctuations of spirit between love and hate, hope and rage and jealousy, have an eloquence apparently beyond the imitation or invention of art. Three days after this discovery Lord Lindsay, Lord Ruthven, and Sir Robert Melville were despatched to

Lochleven, there to obtain the queen's signature to an act of abdication in favour of her son, and another appointing Murray regent during his minority. She submitted, and a commission of regency was established till the return from France of Murray, who, on the 15th of August, arrived at Lochleven with Morton and Athole. According to his own account, the expostulations as to her past conduct which preceded his admonitions for the future were received with tears, confessions, and attempts at extenuation or excuse; but when they parted next day on good terms she had regained her usual spirits. Nor from that day forward had they reason to sink again, in spite of the close keeping in which she was held, with the daughters of the house for bedfellows. Their mother and the regent's, her father's former mistress, was herself not impervious to her prisoner's lifelong power of seduction and subjugation. Her son George Douglas fell inevitably under the charm. A rumour transmitted to England went so far as to assert that she had proposed him to their common half-brother Murray as a fourth husband for herself; a later tradition represented her as the mother of a child by him. A third report, at least as improbable as either, asserted that a daughter of Mary and Bothwell, born about this time, lived to be a nun in France. It is certain that the necessary removal of George Douglas from Lochleven enabled him to devise a method of escape for the prisoner on March 25, 1568, which was frustrated by detection of her white hands under the disguise of a laundress. But a younger member of the household, Willie Douglas, aged eighteen, whose devotion was afterwards remembered and his safety cared for by Mary at a time of utmost risk and perplexity to herself, succeeded on May 2d in assisting her to escape by a postern gate to the lake-side, and thence in a boat to the mainland, where George Douglas, Lord Seton, and others were awaiting her. Thence they rode to Seton's castle of Niddry, and next day to Hamilton Palace, round which an army of 6000 men was soon assembled, and whither the new French ambassador to Scotland hastened to pay his duty. The queen's abdication was revoked, messengers were despatched to the English and French courts, and word was sent to Murray at Glasgow that he must resign the regency, and should be pardoned in common with all offenders against the queen. But on the day when Mary arrived at Hamilton Murray had summoned to Glasgow the feudatories of the crown, to take arms against the insurgent enemies of the infant king. Elizabeth sent conditional offers of help to her kinswoman, provided she would accept of English intervention and abstain from seeking foreign assistance; but the messenger came too late. Mary's followers had failed to retake Dunbar Castle from the regent, and made for Dumbarton instead, marching two miles south of Glasgow, by the village of Langside. Here Murray, with 4500 men, under leaders of high distinction, met the 6000 of the queen's army, whose ablest man, Herries, was as much distrusted by Mary as by every one else, while the Hamiltons could only be trusted to think of their own interests, and were suspected of treasonable designs on all who stood between their house and the monarchy. On the 13th of May the battle or skirmish of Langside determined the result of the campaign in three quarters of an hour. Kirkaldy of Grange, who commanded the regent's cavalry, seized and kept the place of vantage from the beginning, and at the first sign of wavering on the other side shattered at a single charge the forces of the queen, with a loss of one man to three hundred. Mary fled 60 miles from the field of her last battle before she halted at Sanquhar, and for three days of flight, according to her own account, had to sleep on the hard ground, live on oatmeal and sour milk, and fare at night like the owls, in hunger, cold, and fear. On the third day from the rout of Langside she crossed the Solway, and landed at Workington in Cumberland, May 16, 1568. On the 20th Lord Scrope and Sir Francis Knollys were sent from court to carry messages and letters of comfort from Elizabeth to Mary at Carlisle. On June 11th Knollys wrote to Cecil at once the best description and the noblest panegyric extant of the queen of Scots,—enlarging, with a brave man's sympathy, on her indifference to form and ceremony, her daring grace and openness of manner, her frank display of a great desire to be avenged of her enemies, her readiness to expose herself to all perils in hope of victory, her delight to hear of hardihood and courage, commending by name all her enemies of approved valour, sparing no cowardice in her friends, but above all things athirst for victory by any means at any price, so that for its sake pain and peril seemed pleasant to her, and wealth and all things, if compared with it, contemptible and vile. What was to be done with such a princess, whether she were to be nourished in one's bosom, above all whether it could be advisable or safe to try any diplomatic tricks upon such a lady, Knollys left for the minister to judge. It is remarkable that he should not have discovered in her the qualities so obvious to modern champions of her character,—easiness, gullibility, incurable innocence and invincible ignorance of evil, incapacity to suspect or resent anything, readiness to believe and forgive all things. On the 15th of July, after various delays interposed by her reluctance to leave the neighbourhood of the border, where on her arrival she had received the welcome and the homage of the leading Catholic houses of Northumberland and Cumberland, she was removed to Bolton Castle in North Yorkshire. During her residence here a conference was held at York between her own and Elizabeth's commissioners and those appointed to represent her son as king of Scots. These latter, of whom Murray himself was the chief, privately laid before the English commissioners the contents of the famous casket. On the 24th of October the place of the conference was shifted from York to London, where the inquiry was to be held before Queen Elizabeth in council. Mary was already aware that the chief of the English commissioners, the duke of Norfolk, was secretly an aspirant to the peril of her hand; and on October 21st she gave the first sign of assent to the suggestion of a divorce from Bothwell. On the 26th of October the charge of complicity in the murder of Darnley was distinctly brought forward against her in spite of Norfolk's reluctance and Murray's previous hesitation. Elizabeth, by the mouth of her chief justice, formally rebuked the audacity of the subjects who durst bring such a charge against their sovereign, and challenged them to advance their proofs. They complied by the production of an indictment under five heads, supported by the necessary evidence of documents. The number of English commissioners was increased, and they were bound to preserve secrecy as to the matters revealed. Further evidence was supplied by Thomas Crawford, a retainer of the house of Lennox, tallying so exactly with the text of the casket letters as to have been cited in proof that the latter must needs be a forgery. Elizabeth, on the close of the evidence, invited Mary to reply to the proofs alleged before she could be admitted to her presence; but Mary simply desired her commissioners to withdraw from the conference. She declined with scorn the proposal made by Elizabeth through Knollys, that she should sign a second abdication in favour of her son. On January 10, 1569, the judgment given at the conference acquitted Murray and his adherents of rebellion, while affirming that nothing had been proved against Mary,—a verdict accepted by Murray as equivalent to a practical recognition of his office as regent for the infant king. This position he was not long to hold; and the fierce exultation of Mary at the news of his murder gave to those who believed in her complicity with the murderer, on whom a pension was bestowed by her unblushing gratitude, fresh reason to fear, if her liberty of correspondence and intrigue were not restrained, the likelihood of a similar fate for Elizabeth. On January 26, 1569, she had been removed from Bolton Castle to Tutbury in Staffordshire, where proposals were conveyed to her, at the instigation of Leicester, for a marriage with the duke of Norfolk, to which she gave a graciously conditional assent; but the discovery of these proposals consigned Norfolk to the Tower, and on the outbreak of an insurrection in the north Mary, by Lord Hunsdon's advice, was again removed to Coventry, when a body of her intending deliverers was within a day's ride of Tutbury. On the 23d of January following Murray was assassinated; and a second northern insurrection was crushed in a single sharp fight by Lord Hunsdon. In October Cecil had an interview with Mary at Chatsworth, when the conditions of her possible restoration to the throne in compliance with French demands were debated at length. The queen of Scots, with dauntless dignity, refused to yield the castles of Edinburgh and Dumbarton into English keeping, or to deliver up her fugitive English partisans then in Scotland; upon other points they came to terms, and the articles were signed October 16. On the same day Mary wrote to Elizabeth, requesting with graceful earnestness the favour of an interview which might reassure her against the suggestion that this treaty was a mere pretence. On November 28 she was removed to Sheffield Castle, where she remained for the next fourteen years in charge of the earl of Shrewsbury. The detection of a plot, in which Norfolk was implicated, for the invasion of England by Spain on behalf of Mary, who was then to take him as the fourth and most contemptible of her husbands, made necessary the reduction of her household and the stricter confinement of her person. On May 28, 1572, a demand from both houses of parliament for her execution as well as Norfolk's was generously rejected by Elizabeth; but after the punishment of the traitorous pretender to her hand, on whom she had lavished many eloquent letters of affectionate protestation, she fell into "a passion of sickness" which convinced her honest keeper of her genuine grief for the ducal caitiff. A treaty projected on the news of the massacre of St Bartholomew, by which Mary should be sent back to Scotland for immediate execution, was broken off by the death of the earl of Mar, who had succeeded Lennox as regent; nor was it found possible to come to acceptable terms on a like understanding with his successor Morton, who in 1577 sent a proposal to Mary for her restoration, which she declined, in suspicion of a plot laid to entrap her by the policy of Sir Francis Walsingham, the most unscrupulously patriotic of her English enemies, who four years afterwards sent word to Scotland that the execution of Morton, so long the ally of England, would be answered by the execution of Mary. But on that occasion Elizabeth again refused her assent either to the trial of Mary or to her transference from Sheffield to the Tower. In 1581 Mary accepted the advice of Catherine de' Medici and Henry III. that she should allow her son's title to reign as king of Scotland conjointly with herself when released and restored to a share of the throne. This plan was but part of a scheme including the invasion of England by her kinsman the duke of Guise, who was to land in the north and raise a Scottish army to place the released prisoner of Sheffield beside her son on the throne of Elizabeth. After the overthrow of the Scottish accomplices in this notable project, Mary poured forth upon Elizabeth a torrent of pathetic and eloquent reproach for the many wrongs she had suffered at the hands of her hostess, and pledged her honour to the assurance that she now aspired to no kingdom but that of heaven. In the spring of 1583 she retained enough of this saintly resignation to ask for nothing but liberty, without a share in the government of Scotland; but Lord Burghley not unreasonably preferred, if feasible, to reconcile the alliance of her son with the detention of his mother. In 1584 the long-suffering earl of Shrewsbury was relieved of his fourteen years' charge through the involuntary good offices of his wife, whose daughter by her first husband had married a brother of Darnley; and their orphan child Arabella, born in England, of royal descent on the father's side, was now, in the hopeful view of her grandmother, a more plausible claimant than the king or queen of Scots to the inheritance of the English throne. In December 1583 Mary had laid before the French ambassador her first complaint of the slanders spread by Lady Shrewsbury and her sons, who were ultimately compelled to confess the falsehood of their imputations on the queen of Scots and her keeper. It was probably at the time when a desire for revenge on her calumniatress made her think the opportunity good and safe for discharge of such a two-edged dart at the countess and the queen that Mary wrote, but abstained from despatching, the famous and terrible letter in which, with many gracious excuses and professions of regret and attachment, she transmits to Elizabeth a full and vivid report of the hideous gossip retailed by Bess of Hardwick regarding her character and person at a time when the reporter of these abominations was on friendly terms with her husband's royal charge. In the autumn of 1584 she was removed to Wingfield Manor under charge of Sir Ralph Sadler and John Somers, who accompanied her also on her next removal to Tutbury in January 1585. A letter received by her in that cold, dark, and unhealthy castle, of which fifteen years before she had made painful and malodorous experience, assured her that her son would acknowledge her only as queen-mother, and provoked at once the threat of a parent's curse and an application to Elizabeth for sympathy. In April 1585 Sir Amyas Paulet was appointed to the office of which Sadler, accused of careless indulgence, had requested to be relieved; and on Christmas Eve she was removed from the hateful shelter of Tutbury to the castle of Chartley in the same county. Her correspondence in cipher from thence with her English agents abroad, intercepted by Walsingham and deciphered by his secretary, gave eager encouragement to the design for a Spanish invasion of England under the prince of Parma,—an enterprise in which she would do her utmost to make her son take part, and in case of his refusal would induce the Catholic nobles of Scotland to betray him into the hands of Philip, from whose tutelage he should be released only on her demand, or if after her death he should wish to return, nor then unless he had become a Catholic. But even these patriotic and maternal schemes to consign her child and reconsign the kingdom to the keeping of the Inquisition, incarnate in the widower of Mary Tudor, were superseded by the attraction of a conspiracy against the throne and life of Elizabeth. Anthony Babington, in his boyhood a ward of Shrewsbury, resident in the household at Sheffield Castle, and thus subjected to the charm before which so many victims had already fallen, was now induced to undertake the deliverance of the queen of Scots by the murder of the queen of England. It is maintained by those admirers of Mary who assume her to have been an almost absolute imbecile, gifted with the power of imposing herself on the world as a woman of unsurpassed ability, that, while cognizant of the plot for her deliverance by English rebels and an invading army of foreign auxiliaries, she might have been innocently unconscious that this conspiracy involved the simultaneous assassination of Elizabeth. In the conduct and detection of her correspondence with Babington, traitor was played off against traitor, and spies were utilized against assassins, with as little scruple as could be required or expected in the diplomacy of the time. As in the case of the casket letters, it is alleged that forgery was employed to interpolate sufficient evidence of Mary's complicity in a design of which it is thought credible that she was kept in ignorance by the traitors and murderers who had enrolled themselves in her service,—that one who pensioned the actual murderer of Murray and a would-be murderer of Elizabeth was incapable of approving what her keen and practised intelligence was too blunt and torpid to anticipate as inevitable and inseparable from the general design. In August the conspirators were netted, and Mary was arrested at the gate of Tixall Park, whither Paulet had taken her under pretence of a hunting party. At Tixall she was detained till her papers at Chartley had undergone thorough research. That she was at length taken in her own toils even such a dullard as her admirers depict her could not have failed to understand; that she was no such dastard as to desire or deserve such defenders the whole brief course of her remaining life bore consistent and irrefragable witness. Her first thought on her return to Chartley was one of loyal gratitude and womanly sympathy. She cheered the wife of her English secretary, now under arrest, with promises to answer for her husband to all accusations brought against him, took her new-born child from the mother's arms, and in default of clergy baptized it, to Paulet's Puritanic horror, with her own hands by her own name. The next or the twin-born impulse of her indomitable nature was, as usual in all times of danger, one of passionate and high-spirited defiance, on discovering the seizure of her papers. A fortnight afterwards her keys and her money were confiscated, while she, bedridden and unable to move her hand, could only ply the terrible weapon of her bitter and fiery tongue. Her secretaries were examined in London, and one of them gave evidence that she had first heard of the conspiracy by letter from Babington, of whose design against the life of Elizabeth she thought it best to take no notice in her reply, though she did not hold herself bound to reveal it. On the 25th of September she was removed to the strong castle of Fotheringay in Northamptonshire. On the 6th of October she was desired by letter from Elizabeth to answer the charges brought against her before certain of the chief English nobles appointed to sit in commission on the cause. In spite of her first refusal to submit, she was induced by the arguments of the vice-chamberlain, Sir Christopher Hatton, to appear before this tribunal on condition that her protest should be registered against the legality of its jurisdiction over a sovereign, the next heir of the English crown.

On the 14th and 15th of October 1586 the trial was held in the hall of Fotheringay Castle. Alone, "without one counsellor on her side among so many," Mary conducted the whole of her own defence with courage incomparable and unsurpassable ability. Pathos and indignation, subtlety and simplicity, personal appeal and political reasoning, were the alternate weapons with which she fought against all odds of evidence or inference, and disputed step by step every inch of debatable ground. She repeatedly insisted on the production of proof in her own handwriting as to her complicity with the project of the assassins who had expiated their crime on the 20th and 21st of the month preceding. When the charge was shifted to the question of her intrigues with Spain, she took her stand resolutely on her right to convey whatever right she possessed, though now no kingdom was left her for disposal, to whomsoever she might choose. One single slip she made in the whole course of her defence; but none could have been more unluckily characteristic and significant. When Burghley brought against her the unanswerable charge of having at that moment in her service, and in receipt of an annual pension, the instigator of a previous attempt on the life of Elizabeth, she had the unwary audacity to cite in her justification the pensions allowed by Elizabeth to her adversaries in Scotland, and especially to her son. It is remarkable that just two months later, in a conversation with her keepers, she again made use of the same extraordinary argument in reply to the same inevitable imputation, and would not be brought to admit that the two cases were other than parallel. But except for this single instance of oversight or perversity her defence was throughout a masterpiece of indomitable ingenuity, of delicate and steadfast courage, of womanly dignity and genius. Finally she demanded, as she had demanded before, a trial either before the estates of the realm lawfully assembled, or else before the queen in council. So closed the second day of the trial; and before the next day's work could begin a note of two or three lines hastily written at midnight informed the commissioners that Elizabeth had suddenly determined to adjourn the expected judgment and transfer the place of it to the star-chamber. Here, on the 25th of October, the commissioners again met; and one of them alone, Lord Zouch, dissented from the verdict by which Mary was found guilty of having, since the 1st of June preceding, compassed and imagined divers matters tending to the destruction of Elizabeth. This verdict was conveyed to her, about three weeks later, by Lord Buckhurst and Robert Beale, clerk of the privy council. At the intimation that her life was an impediment to the security of the received religion, "she seemed with a certain unwonted alacrity to triumph, giving God thanks, and rejoicing in her heart that she was held to be an instrument" for the restoration of her own faith. This note of exultation as in martyrdom was maintained with unflinching courage to the last. She wrote to Elizabeth and the duke of Guise two letters of almost matchless eloquence and pathos, admirable especially for their loyal and grateful remembrance of all her faithful servants. Between the date of these letters and the day of her execution wellnigh three months of suspense elapsed. Elizabeth, fearless almost to a fault in face of physical danger, constant in her confidence even after discovery of her narrow escape from the poisoned bullets of household conspirators, was cowardly even to a crime in face of subtler and more complicated peril. She rejected with resolute dignity the intercession of French envoys for the life of the queen-dowager of France; she allowed the sentence of death to be proclaimed, and welcomed with bonfires and bell-ringing throughout the length of England; she yielded a respite of twelve days to the pleading of the French ambassador, and had a charge trumped up against him of participation in a conspiracy against her life; at length, on the 1st of February 1587, she signed the death-warrant, and then made her secretaries write word to Paulet of her displeasure that in all this time he should not of himself have found out some way to shorten the life of his prisoner, as in duty bound by his oath, and thus relieve her singularly tender conscience from the guilt of bloodshed. Paulet, with loyal and regretful indignation, declined the disgrace proposed to him in a suggestion "to shed blood without law or warrant"; and on the 7th of February the earls of Shrewsbury and Kent arrived at Fotheringay with the commission of the council for execution of the sentence given against his prisoner. Mary received the announcement with majestic tranquillity, expressing in dignified terms her readiness to die, her consciousness that she was a martyr for her religion, and her total ignorance of any conspiracy against the life of

Elizabeth. At night she took a graceful and affectionate leave of her attendants, distributed among them her money and jewels, wrote out in full the various legacies to be conveyed by her will, and charged her apothecary Gorion with her last messages for the king of Spain. In these messages the whole nature of the woman was revealed. Not a single friend, not a single enemy, was forgotten; the slightest service, the slightest wrong, had its place assigned in her faithful and implacable memory for retribution or reward. Forgiveness of injuries was as alien from her fierce and loyal spirit as forgetfulness of benefits; the destruction of England and its liberties by Spanish invasion and conquest was the strongest aspiration of her parting soul. At eight next morning she entered the hall of execution, having taken leave of the weeping envoy from Scotland, to whom she gave a brief message for her son; took her seat on the scaffold, listened with an air of even cheerful unconcern to the reading of her sentence, solemnly declared her innocence of the charge conveyed in it and her consolation in the prospect of ultimate justice, rejected the professional services of Richard Fletcher, dean of Peterborough, lifted up her voice in Latin against his in English prayer, and when he and his fellow-worshippers had fallen duly silent prayed aloud for the prosperity of her own church, for Elizabeth, for her son, and for all the enemies whom she had commended overnight to the notice of the Spanish invader; then, with no less courage than had marked every hour and every action of her life, received the stroke of death from the wavering hand of the headsman.

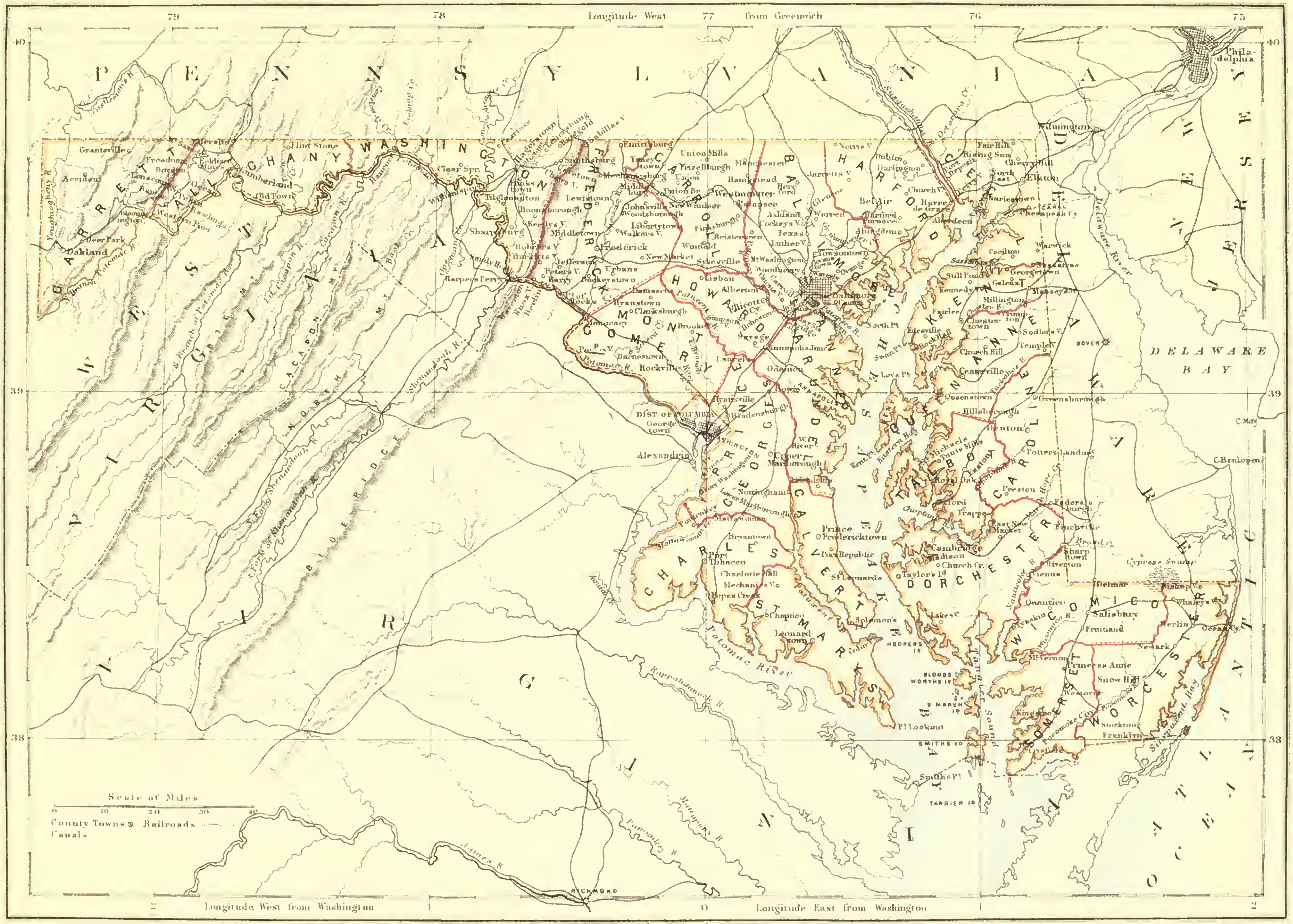
Mary Stuart was in many respects the creature of her age, of her creed, and of her station; but the noblest and most noteworthy qualities of her nature were independent of rank, opinion, or time. Even the detractors who defend her conduct on the plea that she was a dastard and a dupe are compelled in the same breath to retract this implied reproach, and to admit, with illogical acclamation and incongruous applause, that the world never saw more splendid courage at the service of more brilliant intelligence, that a braver if not "a rarer spirit never did steer humanity." A kinder or more faithful friend, a deadlier or more dangerous enemy, it would be impossible to dread or to desire. Passion alone could shake the double fortress of her impregnable heart and ever active brain. The passion of love, after very sufficient experience, she apparently and naturally outlived; the passion of hatred and revenge was as inextinguishable in her inmost nature as the emotion of loyalty and gratitude. Of repentance it would seem that she knew as little as of fear, having been trained from her infancy in a religion where the Decalogue was supplanted by the Creed. Adept as she was in the most exquisite delicacy of dissimulation, the most salient note of her original disposition was daring rather than subtlety. Beside or behind the voluptuous or intellectual attractions of beauty and culture, she had about her the fresher charm of a fearless and frank simplicity, a genuine and enduring pleasure in small and harmless things no less than in such as were neither. In 1562 she amused herself for some days by living "with her little troop" in the house of a burgess of St Andrews "like a burgess's wife," assuring the English ambassador that he should not find the queen there,—"nor I know not myself where she is become." From Sheffield Lodge, twelve years later, she applied to the archbishop of Glasgow and the cardinal of Guise for some pretty little dogs, to be sent her in baskets very warmly packed,—"for besides reading and working, I take pleasure only in all the little animals that I can get." No lapse of reconciling time, no extent of comparative indulgence, could break her in to resignation, submission, or toleration of even partial restraint. Three months after the massacre of St Bartholomew had caused some additional restrictions to be placed upon her freedom of action, Shrewsbury writes to Burghley that "rather than continue this imprisonment she sticks not to say she will give her body, her son, and country for liberty"; nor did she ever show any excess of regard for any of the three. For her own freedom of will and of way, of passion and of action, she cared much; for her creed she cared something; for her country she cared less than nothing. She would have flung Scotland with England into the hellfire of Spanish Catholicism rather than forego the faintest chance of personal revenge. Her profession of a desire to be instructed in the doctrines of Anglican Protestantism was so transparently a pious fraud as rather to afford confirmation than to arouse suspicion of her fidelity to the teaching of her church. Elizabeth, so shamefully her inferior in personal loyalty, fidelity, and gratitude, was as clearly her superior on the one all-important point of patriotism. The saving salt of Elizabeth's character, with all its wellnigh incredible mixture of heroism and egotism, meanness and magnificence, was simply this, that, overmuch as she loved herself, she did yet love England better. Her best though not her only fine qualities were national and political, the high public virtues of a good public servant; in the private and personal qualities which attract and attach a friend to his friend and a follower to his leader, no man or woman was ever more constant and more eminent than Mary Queen of Scots. (A. C. S.)

MARYBOROUGH, a town of Queensland, Australia, in the county of March, on the left bank of the Mary river, 25 miles from its mouth, about 180 miles north of Brisbane, in 25° 35′ S. lat. and 152° 43′ E. long. It is the principal shipping port for an extensive district, communicating by steamer and coach with Brisbane and (since 1881) by railway with the Gympie gold-fields, 54 miles to the south. A large shipbuilding yard, saw-mills, distilleries, breweries, and soap-works are among the industrial establishments of the town, and extensive sugar factories exist in the neighbourhood. Besides a handsome court-house and town-hall, the public buildings comprise a hospital, a school of arts with a considerable library, and immigration barracks. Gas-lighting and water from the Tinana creek were both introduced in 1879. The population of the census district in 1876 was 8608, that of the municipal area about 7000. Maryborough had only about 600 inhabitants in 1860; the municipality dates from 1861, and was reincorporated in 1875.

MARYLAND

MARYLAND, one of the thirteen original States of the American Union, lies between the parallels of 37° 53′ and 39° 43′ 26″ N. lat., and 75° 4′ and 79° 33′ W. long. It is bounded on the N. by Pennsylvania and Delaware; E. by Delaware and the Atlantic Ocean; and S. and W. by Virginia and West Virginia. The total area of the State is 12,210 square miles, of which about 2350 square miles are covered by the waters of the Chesapeake Bay and of the Potomac and other rivers. Plate

Topography.—The configuration of the State is very irregular. Its extreme length east and west is about 200 miles, and its breadth varies from 4 to 120 miles. The coast-line has no harbours; but a narrow beach and a shallow lagoon, called Sinepuxent Bay, extend along its entire length. The central geographical feature of the State is the Chesapeake Bay, the greatest inlet in the United States, and one which is navigable throughout for the largest vessels. The bay at its ocean mouth, between Cape Charles and Cape Henry, is 12 miles wide; it extends north and south about 200 miles; its breadth at


PENNSYLVANIA
WEST VIRGINIA
VIRGINIA
NEW JERSEY
DELAWARE
DELAWARE BAY
ATLANTIC OCEAN
CHESAPEAKE BAY
GARRETT
ALLEGHANY
WASHINGTON
FREDERICK
CARROLL
BALTIMORE
HARFORD
CECIL
HOWARD
MONTGOMERY
ANNE ARUNDEL
PRINCE GEORGE
CHARLES
CALVERT
ST MARYS
KENT
QUEEN ANNE
CAROLINE
TALBOT
DORCHESTER
WICOMICO
SOMERSET
WORCESTER
Baltimore
Annapolis
Washington
Alexandria
Philadelphia
Wilmington
Richmond
Potomac River
Delaware River
Longitude West from Greenwich
Longitude West from Washington
Longitude East from Washington
Scale of Miles
County Towns
Railroads
Canals

the widest point is 40 miles, and its average breadth is 10 miles. It contains many islands, and its shore-line, which is extremely irregular, is deeply indented with estuaries. That part of the State which lies between the bay on the west and the State of Delaware and the ocean on the east is locally known as the Eastern Shore. The surface of this region is for the most part level, and but little raised above the sea. The peninsula between the Potomac river and the west shore of the bay constitutes another geographical division similar in its general features to the Eastern Shore. Its surface, however, is more undulating, and on the north-west it rises to a ledge of Primitive rocks which runs from the Potomac river at a point about 10 miles above Washington city north-east to the Susquehanna river, and separates the tide-water portion of the State from the third division. This latter region gradually rises as it extends westward until it culminates in the mountains of the great Appalachian range, which are called, in Maryland, the Blue Ridge and the Alleghanies. The principal rivers of the Eastern Shore are the Pocomoke, Nanticoke, Choptank, and Elk. These are rather estuaries than rivers, and are not navigable for any distance from their mouths. The Susquehanna flows into the bay at its head, and is navigable for a few miles. On the western shore are the Potomac, navigable for 125 miles, to Washington city, the Patuxent,—the largest river which is altogether within the State,—navigable for small vessels for 40 miles, and the Patapsco, on which Baltimore city is situated, navigable for 22 miles. The tide rises and falls in all these rivers. With the exception of the Youghiogheny, all the Maryland streams flow into the Chesapeake Bay.

Geology and Minerals.—A great diversity of geological formation is found in Maryland. The lower part of the Eastern Shore is an alluvial plain, and the numerous islands in the bay are composed of similar alluvial deposits. The northern part of the Eastern Shore, beginning at the Choptank river, is a Tertiary formation, whose strata of sands and clays overspread deposits of marl, which is of great value as a fertilizer. The peninsula on the western shore of the bay belongs to the same Tertiary formation, which, towards the north-west, gives place to a range of metamorphic rocks. This belt of rocks, which includes a strip of New Red Sandstone, enters the State near the head of the bay, and extends south-west to the Potomac, with an average breadth of about 20 miles. The principal rocks are gneiss, talc-slates, limestone, granite, serpentine, and divers hydrated magnesian silicates. The limestone supplies a marble highly valued as a building material, and the serpentine rocks yield the valuable metallic element of chromium, which has been extensively and profitably worked. Oxides of iron occur in gneiss, and the Jurassic clays contain the brown hæmatite ores from which iron is manufactured. These ores were worked even during the colonial period, and in 1751 Maryland exported 2950 tons of pig iron to England. Bog iron ore is also found on the Eastern Shore. Beds of different kinds of clays which are used in the manufacture of bricks, porcelain, &c., are abundant, and veins of copper ore are also worked. Passing westward of the metamorphic rocks, we meet a wide belt of Silurian and Devonian formation, and the first ridge of the Appalachian range, beyond which lies the broad Hagerstown valley resting upon Trenton limestone. Numerous parallel ridges, enclosing valleys of great fertility, and belonging to the Middle Silurian, Devonian, and Carboniferous formations, follow. This belt of lines of elevation nearly parallel with the ocean, which is a characteristic of the Appalachian chain, has, in Maryland, an average breadth of about 40 miles, and trends to the south-west. The mountainous region, which extends to the western extremity of the State, but with elevations rarely exceeding 2500 feet, begins at Cumberland, and here the Silurian and Devonian formations give place to the Carboniferous. This portion of Maryland is one of the most important bituminous coal regions in America. There are several coal-fields with horizontal seams lying near the surface, but the most considerable is that of the George's Creek valley between Dan's Mountain on the east and Savage Mountain on the west. This narrow valley, about 20 miles long, contains the "big seam" of bituminous coal, of the extraordinary thickness of 14 feet. The Maryland coal is unequalled in the manufacture of iron and the generation of steam. The number of tons mined in 1881 was 2,261,918, and it is estimated that 550 square miles of Coal-measures remain. This Carboniferous formation also contains deposits of iron ore which are extensively worked.

Climate, Soil, &c.—The climate of Maryland is equable and salubrious, except in some of the lower counties on the bay, which, in summer, are subject to malarious exhalations. The mean annual temperature in the southern part of the State is 56°, in the middle 54°, and in the western 50°. The mean temperature at Baltimore is in spring 53°·8, in summer 76°·2, in autumn 57°·1, in winter 36°·2. The mean annual temperature is 55°·9. The mean annual barometer is 30·064 inches, and the annual rainfall 41·94 inches. The death-rate in the State is 1·81 per cent. In Baltimore city it was 19·34 per 1000 in 1879, and 24·7 in 1880.

The soil of the Eastern Shore, and of the peninsula on the western shore of the bay, is composed of sand and clay, and when properly cultivated is very productive. Much attention is there bestowed upon the growth of peaches and other fruits. The land in the central part of the State, and in the valleys of the mountainous part, is of great fertility. The original forest still covers a considerable area of the western portion. There are about one hundred species of trees in the State. The deciduous oaks, hickory, chestnut, walnut, cedar, and beech trees are especially abundant. The bay and its estuaries contain inexhaustible beds of the finest oysters, yielding many thousand bushels annually.[1] There are several kinds of tortoises, the most highly esteemed of which are the *Malaclemys palustris* and the *Ptychemys rugosa.* At least eighty kinds of edible fishes abound in the waters of the State, and swimming birds are very numerous.

Population, Divisions.—The State is divided into twenty-three counties and the corporation of Baltimore city. The counties are — Alleghany, Anne Arundel, Baltimore, Calvert, Caroline, Carroll, Cecil, Charles, Dorchester, Frederick, Garrett, Harford, Howard, Kent, Montgomery, Prince George's, Queen Anne, St Mary's, Somerset, Talbot, Washington, Wicomico, and Worcester. There are five cities—Baltimore, the metropolis of the State, and the seventh city in the United States (population in 1880, 332,313; in 1870, 267,354), Cumberland (population in 1880, 10,693), Frederick (8659), Hagerstown (6627), and Annapolis (6498), the capital of the State, and the seat of the naval academy of the United States.

The body of 200 emigrants who colonized Maryland in 1634 had increased twenty-five years later to 12,000. In 1671 the population was 20,000; in 1715, 30,000; in 1748, 130,000, of whom 36,000 were negroes; in 1761, 164,007 (including 49,675 negroes); in 1775, 200,000; in 1782, 254,050 (including 83,362 negroes). The growth of population as exhibited by the decennial census returns of the United States is as follows:—

[1] In 1880 the amount of capital invested in the Maryland oyster business was $6,245,876; the number of persons employed, 24,377; and the oysters taken, 10,569,012 bushels.

Years	White.	Free Coloured.	Slaves.	Total.
1790	208,649	8,043	103,036	319,728
1800	216,326	19,587	105,635	341,548
1810	235,117	33,927	111,502	380,546
1820	260,223	39,730	107,397	407,350
1830	291,108	52,938	102,994	447,040
1840	318,204	62,078	89,737	470,019
1850	417,943	74,723	90,368	583,034
1860	515,918	83,942	87,189	687,049
1870	605,497	175,397	...	780,894
1880	724,693	210,250	...	934,943

In 1880 the native-born were 852,137, and the foreign-born 82,806. There were 10,569 more females than males. The number of males of twenty-one years of age and over was 232,106, of whom 144,586 were native white, 38,936 foreign white, and 48,584 coloured. The number of persons over the age of ten years who were unable to read and write was 134,488. The number of families in Maryland was 175,318 ; dwellings, 155,070 ; persons to a square mile (land surface), 94·82; families to a square mile, 17·78; dwellings to a square mile, 15·73 ; acres to a person, 6·75 ; acres to a family, 35·99 ; persons to a dwelling, 6·03 ; persons to a family, 5·33.

Agriculture, Manufactures, Commerce.—The following statistics relating to agricultural labour in Maryland are those of the census of 1880. The number of farms was 40,517 (the rate of increase since 1870 being 50 per cent.) ; 27,978 farms were occupied by the owners, 3878 were rented for a fixed money rental, and 8661 were rented for shares of produce. In 19,920 farms the number of acres under cultivation was less than 100, and only 805 farms were of or above 500 acres' extent. The staple crops are tobacco, maize, and wheat, and the average cash value per acre of crops was $17.82. In the production of tobacco Maryland ranks as the seventh State in the Union. The acreage devoted to it was 38,174 ; the production was 26,082,147 ℔ ; and the value of the crop in the farmers' hands was $1,825,750. The cereal production was as follows :—Barley, 226 acres, 6097 bushels ; buckwheat, 10,294 acres, 136,667 bushels ; Indian corn, 664,928 acres, 15,968,533 bushels ; oats, 101,127 acres, 1,794,872 bushels; rye, 32,405 acres, 288,067 bushels; wheat, 569,296 acres, 8,004,864 bushels. The live stock on the farms, June 1, 1880, was as follows :—horses, 117,796 ; mules and asses, 12,561 ; working oxen, 22,246 ; milch cows, 122,907 ; other cattle, 117,387 ; sheep, 171,184 ; swine, 335,408.

The statistics of the iron and steel industries for 1880 showed that the number of establishments in Maryland was twenty-three ; capital, $4,962,125 ; number of hands, 2763 ; wages paid, $905,090 ; value of materials, $2,888,574 ; value of products, $4,470,050. The production of pig iron was 59,664 tons. The cotton manufactures had 2325 looms, 125,014 spindles, used 46,947 bales of cotton, and employed 4159 hands. Baltimore stands eighth in the list of manufacturing cities in the United States. The number of establishments in that city is 3596 ; capital $35,760,108 ; average number of hands employed 55,201 ; annual product $75,621,388.

The large foreign commerce of the State is conducted almost wholly through the port of Baltimore, although there are two other ports of entry. In 1881 the number of foreign vessels arriving was 1307 ; in 1880, 1508. The number of foreign clearances in 1881 was 1179 ; in 1880, 1633. The number of vessels registered in the State is 1788. The chief imports are iron, coffee, and salt ; the chief exports, tobacco, petroleum, and grain. The grain elevators at Baltimore have a capacity of 6,150,000 bushels. In 1880 the value of the foreign imports was $18,643,245, and that of the foreign exports $74,398,971. The aggregate exchanges at the Baltimore clearing house in 1881 were $732,448,141. There are one hundred and fifty-two fire and marine insurance companies doing business in the State. In 1881 these received $1,680,109 in premiums, and paid losses amounting to $1,015,658. The twenty-nine life insurance companies in the State received in 1881 $1,116,540 in premiums, and paid losses amounting to $895,092.

Railways and Canals.—The Baltimore and Ohio Railway, incorporated in 1827, is one of the chief lines of communication between the seaboard and the Western States. The number of miles of all railways in operation wholly within the State is 1048. The Chesapeake and Ohio Canal, begun in 1828, and completed in 1845, at a cost of $11,375,000, extends from Cumberland, along the left bank of the Potomac, to Georgetown, in the District of Columbia, a distance of 184 miles. It there crosses the river by an aqueduct and continues to Alexandria, Va. Its depth is 6 feet, and its width varies from 52 to 70 feet. The Chesapeake and Delaware Canal, connecting the Chesapeake and Delaware Bays, is 12 miles long, 66 feet wide, 10 feet deep, and cost $3,547,561.

Revenue, Debts, Taxation.—The total amount of the funded debt of the State on September 30, 1881, was $11,257,560. About one-half of this debt bears interest at 5 per cent., and the remainder at 6 per cent. As an offset to this debt the State owns interest-paying securities amounting to $3,461,085, and non-productive property valued at 25 million dollars. The property assessed for purposes of State taxation in 1881 was valued at $461,459,939, and the State tax was 18¾ cents on each $100. The total receipts of the State from all sources were $1,996,641. The debt of Baltimore city, on January 1, 1882, was $36,381,351. The city owns productive property worth $15,304,596, and unproductive property valued at $5,150,780. The property assessed for city taxation was valued at $247,230,189, and the city tax was $1·37 on each $100. The debts of the cities and counties, exclusive of Baltimore, amount to nearly two million dollars.

Social Statistics.—In 1881 the average number of convicts in the State penitentiary was 545, nearly one-half of whom were sentenced for larceny. The convicts are employed upon profitable labour, and the institution is not only self-supporting, but is a source of revenue to the State. The State house of correction received in 1881 414 prisoners, most of whom were sentenced for short terms. Provision is made for juvenile offenders in houses of reformation and similar establishments. The number of inmates in the almshouses in 1879 was 2384. The M'Donogh Industrial School has an endowment of $861,968, and educates and supports about fifty poor boys annually. The State extends its aid to a hospital for the insane (with 400 inmates), an asylum for the blind, two deaf and dumb asylums, and other charitable institutions. In 1880 there were one hundred and thirty-eight periodicals published in the State. The principal religious denominations are the Methodist, Roman Catholic, Episcopalian, Presbyterian, and Baptist.

Education and Libraries.—Maryland has an excellent system of free public schools supported by State, county, and municipal taxation. In 1881 the number of schools was 2039, the number of pupils 158,909, the number of teachers 3180, and the total expenses $1,604,580. The schools are managed by school commissioners who, in the counties, are appointed by the judges of the circuit courts, and in Baltimore city are elected by the city council. There is also a State board of education, invested with comprehensive visitorial powers. A number of higher educational institutions are maintained in part by the State. The principal of these are the normal school at Baltimore, St John's College at Annapolis (founded in 1783), the Western Maryland, Maryland Agricultural, Baltimore Female, Washington, and Frederick colleges. In 1881 these colleges had 723 students and 56 instructors, and received from the State $40,300. In Baltimore are two medical colleges—the college of physicians and surgeons, with 10 professors and 330 students, and the medical school of the university of Maryland, with 10 instructors and 200 students. There are also two dental colleges in the State. The law school of the university of Maryland has 4 instructors and 60 students. The Johns Hopkins University, at Baltimore, which has an endowment of more than 3 million dollars, was opened in 1876. It has 34 professors and associates, 20 fellows, 155 students, and 12,000 volumes in its library. The buildings of the Johns Hopkins Hospital, which has a similar endowment of more than 3 million dollars, are now (1882) being erected. The Peabody Institute, which has $1,300,000 in productive funds, the gift of George Peabody, was founded in 1857. It embraces a lecture department, a conservatory of music, a gallery of fine arts, and a library. The library, containing 75,459 volumes in 1882, is designed to be a collection of such books as are not ordinarily accessible to scholars. The Pratt Public Library, endowed with one million dollars, was founded in 1882.

Administration.—The chief executive officer of the State is the governor, who is elected for the term of four years, and receives a salary of $4500 per annum. He is invested with power to grant pardons and reprieves except in cases of impeachment, and a three-fifths vote of the legislature is necessary to overcome his veto of an Act. The legislature, called the General Assembly, meets biennially, and its sessions are limited by the constitution to ninety days. It is composed of a senate, elected for four years (one-half being chosen every second year), and a house of delegates, elected for two years. The present number of senators is 26, and of delegates 91. The judicial power of the State is vested in a court of appeals, consisting of 8 judges, in a circuit court and an orphans' court for each county, in six courts of record for Baltimore city, and in justices of the peace. The judges are elected by the people for fifteen years, and retire upon attaining the age of seventy years. The justices of the peace are appointed by the governor, with the consent of the senate. The law officers are an attorney-general for the State, and a State's attorney for each county, who is the prosecuting officer in all criminal cases. The local affairs of the counties are managed by county commissioners elected for two years, and those of each city by a mayor and city council. All elections are by ballot, and every male citizen of the United States who has been a resident of the State for one year and of the district in which he offers to vote for six months preceding the election is entitled to be registered as a voter. The present constitution was adopted in 1867. Maryland is represented in the national congress by two senators and six representatives. The arms of the State are those prescribed by Lord Baltimore for the province in 1648, viz. :—quarterly—1st and 4th, paly of six, or and sable, a bend counterchanged ; 2d and 3d, quarterly, argent and gules, a cross botonny, counterchanged; crest (which is placed upon a helmet, showing five bars, over a count palatine's coronet), on a ducal coronet proper two pennons, dexter or, the other sable, staves gules; motto, *Fatti maschii parole femine*; supporters, a ploughman and fisherman, proper. On the great seal a mantle doubled with ermine surrounds the arms and supporters, as above, and upon a border encircling the seal is engraven the legend, *scuto bonæ voluntatis tuæ coronasti nos.*

History.—The charter of Maryland, which constituted the first proprietary government established in America, was obtained from Charles I. by Sir George Calvert, the first Lord Baltimore, who had been one of the principal secretaries of state to James I. Lord Baltimore died before the patent passed the seals, and it was issued to his son the second Lord Baltimore on June 20, 1632. The name Maryland (*Terra Mariæ*) was bestowed upon the colony by Charles I. in honour of his queen Henrietta Maria. In 1633 Lord Baltimore despatched a number of emigrants, under the command of his brother Leonard Calvert, to colonize the territory. They settled at St Mary's on the 27th March 1634, and the first legislative assembly, which was composed of all the freemen of the province, met in February 1635. Before the grant of the charter a trading station had been established, by William Clayborne of Virginia, upon Kent Island, in Chesapeake Bay, and the early years of the colony were greatly disturbed by contests with him, in which, however, Lord Baltimore was finally successful. The Baltimores were Catholics, and Maryland was designed to be a place of refuge for English Catholics, but, from the earliest period, religious toleration for all Christians was proclaimed and practised. Maryland has always claimed the honour of having been the first government in which liberty in matters of faith was established by law. Under the charter by which Maryland was made a province of the empire Baltimore was the owner of the soil, and enjoyed all the rights that had ever been exercised by a count palatine. The laws of the provincial assemblies which received his assent were not subject to the revision of the crown. In 1652 the parliamentary commissioners deposed Lord Baltimore's officers, and appointed a Puritan council to govern the province. After several years of contest between the proprietary and Puritan parties, the power of the former was finally re-established. At the time of the Revolution of 1688 the failure of Lord Baltimore's deputies to proclaim William and Mary gave an opportunity to the disaffected Protestants in the province to incite a revolt, which resulted in the overthrow of their feudal lord. The king and queen approved of this colonial Protestant revolution, and Maryland was taken directly under the government of the crown. The Church of England was then established, and disabilities imposed upon Catholics and dissenters. Maryland remained a royal colony until 1714, when, upon the death of the third Lord Baltimore, his son, who was a Protestant, was recognized as the proprietary. The province was governed by the Baltimores until the revolution of 1776. The original charter limits included all the present State of Delaware and a large part of Pennsylvania. The grant to William Penn conflicted with that of Maryland, and a controversy between the two colonies began in 1682, and was not concluded until 1760, when the Penns, armed with a decision of the privy council and a decree in chancery, were successful. "Mason and Dixon's line"—famous in American politics—was established between the provinces in 1763–67. During the war for independence Maryland furnished her full quota of troops, but refused to ratify the articles of confederation until those colonies which had claims to western lands surrendered them to the general Government. Washington resigned his commission as commander-in-chief to the colonial congress at Annapolis in December 1783. Maryland ratified the constitution of the United States on the 28th April 1788, and in 1790 ceded to the United States 60 square miles of territory, where the national capital is situated. At the outbreak of the civil war Maryland was a slave-holding State, and popular sentiment was divided between the North and the South, but the decisive measures adopted by the Federal Government made it impossible for the State to leave the Union. The history of the State has been written by M'Mahon (1831), Bozman (1837), M'Sherry (1849), and Scharf (1879). The Maryland Historical Society at Baltimore has a large collection of colonial and revolutionary MSS., newspapers, and historical works, and has published numerous essays upon questions of local history. (W. T. B.)

MARYPORT, a market and seaport town of Cumberland, England, is situated on the Irish Sea, 29 miles southwest from Carlisle. It is irregularly built, partly on a cliff and partly on the sea-shore. The streets are spacious, but there are no public buildings of importance. The town until 1750 consisted of a few huts called Ellenfoot, when a harbour was constructed by Humphrey Senhouse, which gave a great impulse to its prosperity. The principal exports are coal to Ireland and pig-iron to the Continent, the principal imports timber and general merchandise. Shipbuilding is carried on to a small extent. In 1881 the number of vessels that entered from foreign and colonial ports was 72, of 35,241 tons burden; the number that cleared 120, of 60,840 tons burden. The coasting trade is much more important, the number of vessels that entered being 1805, of 215,332 tons burden, and the number that cleared 1753, of 187,290 tons. There are rope and sailcloth works, iron foundries, and saw-mills, also brewing and tanning. The population of the urban sanitary district in 1871 was 7443, and in 1881 it was 8177. There was a Roman camp in the neighbourhood of Maryport, and the district is rich in Roman antiquities.

MASACCIO (1402-1429). Tommaso Guidi, son of a notary, Ser Giovanni di Simone Guidi, of the family of the Scheggia, who had property in Castel S. Giovanni di Val d'Arno, was born in 1402, and acquired the nickname of Masaccio, which may be translated "Lubberly Tom," in consequence of his slovenly dressing and deportment. He loved to be alone and at home, neglected "appearances" of all sorts, and was constantly wool-gathering when not intently occupied with his work; he had no vices, however, and would always do a good turn to an acquaintance. From childhood he showed a great inclination for the arts of design, and he is said to have studied under his contemporary Masolino da Panicale. In 1421, or perhaps 1423, he was enrolled in the guild of the speziali (druggists) in Florence, in 1424 in the guild of painters. His first attempts in painting were made in Florence, and then in Pisa. Next he went to Rome, still no doubt very young; although the statement that he returned from Rome to Florence, in 1420, when only eighteen or nineteen, seems incredible, considering what were the works which he undertook in the papal city. These included a series of frescos still extant in a chapel of the church of S. Clemente, a Crucifixion, and scenes from the life of St Catherine and of St Clement, or perhaps some other saint. Though much inferior to his later productions, these paintings are, for naturalism and propriety of representation, in advance of their time. Some critics, however, consider that the design only, if even that, was furnished by Masaccio, and the execution left to an inferior hand; this appears highly improbable, as Masaccio, at his early age, can scarcely have held the position of a master laying out work for subordinates; indeed Vasari says that Lubberly Tom was held in small esteem at all times of his brief life. In the crucifixion subject the group of the Maries is remarkable; the picture most generally admired is that of

Catherine, in the presence of Maxentius, arguing against and converting eight learned doctors. After returning to Florence, Masaccio was chiefly occupied in painting in the church of the Carmine, and especially in that "Brancacci chapel" which he has rendered famous almost beyond rivalry in the annals of painting.

The chapel had been built early in the 15th century by Felice Michele di Piuvichese Brancacci, a noble Florentine. Masaccio's work in it began probably in 1423, and continued at intervals until he finally quitted Florence in 1428. There is a whole library-shelf of discussion as to what particular things were done by Masaccio and what by Masolino, and long afterwards by Filippino Lippi, in the Brancacci chapel, and also as to certain other paintings by Masaccio in the Carmine. He began with a trial piece, a majestic figure of St Paul, not in the chapel; this has perished. A monochrome of the Procession for the Consecration of the Chapel, regarded as a wonderful example, for that early period, of perspective and of grouping, has also disappeared, though there is some suspicion that it might yet, with due pains and research, be recovered; it contained portraits of Brunelleschi, Donatello, and many others. In the cloister of the Carmine was discovered in recent years a portion of a fresco by Masaccio representing a procession; but this, being in colours and not in monochrome, does not appear to be the Brancacci procession. As regards the works in the Brancacci chapel itself, the prevalent opinion now is that Masolino, who used to be credited with a considerable portion of them, did either nothing, or at the utmost the solitary compartment which represents St Peter restoring Tabitha to life, and the same saint healing a cripple. The share which Filippino Lippi bore in the work admits of little doubt; to him are due various items on which the fame of Masaccio used principally to be based—as for instance the figure of St Paul addressing Peter in prison, which Raphael partly appropriated; and hence it may be observed that an eloquent and often-quoted outpouring of Sir Joshua Reynolds in praise of Masaccio ought in great part to be transferred to Filippino. What Masaccio really painted in the chapel appears with tolerable certainty to be as follows, and is ample enough to sustain the high reputation he has always enjoyed:—(1) The Temptation of Adam and Eve; (2) Peter and the Tribute-Money; (3) The Expulsion from Eden; (4) Peter Preaching; (5) Peter Baptizing; (6) Peter Almsgiving; (7) Peter and John Curing the Sick; (8) Peter Restoring to Life the Son of King Theophilus of Antioch was begun by Masaccio, including the separate incident of Peter Enthroned, but a large proportion is by Filippino; (9) the double subject already allotted to Masolino may perhaps be by Masaccio, and in that case it must have been one of the first in order of execution. A few words may be given to these pictures individually. (1) The Temptation shows a degree of appreciation of nude form, corresponding to the feeling of the antique, such as was at that date unexampled in painting. (2) The Tribute-Money, a full, harmonious, and expressive composition, contains a head reputed to be the portrait of Masaccio himself,—one of the apostles, with full locks, a solid resolute countenance, and a pointed beard. (3) The Expulsion was so much admired by Raphael that, with comparatively slight modifications, he adopted it as his own in one of the subjects of the Logge of the Vatican. (5) Peter Baptizing contains some nude figures of strong naturalistic design; that of the young man, prepared for the baptismal ceremony, who stands half-shivering in the raw air, has always been a popular favourite, and an object of artistic study. (8) The restoration of the young man to life has been open to much discussion as to what precise subject was in view, but the most probable opinion is that the legend of King Theophilus was intended.

In 1427 Masaccio was living in Florence with his mother, then for the second time a widow, and with his younger brother Giovanni, a painter of no distinction; he possessed nothing but debts. In 1428 he was working, as we have seen, in the Brancacci chapel. Before the end of that year he disappeared from Florence, going, as it would appear, to Rome, to evade the importunities of creditors. Immediately afterwards, in 1429, when his age was twenty-seven, he was reported dead. Poisoning by jealous rivals in art was rumoured, but of this nothing is known. The statement that several years afterwards, in 1443, he was buried in the Florentine church of the Carmine, without any monument, seems to be improbable, and to depend upon a confused account of the dates, which have now, after long causing much bewilderment, been satisfactorily cleared up from extant documents.

It has been said that Masaccio introduced into painting the plastic boldness of Donatello, and carried out the linear perspective of Paolo Uccello and Brunelleschi (who had given him practical instruction), and he was also the first painter who made some considerable advance in atmospheric perspective. He was the first to make the architectural framework of his pictures correspond in a reasonable way to the proportions of the figures. In the Brancacci chapel he painted with extraordinary swiftness. The contours of the feet and articulations in his pictures are imperfect; and his most prominent device for giving roundness to the figures (a point in which he made a great advance upon his predecessors) was a somewhat mannered way of putting the high lights upon the edges. His draperies were broad and easy, and his landscape details natural, and superior to his age. In fact, he led the way in representing the objects of nature correctly, with action, liveliness, and relief. Soon after his death, his work was recognized at its right value, and led to notable advances; and all the greatest artists of Italy, through studying the Brancacci chapel, became his champions and disciples.

Of the works attributed to Masaccio in public or private galleries hardly any are authentic. The one in the Florentine Academy, the Virgin and Child in the Lap of St Anna, is an exception. The so-called portrait of Masaccio in the Uffizi Gallery is more probably Filippino Lippi; and Filippino, or Botticelli, may be the real author of the head, termed a Masaccio, in the London National Gallery.

MASANIELLO (an abbreviation of Tommaso Aniello or Anello) was the leader of the Neapolitan revolt in July 1647. For many years the Spanish Government, in straits for money, had exacted large sums from the Two Sicilies, although the privileges granted by Ferdinand and Charles V. had exempted them both from taxes on the necessaries of life and from all external payments whatever. Now, however, under Philip III. and Philip IV., the exactions, heavy in themselves, were made more oppressive by being farmed out to contractors, while the sums raised were usually conveyed to Spain and spent on purposes often having no connexion with Naples. Meantime the industrial classes were scourged by the excesses of the nobility and the lawlessness of banditti. At length, at the end of 1646, the duke of Arcos demanded a million ducats in gold; and it was resolved after much opposition to raise it from fruit, one of the most important articles of food to a southern people. Petitions delayed but did not remove the tax; on June 6 a toll-house was actually blown up, but the viceroy did not give way. The discontent was fomented by Genovino, who had been chosen "elect of the people" (that is, of the district of the city where the common people had the right of voting) in 1619 by the duke of Osuna's influence, and had been employed by him as an agitator. After the duke's recall he had been long in prison, and then returned to Naples and became a priest. He selected for his purpose Masaniello, a fisherman of Naples, then twenty-seven years old, well built, intelligent, and very popular in the city. He was so poor, we are told, that he was usually obliged to content himself with selling paper to wrap up the fish that others sold. He had special cause too for hatred to the taxes: his wife had tried to smuggle a bag of flour into the city as an infant; she had been imprisoned, and his scanty possessions had barely sufficed to pay her fine. The temporary success of a rising at Palermo had stirred the people to a sense of their power, and very little was wanted to produce an explosion. On July 16, the feast of S. Maria del Carmine, it was customary to make a sort of castle which was defended by one body of youths armed with sticks and stormed by another. Masaniello had been chosen captain of one of these parties, and got together four hundred young men, with whom he had already raised the cry of "Down with the taxes" when the crisis was precipitated by a quarrel. On Sunday the 7th a dispute arose in the market (on which Masaniello's house looked) whether the gardeners or the buyers of their fruit should pay the tax. Finally the owner of the fruit (said to have been a kinsman of Masaniello) upset his basket, saying he would sooner let the people have it for nothing than pay the tax. Masaniello came up; the tax collectors were pelted with fruit and then with stones, and the toll-house was burnt with cries of—"The king of Spain and plenty; down with misgovernment and taxes." The viceroy attempted without effect to quiet the people by promises; his carriage was surrounded, and he escaped with difficulty to St Elmo. Meanwhile the populace broke open the prisons, and released all charged with offences against the customs. In the evening, by advice of Genovino, a meeting elected officers, and decided on their demands. Masaniello was chosen captain, with one Perrone, who had been in the service of Maddaloni, and at another time a captain of banditti, as his lieutenant. Next day the people went in search of arms; many houses of persons who had made themselves obnoxious to the people, and especially of tax farmers, were sacked, and their contents burnt; but most of the historians of the time state that there were few attempts to appropriate anything, and those few were immediately punished. The duke of Maddaloni, a man of lawless life, but a decided opponent of the viceroy, was selected as a likely intermediary with the people. The latter demanded the original charter granted by Charles V., which was said to have wrongfully come into the viceroy's own hands, the removal of all taxes imposed since Charles V.'s death, and that the elect of the people should have as many votes as the representatives of the nobles. All was granted; but the viceroy made entrenchments to guard the approaches to the castle. Next day the sacking of tax farmers' houses went on. The viceroy attempted to cheat the people by sending documents simply drawn up by himself; and then their rage burst out. Maddaloni was seized and given into custody, but escaped in the night by Perrone's connivance. The people were summoned to arms. The cardinal archbishop Filomarino, who did his best to mediate between the parties all through, came to them from the viceroy, and it was arranged that he should bring them the document. The seizure of arms went on, and Masaniello marching out of the city disarmed and took prisoners four hundred soldiers, while another body of people did the same with six hundred German mercenaries. On Wednesday Perrone made his appearance at the head of three hundred bandits partly mounted, and fired upon Masaniello, but without injuring him. The people rushed upon them, and they were killed almost without exception. Some confessed to having been instigated by Maddaloni, and a price was set upon his head. His brother Giuseppe Caraffa was found in a monastery and killed, and his head and foot were set upon pikes. A new elect of the people was chosen, Arpaia, who had been a partisan of Genovino's in the duke of Osuna's time, and had been condemned to the galleys. On Thursday Maddaloni's house was plundered and his property placed in a heap in the market under guard. The castle being short of provisions, Masaniello sent some as a present to the viceroy. The Neapolitan galleys, under Gianettino Doria, arrived the same day, and Masaniello refused permission to land or to come nearer than a mile to the shore, but sent provisions on board. In fact he was now undisputed master of the city, not only organizing the military force in it with surprising ability, but dispensing strict though severe justice. Often he sat inside his little house on the market, sword or loaded gun in hand, while petitions and complaints were handed to him on the end of a pike through the window; yet he still went barefoot, dressed as a simple fisherman. The people having assembled consulted together on the terms of agreement; it was settled by the advice of Genovino that Masaniello should show the articles agreed on to the duke at the palace (he would not risk himself in the castle), and that the viceroy should afterwards swear to them in the cathedral. Towards evening the procession set out, Masaniello in a dress of cloth of silver pressed upon him by the archbishop. An immense concourse of armed men, estimated at one hundred and forty thousand, lined the way or accompanied him. Before them went a trumpet proclaiming *Viva il rè di Spagna ed il fedelissimo popolo di Napoli.* Before entering the palace he exhibited the charter brought by the archbishop, and charged them not to lay down their arms till they had received the confirmation of their rights from the king of Spain. "If I do not return in an hour," he added, "wreck the city." He was received by the viceroy as an equal. All the conditions were agreed to, the chief being—that the elect of the people should have as many votes as the nobles; that all taxes should be removed except those already existing in Charles V.'s time; that the viceroy should get the articles ratified by the king within three months; that no punishment should be inflicted on those who had taken part in the rising; and that the people should keep their arms till the ratification. On the Friday Masaniello dismissed most of his followers to their work, keeping a patrol of four men and a corporal in each street. Next day the ceremony in the cathedral took place; the duke of Canjano read the articles, Masaniello meanwhile correcting and explaining, and the viceroy solemnly swore to observe them. Then Masaniello tore off his rich dress; it was time, he said, to return to his fish. And indeed from this time began his ruin. For a week the care of a city, with hundreds of thousands of inhabitants, had rested upon him; he had been general, judge, legislator, and during the whole time he had hardly slept or eaten, the latter through dread of poison; no wonder if the fisherman's brain reeled under all this. His justice had been severe, but hitherto it had struck men who deserved punishment, the oppressor, the robber, the hired cut-throat; henceforth every one who ventured to contradict him risked his life, and the only man who could persuade him to mercy was the good archbishop. Five hundred in all, it is said, were put to death by his order; though it is probable that they were few compared to the lives taken a short time afterwards by the viceroy in defiance of his plighted word. Next day in fact the duke set to work; Genovino was made president of the chamber in order to detach him from Masaniello, for which he was the more ready as Masaniello was no longer the tool he wanted. Genovino had already prevented the demand for the surrender of St Elmo, which could easily have been enforced, as the fort was not provisioned. Carlo and Salvatore Cataneo with two others offered to the viceroy to murder Masaniello, and he welcomed their services. On Sunday Masaniello gave orders for laying down arms and submitting to the viceroy, which were obeyed in some quarters of the city before they could be recalled. He tried in vain to get the viceroy to accompany him to Posilippo, where he drank deeply, and in reckless extravagance threw gold into the water to be dived for. Next day his violence continued; he struck his followers in the street, and condemned several of his officers to death for not immediately executing his orders. He cut out the head from a picture of Maddaloni and set it on a pike. Vitale his secretary, sent on a message to the viceroy, talked of his intention to raise a million ducats for the king by means of forced gifts from the rich; Vitale was detained in the castle on some pretext, and on leaving next morning was killed by the people of the quarter, who had returned to their allegiance. On Tuesday the 16th, the feast of S. Maria del Carmine, Masaniello went up into the pulpit, and in a wild harangue recapitulated his services. He knew, he said, his death was near at hand; then tearing open his dress he showed his body emaciated by fatigue and want of food. After some more wild talk he was disarmed and confined in a cell in the monastery. There the quiet seems to have restored him; but his assassins soon broke in; he turned to meet them; five shots were at once fired, and he fell dead. His head was cut off and carried through the streets, while his body was dragged about for a while and then buried outside the city. Next day some boys went and dug up the body, washed it, and took the head from the guard in charge of it. The Neapolitans forgot the excesses of the last few days, and only remembered the leader who had won them their great victory. People plucked out his hairs and preserved them as relics, some even prayed to him as a saint. All the priests of the city officiated at the funeral, and even the viceroy was represented by eight of his pages. (G. H. B.)

MASAYA, a town in Nicaragua, Central America, on the east side of the Lake of Masaya, about 55 miles south-east of Managua, and 25 miles north-west of Granada. The population, mostly of Indian blood, is estimated at 15,000 or 18,000; but, as nearly every house has its orchard or garden, the buildings are spread over a much larger area than this would suggest. Previous to 1871, when a steam-pump was erected, all the water required had to be carried from the lake, which lies 340 feet below the level of the town. The volcano of Masaya on the opposite side of the lake was active at the time of the conquest of Nicaragua in 1522, and the conquerors, thinking the lava they saw was gold, had themselves lowered into the crater at the risk of their lives; it had a great eruption in 1670, and began to smoke again in 1860.

MASCARA, a fortified town of Algeria in the province of Oran, 60 miles south-east of Oran, lies at a height of 1900 feet above the sea, on the southern slope of the first chain of the Atlas mountains, and occupies two small hills separated by the Oued Toudman. The walls, upwards of 2 miles in circuit, and strengthened by bastions and towers, give the place a somewhat imposing appearance; the French part of the town is substantial and clean; and among the public buildings are three mosques (one used as a church, another as a granary), a large hospital, a small theatre, and the usual establishments attaching to the seat of a sub-prefect and the centre of a military subdivision. A public garden of 10 acres has been laid out in the ravine. The population was 9442 in 1866, and 9240 in 1872.

Mascara (*i.e.*, place of soldiers) was the capital of a beylik during the Spanish occupation of Oran from the 16th to the close of the 18th century; but for the most of that period it occupied a site about 2 miles distant from the present position. On the removal of the bey to Oran its importance rapidly declined; and it was quite an insignificant place when in 1832 Abd-el-Kádir, who had been born in the neighbourhood, chose it as the seat of his power. It was laid in ruins by the French under Marshal Clausel and the duke of Orleans in 1835, and, being again occupied by Abd-el-Kádir in 1838, was again captured in 1841 by Bugeaud and Lamoricière.

MASCARENE ISLANDS, or MASCARENHAS, a group in the Indian Ocean to the east of Madagascar, consisting of Mauritius (Île de France), Réunion (Bourbon), and Rodriguez. Mauritius and Rodriguez belong to Great Britain, Réunion to France. The collective title is derived from the Portuguese navigator Garcia Mascarenhas, by whom Bourbon, at first called Mascarenhas, was discovered in 1505.

MASCARON, JULES, was born at Marseilles in 1634, and died at his diocesan city of Agen in 1703. His father was an advocate, and he was himself intended for the law, but he preferred the church. As a member of the Oratorian congregation he preached in different provincial towns, beginning with Saumur, and in all produced a great effect. Then he went to Paris and quickly established his reputation at a time when the court, dissolute enough in manners, had already begun to exercise its connoisseurship in matters of sacred eloquence. Several complimentary speeches of Louis XIV. to Mascaron are handed down by tradition. He was not, however, in the ordinary sense a courtier; or if so he was a very bold and adroit one. In Lent 1669 he preached before the king against adultery in the strongest terms. Either from respect for him or to get rid of him Louis made him bishop of Tulle, but he still continued occasionally to preach and to deliver *oraisons funèbres* before the court. His reputation for these was so high that the king not unfrequently indicated subjects to him himself. His crowning success in this way was his funeral sermon on Turenne in 1675. He was afterwards translated to Agen, where he died, as has been said; but his appointment was not a banishment, and he was summoned more than once to preach before the court, notably in his sixtieth year, when Louis is said to have remarked to him, "Votre eloquence n'a pas vieilli." Mascaron, though the contemporary of Bossuet, belongs to an older school of oratory. His style is unequal, and his taste not always sure, but occasionally he has much vigour. Besides the Turenne address his funeral sermon on the chancellor Séguier ranks as his chief performance. These, with other similar pieces, were collected and edited by Father Borde, a member of the author's own congregation, in 1740.

MASCHERONI, LORENZO (1750–1800), an Italian geometer, was professor of mathematics at the university of Pavia, and published a variety of mathematical works, the best-known of which is his *Geometria del Compasso* (Pavia, 1797), a body of constructive geometry in which the use of the circle alone is postulated. Many of the solutions are most ingenious, and some of the constructions of considerable practical importance.

The English reader will find a copious extract from Mascheroni's work in Leslie's *Geometry*, 3d ed., p. 204. There is a French translation by Carette (Paris, 1798), who also wrote a biography of Mascheroni.

MASINISSA, a Numidian prince whose history is closely intertwined with that of the wars between Rome and Carthage. With true barbarian fickleness, and a keen eye to his own interests, he espoused now one side now the other, inclining however on the whole decidedly in favour of Rome, so much so indeed as to be spoken of by Roman orators and historians as "a most faithful ally of the Roman people." He was the son of a Numidian king or chief, Gala, whose dominions coincided with the eastern portions of Numidia, and thus bordered on Carthaginian territory, or what is now Tunis. He was educated, like many of the Numidian chiefs, at Carthage, learnt Latin and Greek, it is said, and was in short an accomplished as well as a naturally clever man. Although his kingdom was nominally independent of Carthage, it really stood to it in a relation of vassalage; it was directly under Carthaginian influences, and was imbued to a very considerable extent with Carthaginian civilization. It was to this that Masinissa owed his fame and success; he was a barbarian at heart, but he had a varnish of culture, and to this he added the craft and cunning in which Carthaginian statesmen were supposed to excel. While yet a young man, he drove his neighbour Syphax, prince of western Numidia, out of the country now known as Algiers, and forced him to fly to the Moors in the extreme west of Africa. Soon afterwards he appears in Spain, fighting for Carthage with a large force of Numidian cavalry against the Romans under the two Scipios. The defeat of the Carthaginian army in 206 B.C., which for a time at least gave the Romans complete mastery of the south of Spain, led him to desert his old allies and to cast in his lot with the fortunes of Rome. The famous Scipio Africanus is said to have cultivated his friendship and done all he could to secure his services for his country. Masinissa now quitted Spain for a while for Africa, and was again engaged in a war with Syphax, in which he was so decidedly worsted that he found himself at last merely the head of a small band of marauders, and was obliged to confine his movements to the coast. Scipio's arrival in Africa in 204 gave him another chance, and no sooner had he joined the Roman general than he quite crushed his old enemy, Syphax, and captured Cirta (Constantineh), the capital of Syphax. Here occurs the romantic story of Sophonisba, daughter of the Carthaginian Hasdrubal, who had been promised in marriage to Masinissa, but who had subsequently become the wife of Syphax. Masinissa, it is said, wedded her immediately after his victory, but was required by Scipio to dismiss her as a Carthaginian, and consequently an enemy to Rome. To save her from such humiliation he sent her poison, with which she destroyed herself. Masinissa was now accepted as a thoroughly loyal ally of Rome, and was confirmed by Scipio in the possession of his hereditary kingdom. In the decisive battle of Zama, 202 B.C., which witnessed Hannibal's downfall, he commanded the cavalry on Scipio's right wing, and materially assisted the Roman victory. For his services on that great day he had given him, under a treaty with Rome, the kingdom of Syphax with its capital Cirta, and thus under Roman protection he became master of the whole of Numidia, and his dominions completely enclosed the Carthaginian territories, now straitened and reduced at the close of the Second Punic War.

Masinissa was still far from satisfied, and it would seem that he almost had thoughts of annexing Carthage itself with the connivance of Rome. He spared no opportunity to harass and annoy the city by pressing unfair claims to some of its best and oldest possessions, and threatening perpetual encroachments. In a war which soon followed he was successful; the remonstrances of Carthage with Rome on the behaviour of their ally were answered by deputing Scipio to arbitrate in the quarrel, but, as though intentionally on the part of Rome, no definite settlement was arrived at, and thus the relations between Masinissa and the Carthaginians were still unfriendly. Rome, it is certain, deliberately favoured her ally's unjust claims with the view of keeping Carthage weak. Masinissa too was cunning enough to retain the friendship and good opinion of the Roman people by helping them with liberal supplies in their wars in the East, with Perseus of Macedon and with Antiochus. As soon as Carthage seemed to be recovering herself, and some of Masinissa's partisans were driven from the city into exile, his policy was to alarm the fears of Rome, till at last, in 149, war was declared, the Third Punic War, which ended in the final and utter overthrow of Carthage. The king bore some part in the negotiations which preceded the war, and died soon after its commencement in 148 B.C., after a life of ninety and a reign of sixty years.

Masinissa was an able ruler and a decided benefactor to Numidia, the resources of which he developed, while he converted a people which had been little better than a plundering tribe into a settled and civilized population, and out of robbers and marauders made efficient and disciplined soldiers. To his sons he bequeathed a well-stored treasury, a formidable army, and even a fleet. Cirta, his capital, became a famous centre of Phœnician civilization. In fact Masinissa changed for the better the whole aspect of a great part of northern Africa. He had much of the Arab nature, was singularly temperate, and equal to any amount of fatigue. His fidelity to Rome was not the fidelity of principle, but merely that of temporary expediency; it is in the really good work he did for his country that the noblest side of his character comes into display.

For Masinissa, Livy and Sallust's *Jugurtha* must be specially consulted by scholars. English readers may be referred to a very full article in Smith's *Dictionary of Classical Biography*; also to Mommsen's *History of Rome* and Niebuhr's *Lectures*.

MASK, or MASQUE. See DRAMA, vol. vii. p. 431 *sq.*

MASKELYNE, NEVIL (1732-1811), astronomer-royal at Greenwich for nearly half a century, was born in London October 6, 1732. The great solar eclipse of 1748 seems to have made a deep impression upon him; and after studying divinity at Trinity College, Cambridge, of which he was elected a fellow in 1756, he determined to devote himself wholly to astronomy. He early became intimate with Bradley, and in 1761 was deputed by the Royal Society to make observations of the transit of Venus at St Helena. During the voyage he introduced into navigation the determination of longitude by lunar distances, a method which Mayer's recently published tables had made practically possible. In 1763 he undertook a voyage to Barbados to test Harrison's watches, which, however, he reported to be inferior to the method of lunars for determining longitude. In 1765 he succeeded Bliss as astronomer-royal, and thereafter devoted himself with singular energy to the duties of his office, which he held till his death, February 9, 1811.

Maskelyne's first contribution to astronomical literature was "A Proposal for Discovering the Annual Parallax of Sirius," published in 1760 in the *Philosophical Transactions*, in which also most of his later original memoirs appeared—*e.g.*, his observations of the transit of Venus (1761 and 1769), observations on the tides at St Helena (1762), astronomical observations at St Helena (1764) and at Barbados (1764). In 1763 he published a small octavo, *The British Mariner's Guide*, which contains the valuable suggestion that, in order to facilitate the finding of longitude at sea, lunar distances should be calculated beforehand for each year and published in a form accessible to navigators. This suggestion, the germ of the *Nautical Almanac*, was approved of by the Government, and under the care of Maskelyne the *Nautical Almanac* for 1767 was published in 1766. During the remainder of his life Maskelyne continued to superintend the publication of this invaluable annual, the *Nautical Almanac* for 1815 being the last which he prepared. Another valuable service which he rendered astronomy was his inducing the Government to print his observations annually. Flamsteed's and Bradley's observations had been private property, and were published as such. The result of Maskelyne's action was the accumulation and rapid dissemination of a long series of observations which from their continuity and accuracy have been of inestimable value to astronomers, and form along with the *Nautical Almanac* his most lasting monument. The whole work of the observatory was carried on by him and his one assistant in a most methodical manner, Greenwich being in point of organization second to none amongst the observatories of the day. He introduced several improvements in the use of the instruments, being, for example, the first astronomer who measured to tenths of a second; and he prevailed upon the Government to replace Bird's mural quadrant, which had become untrustworthy, by a repeating circle of 6 feet in diameter. The new instrument was constructed by Troughton; but Maskelyne did not live to see it completed. In 1772 he suggested to the Royal Society the famous Schehallion experiment for the determination of the earth's density. Forty years previously Bouguer had demonstrated by experiment that Chimborazo in South America affected the direction of the plumb-line quite appreciably; but his observations were not made with sufficient care to deduce therefrom any trustworthy result. Maskelyne's experiments were made in 1774 (see *Philosophical Transactions* for 1775), the apparent difference of latitude between two stations on opposite sides of the mountain being compared with the real difference of latitude obtained by triangulation. From Maskelyne's observations Hutton deduced by laborious calculations that the density of the earth was 4·5 times that of pure water. Playfair subsequently estimated with greater accuracy the mass of Schehallion, and obtained 4·7 for the earth's mean density. Maskelyne also took a great interest in various geodesical operations, notably the measurement of the length of a degree of latitude in Maryland and Pennsylvania (*Philosophical Transactions*, 1769), which was carried out by Mason and Dixon in 1766-68, and later the determination of the relative longitude of Greenwich and Paris (*Philosophical Transactions*, 1787). Cassini, Legendre, and Méchain conducted the triangulation on the French side; on the English side the work was carried on under the superintendence of General Roy. This triangulation was the beginning of the great trigonometrical survey which has since been extended all over the country. A volume of *Selections* (London, 1812) contains several papers that were published by Maskelyne as additions to the *Nautical Almanac*. His observations fill three large folio volumes, and many of them were reprinted in Vince's *Astronomy*.

MASKINONGE. See PIKE.

MASOLINO DA PANICALE (1383–*c.* 1440). The life and art-work of this Florentine painter were related by Vasari in a form which is partly demonstrated and partly inferred to be highly incorrect. We shall follow the account supplied, and in many respects carefully vouched, by Messrs Crowe and Cavalcaselle.

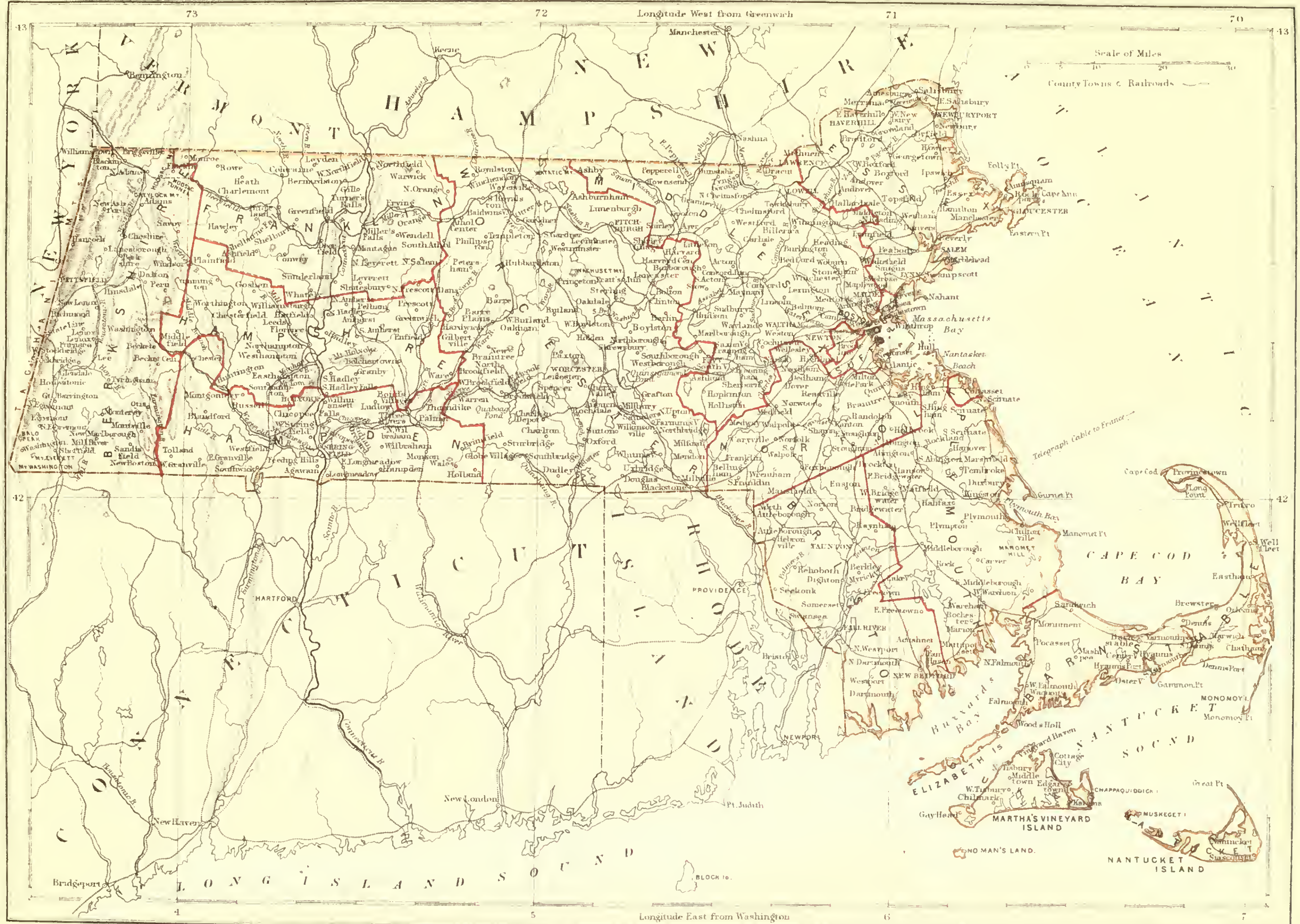
Masolino (a name which corresponds to "Tommy") was said to have been born at Panicale di Valdelsa, near Florence. It is more probable, however, that he was born in Florence itself, his father, Cristoforo Fini, who was an "imbiancatore" or whitewasher, having been domiciled in the Florentine quarter of S. Croce. There is reason to believe that Tommaso, nicknamed Masolino, was a pupil of the painter Starnina, and was principally influenced in style by Antonio Veneziano; he may probably enough have become in the sequel the master of Masaccio. His birth took place in 1383; his death later than 1429, perhaps as late as 1440. The only works which can with certainty be assigned to him are a series of wall paintings executed towards 1428, commissioned by Cardinal Branda Castiglione, in the church of Castiglione d'Olona, not far from Milan, and another series in the adjoining baptistery. The first set is signed as painted by "Masolinus de Florentia." It was recovered in 1843 from a coating of whitewash, and is not a little damaged; its subject-matter is taken from the lives of the Virgin and of Sts Lawrence and Stephen. The series in the baptistery relates to the life and death of John the Baptist. The reputation of Masolino had hitherto rested almost entirely upon the considerable share which he was supposed to have had in the celebrated frescos of the Brancacci chapel, in the church of the Carmine in Florence; he was regarded as the precursor of Masaccio, and by many years the predecessor of Filippino Lippi, in the execution of a large proportion of these works. Now, however, from a comparison of the Castiglione with the Brancacci frescos, and from other data, it is greatly doubted whether Masolino had any hand at all in the latter series. Possibly he painted in the Brancacci chapel certain specified subjects which are now either destroyed or worked over. Of other and still existing subjects, hitherto assigned to Masolino on the authority of Vasari and later writers, the authorship is now more reasonably ascribed to Masaccio,—except only that one compartment, that which represents in one half Peter reviving Tabitha (or curing Petronilla), and in the other half Peter and John healing a cripple, remains in suspenso between Masaccio and Masolino. In the Castiglione frescos there is some tenderness of expression, and the nude figures are studied with an amount of care superior to their epoch; generally the parts are well made out, but without unity of composition, or mastery of perspective, or of contrast and chiaroscuro. The merit of these works is not to be compared with that of the Brancacci frescos, unless in the single instance above excepted.

The now ascertained facts of Masolino's life are that towards 1423 he entered the service of Filippo Scolari, the Florentine-born obergespan of Temeswar in Hungary, that he stayed in consequence some time in that country, and that, returning towards 1427 to Italy, he painted the works in Castiglione. Thus he resettled in Lombardy, not in Florence; nor is there anything to show that he returned to his Tuscan home at a later date.

MASON, FRANCIS (1799–1874), an American missionary, son of a shoemaker in York, England, was born April 2, 1799. After emigrating to the United States in 1818, he practised there the trade he had learned from his father; but, having studied languages with his minister at Canton, Massachusetts, he in 1827 entered the Newton theological institution. In 1830 he was sent by the American Missionary Union to labour among the Karens in Burmah, where he translated the Bible into two dialects of their language, and also conducted a training college for native preachers and teachers. In 1852 he published a book of great value on the fauna and flora of British Burmah, of which an improved edition appeared in 1860 under the title *Burmah, its People and Natural Products.* He was also the author of a grammar and vocabulary of the Pali language, besides various translations from it and other Indian dialects. He died at Rangoon, March 3, 1874. See his autobiography, *The Story of a Working Man's Life, with Sketches of Travel*, 1870.

MASON, GEORGE HEMMING (1818–1872), A.R.A., was born at Whitley, in 1818, the eldest son of a Staffordshire county gentleman. Intended for the medical profession, he studied for five years under Dr Watt of Birmingham; but he had no taste for science; all his thoughts were given to art. In 1844 he abandoned medicine and travelled for a time on the Continent, visiting France, Germany, and Switzerland, and finally settling in Rome. His pencil was busy with the picturesque scenery that surrounded him, and with hardly any instruction, except that received from nature and from the Italian pictures that met his eye, he gradually acquired the painter's skill. At least two important works are referable to this period,—Ploughing in the Campagna, shown in the Royal Academy of 1857, and In the Salt Marshes, Campagna, exhibited in the following year. After Mason's return from the Continent, in 1858, when he settled at Wetley Abbey, he continued to paint Italian subjects from studies made during his foreign tour, and then his art began to touch, in a wonderfully tender and poetic way, the peasant life of his native England, and especially of his native Staffordshire, and the homely landscape in the midst of which that life was set. The first picture of this class was Wind on the Wolds, and it was followed—along with much else—by the painter's three greatest works—the Evening Hymn, 1868, a band of Staffordshire mill-girls, seen, their figures dark against the sunset, returning from their work, singing as they walk; Girls Dancing by the Sea, 1869; and the Harvest Moon, 1872. Mason had long suffered from heart disease, which carried him off on the 22d of October 1872. In his work he laboured under the double disadvantage of feeble and uncertain health, and a want of thorough art-training, and consequently his pictures were never produced easily, or without strenuous and long-continued effort. His art is great in virtue of the solemn pathos which pervades it, of the dignity and beauty which it reveals in rustic life, of its keen perception of noble form and graceful motion and of rich effects of colour and subdued light. In *motif* and treatment it has most in common with the art of Millet and Jules Breton, and of Frederick Walker among Englishmen. An interesting collection of Mason's pictures was brought together by the Burlington Club shortly after his death.

MASON, WILLIAM (1725–1797), was about the beginning of the last quarter of the 18th century one of the most eminent of living poets, but his eminence was owing to the lowness of the poetic level at the time. He is now held in remembrance, not by his poetry, but by his having been the friend, the literary executor, and the biographer of Gray. Born in 1725, the son of a Yorkshire clergyman, entered of St John's College, Cambridge, in 1742, he took his bachelor's degree in 1745, and seems to have at once decided steadily on a literary career, reading little or nothing, Gray says, but writing abundance. Pope died in 1744, and the aspiring young poet lamented him as "Musæus" in a careful imitation of Milton's *Lycidas*, showing an ear for the music of verse and considerable skill in weaving words together, but not a spark of original force. By his *Musæus* (1747) Mason attracted the


Longitude West from Greenwich
Longitude East from Washington
Scale of Miles
County Towns & Railroads
NEW YORK
VERMONT
NEW HAMPSHIRE
CONNECTICUT
RHODE ISLAND
ATLANTIC OCEAN
Massachusetts Bay
CAPE COD BAY
NANTUCKET SOUND
LONG ISLAND SOUND
Buzzards Bay
MARTHA'S VINEYARD ISLAND
NANTUCKET ISLAND
ELIZABETH IS.
NO MAN'S LAND
BLOCK I.
Telegraph Cable to France
HARTFORD
PROVIDENCE
NEWPORT
New London
New Haven
Bridgeport
PITTSFIELD
WORCESTER
LOWELL
LAWRENCE
SALEM
GLOUCESTER
NEWBURYPORT
FALL RIVER
NEW BEDFORD
TAUNTON
FITCHBURGH
Plymouth
Provincetown

notice of Gray, and through his influence was elected a fellow of Pembroke College. Mason was Gray's attached friend, admirer, and poetical pupil to the end of the greater poet's life. More fancy than judgment, and indolence in reading, were the chief faults that Gray found in his young friend. With his usual penetration, Gray discerned the defects of intellect that lie at the root of the weakness of Mason's poetry. He was painstaking enough and more than enough with his verses, his epithets, his phrases, his figures of speech, his rhymes; but he was deficient in energy of thought, his intellectual grasp was feeble, and he accepted and polished the easy suggestions of fancy instead of exerting himself to find exact expression for his subject. For a modest youth, as Gray describes him, he formed a great ambition, nothing less than the reconciliation of the modern with the ancient drama, to be effected by the strict observance of the unities and the restoration of the chorus. His *Elfrida*, a tragedy published in 1752 in pursuance of this ambition, is constructed elaborately upon deeply considered principles, but the principles are drawn from pedantic books and not from the dramatic needs of men, as may be judged from the dramatist's opinion that Shakespeare, "in compliance merely with the taste of the time, showed a disregard of all the necessary rules of the drama." *Elfrida* is highly "incorrect" in two respects—one venial in a play, the other fatal; it abounds in anachronistic allusions and moral improbabilities. Mason's second attempt, *Caractacus* (published in 1759), is much stronger in construction and situation, but he did not possess the rare art of making his characters speak out of their own thoughts; they only speak as Mason the poet might have done in their circumstances if his fancy had been quite cool. Both *Elfrida* and *Caractacus* were acted in 1776, when Mason had made a considerable reputation by his *English Garden* (a poem in blank verse, first book published in 1772), his *Heroic Epistle to Sir W. Chambers* in 1773, and his *Memoirs of Gray* in 1775. The plays were not successful; Mason did not expect success; his plays were intended to be read as poems. The manager perhaps had hopes from the novelty of the choruses of Saxon maidens and Druids. The second book of the *English Garden* was issued in 1777, the third in 1779, the fourth in 1782. Mason took orders in 1754, and soon afterwards was presented to the vicarage of Ashton in Yorkshire, the canonry of York, the prebend of Driffield, and the precentorship of York cathedral. Ashton was his residence till his death in 1797.

MASON AND DIXON'S LINE, a line in the United States between Pennsylvania on the north and Delaware, Maryland, and West Virginia on the south, coinciding with 39° 43′ 26″·3 N. lat., and famous for a long time as the limit between the "free" and the "slave" States. It derives its name from Charles Mason, F.R.S. (1730–87), and Jeremiah Dixon, two English astronomers who, between 1763 and 1767, surveyed the line for 244 miles west from the Delaware river, leaving only 36 miles of the Pennsylvania boundary to be fixed in 1782–84. This line must not be confounded, as has often been done, with the parallel of 36° 30′ N. lat., which was assigned by the "Missouri compromise" of 1820 as the limit to the north of which slavery could not be introduced.

MASS. See EUCHARIST and MISSAL.

MASSA, or, to distinguish it from several places of the same name, MASSA CARRARA, a city of Italy, the chief town of the province of Massa, lies on the left bank of the Frigido, a small stream falling into the Gulf of Genoa about 3 miles lower down. It is 78½ miles south-east of Genoa by rail, and 26 miles north of Pisa. The ancient part of the city stands on a hill. Among the objects of interest it is sufficient to mention the old ducal palace, the new cathedral (erected instead of the building destroyed by Elisa Bacciocchi because it interfered with the view from the palace windows), the technical school, and the academy of science and literature, originally known as Dei Derelitti. Like Carrara, Massa is largely engaged in the marble trade; it also manufactures silk, oil, and paper. The population of the city was 4786 in 1871; that of the commune was 15,017 in 1861 and 18,031 in 1881.

Massa is first mentioned in the 9th century. About the close of the 10th it was bestowed by Otho the Great on the bishops of Luni, and in consequence it came to be distinguished for a time as Massa Lunense. From the bishops it passed to the marquises of Luni (hence *Massa del Marchese*), and more particularly to a branch of the Malaspina family. After a period in which Lucca, Pisa, the Visconti, the Fieschi, and others were successively in possession it returned, under Florentine protection, to Alberico Malaspina, and finally through the marriage of Ricciarda Malaspina with Lorenzo Cybo became (1519) *Massa Cybea.* Raised under Alberico Cybo from being little better than a feudal village to the rank of a fortified town, Massa was in 1568 made the capital of a principality by Maximilian II., and in 1664 the capital of a duchy by Leopold I. By the marriage of Maria Teresa dei Cybei with Duke Ercole III. of Modena it passed to the Este family; and after the period of the French Revolution, during which it formed part of the duchy of Lucca assigned to Napoleon's sister and brother-in-law, it was restored by the congress of Vienna to Beatrice, duchess of Modena. Massa was made an episcopal see only in 1828, though the design of giving it this dignity had been entertained and almost realized in 1757. The total area of the duchy of Massa and Carrara was 62 square miles, of which 35 belonged to Massa.

See Repetti, *Diz. della Toscana*; Viani, *Memorie della famiglia Cybo*; Musellini, *Ricciarda Malaspina e Lorenzo Cybo*; and Farsetti, *Ragion. storico int. della città di Massa.*

MASSACHUSETTS

MASSACHUSETTS, an Indian name originally applied to a small hillock bordering on Boston Harbour, and thence to a neighbouring tribe of Indians. It is the chief political division of New England, and one of the original thirteen States of the American Union. It lies for the most part between 40° and 42° 45′ N. lat., and 70° 30′ and 73° 30′ W. long. Plate IX.

Physical Description.—Its area, of about 7800 square miles, forms in the main a parallelogram, of 160 miles east and west, 50 miles north and south,—with a projection at the south-east and a lesser one at the north-east, which gives a breadth of 90 miles at this part, where it borders upon the ocean, while the general irregularity of this coast-line gives a sea frontage of about 250 miles. No large navigable river flows in any part, though the Connecticut river, bisecting the State during 50 miles of its course, and fed within it by several lateral streams, has been made navigable for small craft. The Housatonic, a lesser stream, flows parallel with the Connecticut, farther west. The two valleys are separated by the Hoosac range (1200 to 1600 feet high) of the Berkshire Hills, a part of the Appalachian system, and a continuation of the Green Mountains of Vermont. These, with the Taconic range on the western side of the Housatonic valley, of which the highest peak is Greylock, or Saddleback (almost 3500 feet), in the extreme north-west corner of the State, form the only considerable elevated land. Bordering on the Connecticut, Mount Tom (1200 feet) and a few other hills form conspicuous landmarks. Wachusett (2018 feet), farther east, rises from a level country. The Blue Hills in Milton are the nearest elevation to the coast, and are conspicuous to navigators approaching Boston.

The Merrimac runs for 35 miles through the north-east corner of the State, and affords valuable water-power at Lowell, Lawrence, and Haverhill. A few small streams, useful for mill purposes and irrigation, seek the ocean through Boston, Buzzard's, and Narragansett Bays, running for the most part through a rolling country. The south-east parts of the State are level,—with a slightly elevated ridge (Manomet) south of Plymouth,—sandy in soil, with tracts of forest, largely white pine, and well watered by ponds. Between Plymouth and Buzzard's Bay there is the most considerable region of untamed soil in the State, where deer are occasionally seen.

South of Cohasset the shore is sandy, with a few isolated rocky ledges and boulders. About Boston, and to the north of it, the shore is rocky and picturesque. Massachusetts Bay is a name now applied to the gulf of which the outer limits are Cape Cod and Cape Ann; but in early days it was applied to the enclosed lesser bay on its western side, now called Boston Harbour, the finest roadstead on the coast. The extreme hook of the Cape Cod peninsula forms Provincetown Harbour, which is an excellent and capacious port of refuge for vessels approaching Boston. Salem Harbour is the most considerable other haven on the bay; while on Buzzard's Bay New Bedford has a good harbour.

The principal islands lie off the southern coast. The largest is Martha's Vineyard, 21 miles long, with an average breadth of 5 or 6. It has in Holmes's Hole a spacious harbour, much frequented by wind-bound vessels seeking a passage round Cape Cod. The island is interesting as the scene of Mayhew's missionary efforts among the Indians, and it still harbours a remnant of a tribe. It has a population (4300 in 1880) formerly dependent wholly upon the sea; and of late years it has become a summer resort of much popularity. Farther east, Nantucket, an island of triangular shape, 15 miles long and 11 wide at its eastern end, is likewise the home of a seafaring folk (population in 1880, 3727), who still retain in some degree primitive habits, though summer visitors are more and more affecting its life. Nantucket Shoals, south-east of the island, is a large sandbank dangerous to navigation.

Flora and Fauna.—The original native trees and plants did not vary from what is common to New England and northern New York. The presence of a dense population has driven some out, and brought in others, including some noxious weeds. The larger wild animals have disappeared except an occasional deer; but small game still runs, and even within the municipal limits of Boston wild foxes are occasionally killed. No very large birds frequent the State, though a stray eagle is sometimes seen. Reptiles of a harmless kind are found, and three kinds of venomous snakes,—the latter even near Boston, particularly in the Blue Hills of Milton. Fish are abundant on the coast, and the cod is sometimes used as an emblem of the State, a figure of one hanging in the Representatives' Chamber at the State House. The artificial propagation and preservation of salmon and other edible pond and river fish have been of late carried on successfully under the supervision of a State commission

Geology.—Professor N. S. Shaler of Harvard University says: "Geologically as well as topographically, the State is divided into four districts, which extend farther than the State limits. In the south-eastern part the whole of Cape Cod and Plymouth county is made up of rearranged glacial drift. Westward, from the shore region to the Connecticut, the rocks are of the Laurentian, Cambrian, and Carboniferous ages. The Connecticut river flows through a basin of Triassic rocks, abounding in reptilian footprints. West of this basin, to the New York line, the surface is occupied by an extensive series of highly metamorphosed rocks, the age of which is doubtful; but the series is certainly as old as the Silurian. The whole surface of the State was greatly affected by the last glacial period, as much so as Scotland or Sweden.

"The economic resources are limited. An area of about 250 square miles in the south-eastern part of the State shows Carboniferous rocks, containing several coals. The deep drift coating, the profoundly dislocated character of the beds, and the graphitic nature of the coals have made mining unsuccessful. Mines of silver-bearing lead have at times been worked in the north-eastern shore districts, and in the Connecticut valley, but without profit. Emery is now successfully worked in the western district. There are also deposits of hematite iron ores all along the border of New York, which are considerably worked. There are numerous quarries of sienite in the eastern parts of the State, some of red sandstone in the Connecticut valley, and of white marble in the western regions."

Climate.—The climate is a trying one, showing great extremes (20° Fahr. below and 100° above), with about 42 inches of rainfall. The mean average temperature of Boston is 48° Fahr. In the interior it is a trifle lower. Changes are often sudden, and the passage from winter to summer is by a rapid spring. The ocean tempers the climate considerably on the seaboard. Boston harbour has been frozen over in the past, but steam-tugs plying constantly prevent now the occurrence of such obstruction.

Agriculture.—The soil, except in some of the valleys, can hardly be called naturally fertile; and sandy barrens are common in the south-eastern parts. High cultivation, however, has produced valuable market-gardens about Boston and the larger towns; and industry has made the tilling of the earth sustaining in most other parts; while the average sterility of the soil has doubtless had a strong influence in developing a sturdy yeomanry in the rural regions.

In 1875 671,131 tons of hay were cut. On the seaboard some extensive salt marshes yield a hay which is much prized. The corn crop diminished one half from 1855 to 1875. The State produced in 1880 1,797,593 bushels of Indian corn, 15,768 of wheat, 645,159 of oats, 80,128 of barley, 213,716 of rye, 67,117 of buckwheat. In 1879 the average cash value per acre of principal farm-crops was $26·71, which amount is exceeded only in Rhode Island. In the Connecticut valley tobacco is grown, 3358 acres being given to it in 1880, producing 5,369,436 lb, which gives the State the thirteenth rank in the Union. In forty years the sheep have fallen from 384,614 to 65,123 in 1880; and in the same year there were 139,861 horses and 174,859 cows. In 1880 there were 38,406 farms, of which 35,266 were owned by occupants. Most of them were between 20 and 500 acres each, nearly 12,000 having over 100 acres.

The Population and its Condition.—The State is divided into twelve congressional districts, each entitled to one representative in the Federal Congress, and representing from 151,000 to 181,000 inhabitants. It is divided also into 346 towns, and these are grouped into 14 counties, with an aggregate in 1880 of 1,783,085 inhabitants, of whom the native-born are 1,339,594, and the foreign-born 443,491. This population was divided into 379,710 families, living in 281,188 dwellings, with nearly 222 persons to the square mile, and less than an average of 3 acres to each person. Nearly every fifth person is a voter. The total vote in the presidential campaign of 1880 was 282,512. The number of persons born within Massachusetts, and living in 1880 out of the State, but within the limits of the United States, was 1,356,295. The population at past censuses has been—

1790	378,787	1840	737,699
1800	422,845	1850	994,514
1810	472,040	1860	1,231,066
1820	523,159	1870	1,457,351
1830	610,408	1880	1,783,085

There were, in 1880, 31 cities and towns of over 10,000 inhabitants.

Births and Deaths.—It is calculated that to every 1000 inhabitants the births are more than 23, the marriages about 8, the deaths 18¼, the excess of births over deaths being nearly 5. In 1880 44,217 were born, and 15,538 couples were married, while 35,292 persons died, at an average age of thirty-two years. Taking persons over twenty years of age, the deaths in $37\frac{3}{12}$ years were 187,264, with an average age of 51·42. During sixteen years the average age at death of all conditions was 30·18 years. In twenty years the birth-rate to 1000 persons was 26·2, the death-rate 19·7.

Health.—A board of health, lunacy, and charity supervises the public hygiene, and the institutions for the insane and paupers. By their reports of 1880 it appears that the prominent causes of death are for the ages from birth to five—diarrhœa, diphtheria, pneumonia, scarlet fever, and obscure diseases of the brain and intestines; from five to ten—infectious diseases and obscure diseases of childhood; from ten to fifteen—diphtheria, consumption, and typhoid fever; from fifteen to twenty—consumption and typhoid fever; from thirty upward—pneumonia and heart disease, with cancer from forty to sixty. Paralysis and apoplexy gain after forty, and after seventy the greatest portion die of old age. The twelve principal causes of fatality in all ages are placed in this order:—consumption, pneumonia, diphtheria, heart disease, old age, cholera infantum, paralysis, cancer, scarlet fever, cephalitis, bronchitis, and apoplexy; and by these disorders 60 per cent. of all deaths occur. Intermittent fever was known in the earlier history of the State, but in this century, before 1877, was practically unknown, except in the form of an occasional epidemic; but since that date it has made rapid progress in the western parts.

Paupers.—Other tables of the same board show that in July 1880 19,318 paupers were receiving, wholly or in part, local or State support; and the same was true of about 3000 insane persons. The average number of inmates of these charitable establishments (State, city, and town) in 1880 was 7467 persons. At public and private insane asylums there were 4398 cases within the year.

Immigration.—The immigrants from Europe during the year ending September 30, 1880, were 33,636 in number, of whom one-third were Irish, and the males in comparison with the females were as 18 to 15. A large part of this influx merely passed through the State to the west.

Business and Finance; Commerce and Manufactures.—Up to 1830 the commerce of the State found various outlets besides Boston; but since then this city has more and more absorbed the whole foreign trade. The whaling business still remained to other ports, and at one time gave occupation to a thousand ships. The introduction of petroleum gradually diminished this resource of the lesser ports.

The packing of pork and beef was formerly centred in Boston; but, while now a similar business tenfold as large is done, it has been greatly exceeded in the west. For many years Massachusetts controlled a vast lumber trade, drawing upon the forests of Maine, but the growth of the west has changed the old channels of trade, and Boston carpenters now make large use of western lumber. The American trade with China and India was begun in Salem, and was next controlled in Boston, till this also was lost some years ago to New York. In commercial relations the chief port of Massachusetts attained its highest influence about forty years ago, when it was selected as the American terminus of the first steamship line (Cunard) connecting England with the United States, but Boston lost the commercial prestige, then won, by the failure of the State to develop railway communication with the west, so as to equal the development effected by other cities. It was between 1840 and 1850 that the cotton manufactures of Massachusetts began to assume large proportions; and about the same time the manufacture of boots and shoes centred here, and has ever since maintained its prominence, much more than one-half of all boots and shoes manufactured in the country being the product of this State. Again, ice and granite became important articles of export; and Quincy granite, from 1849, was sent to various southern ports, having an importance as a building-stone which it has hardly lost now, with the later multiplication of varieties of such stones. Medford ships began to be famed shortly after the beginning of the century, and by 1845 that town employed one quarter of all the shipwrights in the State. From 1840 to 1860 Massachusetts-built ships competed successfully for the carrying trade of the world. Before 1840 500 tons made a large ship, but after the discovery of gold in California the size of ships increased rapidly, and the lines of their models were more and more adapted to speed. The limit of size was reached in an immense clipper of 4555 tons, and the greatest speed attained in a passage from San Francisco to Boston in seventy-five days, and from San Francisco to Cork in ninety-three days. The development of steam navigation for the carrying of large cargoes has driven this fleet from the sea. Hardly 18 per cent. of the exports and imports through Massachusetts is now carried in American bottoms. The grain elevators, which pour corn in bulk into ships at Boston to-day for European markets, are the result of the first attempt at such transportation, made in 1843, when citizens of Massachusetts sent corn to starving Ireland.

Coastwise steam lines, supported by Massachusetts capital, had run to Philadelphia and Baltimore for some years before the civil war broke up other less successful ones, which had connected ports further south. When the war and steam navigation put an end to the supremacy of Massachusetts wooden ships, much of the capital which had been employed in navigation was turned into developing railroad facilities, and coastwise steam lines. An effort to establish a European steam line failed. In 1872 the great fire in Boston, destroying $72,000,000 worth of property, made large drains upon the capital of the State, and several years of depression in business followed, to be succeeded by an era of business prosperity still continuing. The imports of Boston—practically of Massachusetts—for 1880 were $68,649,664; the exports, $69,178,764. In 1880 322 steamships sailed from Boston for European ports. In 1880 180 steam craft were owned in Massachusetts, with a capacity of 48,917 tons. Massachusetts had in 1880 a fleet of 376 sail of cod-fishing vessels, manned by 4185 men,—three quarters of all belonging to one port, Gloucester. In mackerel catching 239 vessels are employed. In 1882 20,117 persons were actively engaged in the fisheries, and it was estimated that 100,000 people depended on them for support. The capital invested is $14,334,450, and the product is worth $8,141,750. The total tonnage of the State in 1881 was 430,182, which gave the State rank after New York and Maine. In 1880, of 39,921 business houses, 329 failed, with liabilities at $3,336,954.

A general Act of 1870, with supplements of later years, allows of the incorporation of companies under it, and in 1880 such corporations, so organized, had $30,150,255 capital,—and this was in some part money disengaged of late years from navigation and its attendant branches of trade.

While the capital of the State may not have developed even yet, as it might, all that is possible for a system of railway communication with the west, it has fostered, and made possible, large facilities in the States of the Mississippi valley and beyond, which may in time so enlarge the terminal facilities of the State's chief port as to make it a more important outlet for export of the produce of the west, and give it a distinction justly its due from its geographical position.

In the working of ores the State is not prominent. Five furnaces in 1880 yielded 19,000 tons of pig iron. In wool, the Boston market is the largest in the country. The State has far more spindles (4,465,290) in cotton manufacture than any other State, and not much short of half the number in the whole United States (10,921,147). She employs in this business 62,794 hands, or about one third of the entire force so employed in the United States.

Massachusetts is the only State in the east, manufacturing textile fabrics, where ten hours is the operative's day; and it is reported by the State bureau of statistics that, equal grades being considered, as much is produced under her system, per man, loom, or spindle, as in States where eleven hours or more is the rule, and that the Massachusetts operative earns as much or more per day. Canadian French now constitute a considerable proportion of the factory hands. In certain departments of labour Chinese are beginning to find employment.

Formerly farmers' daughters of native stock were much employed in factories. Operatives of foreign birth or parentage have taken in great part their places; and those of native stock have sought other occupations,—largely in the manufacturing of small wares in the cities, and particularly in departments of trade where skilled labour is essential. Household service is seldom now done, as it formerly was, by women of native stock,—persons of Irish, Swedish, and Scottish origin, with many from Nova Scotia and New Brunswick, taking their places.

Railways.—The report of the Railroad Commissioners for 1880 shows twenty-nine street railways; capital, $6,144,000; assets, $10,173,079·84; total income, $3,711,378·18; expenses, $3,003,024·87; length of roads, 240 miles; miles run, 12,516,363; passengers carried, 68,631,842.

Of steam railways there were 3044 miles of single track, of which 1893 were main lines; and 27,057 Massachusetts stockholders held $78,806,559·95 capital stock of the total of $118,738,871·58; and 21,615 persons were employed. The total income of these roads was $35,140,374·77; and the dividends declared were $5,987,718·64. Total passengers carried, 45,151,152; freight carried, 17,221,567 tons. There were to passengers in 1880 nine fatal and fifteen other accidents; and one hundred and fifty-seven other persons were injured on the roads.

The Hoosac Tunnel—after that of Mont Cenis the longest in the world, 5¾ miles in length—pierces the Hoosac mountain in the north-west corner of the State, and opens a second direct railway communication with western lines, that of the Boston and Albany having been long without a rival. It cost $9,000,000, the State lending its credit, and was built between 1855 and 1874.

Savings Banks, &c.—In 1880 the number of open accounts was 706,395; amount of deposits, $218,047,922·37 (only exceeded in New York); amount of earnings, $11,894,710·60; ordinary dividends, $7,957,887·09; annual expenses, $581,274·35; number of outstanding loans (none exceeding $3000) 32,320, aggregating $34,203,951·81. The number of banks in 1880 was 164, against 22 in 1834. The number of co-operative saving fund and loan associations was 16, with $372,462·31 assets.

National Banks.—The report of the comptroller of the currency for 1880 says: "The thirteen States having the largest capital [in national banks] are Massachusetts, New York, Pennsylvania, &c. . . . in the order named." In 1879 the capital of national banks in Massachusetts was $94,748,172, that of New York being $85,706,942. In 1881 there were 242 such banks, with $95,605,000 capital, and $525,827 dividends, and in 1880 they issued $3,693,885 in circulating bills,—Pennsylvania with $2,036,890 coming next.

A report to the commissioner of internal revenue, for the six months ending May 31, 1880, shows Massachusetts to have 218 banking and trust companies, private bankers, and savings banks (not organized under the national law), with an aggregate capital of $5,638,099; average deposits to the amount of $208,822,039. These banks also held investments in United States bonds, amounting to $22,909,377.

Public Debt, &c.—The public debt of the State, January 1, 1881, was $32,799,464; the sinking funds, $13,050,192·20; the trust funds $2,890,650·92. The total taxable value was $1,927,855,430·09. The taxes produced $4,950,000. The rate of State taxation is much smaller than that of any other State. The State receipts were on account of revenue $7,881,198; on account of funds, $5,616,418, or $13,497,616 in all.

The Boston stock exchange stands next to New York in the extent of the securities in which it deals.

Citizens of Massachusetts (16,855 in number) hold 45,138,750 of the United States bonds, and the proportion of holders (23·04 per cent.) to the population of the State is in excess of that of all other States; New York, which is next, shows 20·24 per cent.

In 1881 the State contributed $2,699,681 as internal revenue to the Federal treasury, being a twelfth rank among the States and Territories.

Social Statistics.—Intellectual Life.—No statement of the influence which Massachusetts has exerted upon the American people, through intellectual activity and even through vagary, is complete without an enumeration of the names which, to Americans at least, are the signs of this influence and activity. In science, John Winthrop, the most eminent of colonial scientists; Benjamin Thompson (Count Rumford); Nathaniel Bowditch, the translator of Laplace; Benjamin Peirce; and Morse the electrician; not to include an adopted citizen in Louis Agassiz. In history, Winthrop and Bradford laid the foundations of her story in the very beginning; but the best example of the colonial period is Thomas Hutchinson, and in our day, Bancroft, Sparks, Palfrey, Prescott, Motley, and Parkman. In poetry, the pioneer of the modern spirit in American verse was Richard Henry Dana; and later came Bryant, Longfellow, Whittier, Lowell, and Holmes. In philosophy, and the science of living, Jonathan Edwards, Franklin, Channing, Emerson, and Theodore Parker. In oratory, James Otis, Fisher Ames, Josiah Quincy, jun., Webster, Choate, Everett, Sumner, Winthrop, and Wendell Phillips. In fiction, Hawthorne and Mrs Stowe, not to embrace the living and younger names of Howells and Aldrich. In law, Story, Parsons, and Shaw In polite scholarship, Ticknor and Hillard. In art, Copley, Gilbert Stuart, Washington Allston, William M. Hunt, Horatio Greenough, W. W. Story, and Thomas Ball. What in America was called the "transcendental movement"—which sprang out of German affiliations, and swept in its train many scholarly persons, and resulted in the well-known community of Brook Farm, under the leadership of the late Dr George Ripley—was a growth of Massachusetts, and in passing away it left, instead of traces of an organization, a sentiment and an aspiration for what was called a higher thinking, which gave Emerson his friendly sympathizers. It might go without saying that a community which fostered such persons and feelings was not at all times free from riotous and unbalanced ideas, which could inaugurate too many departures from the common course of wisdom.

Education.—Of the 307,321 children between five and fifteen in Massachusetts, 281,757 attend the public schools, in addition to 25,020 over fifteen, and 1833 under five; while 27,370 of all ages attend charitable, reformatory, and private schools. The public schools are 5570 in number; the academies and private schools, 423. The cost of maintaining the public schools is $5,156,731 per annum. This expenditure is exceeded only in the States of New York, Illinois, Pennsylvania, and Ohio. It is a little more in Iowa. A board of education (the governor, lieutenant-governor, and eight others) have the general charge, and their secretary acts as superintendent of the State system in conjunction with local superintendents and committees. Women are eligible to these positions, and among the teachers of the public schools they are largely in excess,—7462 women and 1133 men; and of the combined number (8595) 2228 had attended normal schools. The male teachers on an average receive $67·54 per month; the women, $30·59. The system includes common, high, and normal schools, with one normal art school, and various evening, industrial, and truant schools. No discrimination is made as to race, colour, or religious views. The average attendance is 89 per cent. of the membership. Two-fifths of one per cent. of the native population are illiterate. The State normal schools, where the teachers are trained, are five in number, besides the art school. The attendance upon them was 841 in 1880. Some of the cities and towns maintain their own training schools. Meetings of teachers are held once a month or oftener in various parts of the State, for comparison of views and experience.

The high schools are 215 in number, with 18,758 pupils and 491 teachers; and other secondary instruction is given in the business colleges, private academic schools, and the more distinctive preparatory schools, which send their graduates to the colleges. Of these last the most important is Harvard College, the chief department of what is known as Harvard University, which includes in addition various professional schools, and other colleges of special studies. This university in 1882 had 1382 students, with a staff of 200 officers and instructors; and of these students 823 belong to the academic department (Harvard College), where they are allowed wide latitude in the choice of the studies pursued. The classes of undergraduates are recruited largely from the State; but the establishment of examinations for admission in distant cities, like Philadelphia, Cincinnati, St Louis, and San Francisco, is increasing the proportion who come from other parts of the country. Harvard University is mainly at Cambridge, 3 miles from Boston, but some of the departments are in the latter city.

In the extreme west of the State is Williams College, which in 1880 had 227 students; and in the Connecticut valley is Amherst College, with 339 students. Boston University, in its several departments, had 510 students in 1880; and Tufts College, a few miles from Boston, an institution supported by the Universalist sect, had 63 students. Two Roman Catholic colleges are maintained,—Boston College with 80 students, and College of the Holy Cross, at Worcester, of about the same size. Of the various institutions for the instruction of women, two rank with the colleges for men,—Smith College at Northampton, and Wellesley College, not far from Boston. The income of college funds ($425,958) is only exceeded in New York ($710,164).

For agricultural students there are two schools,—one supported by the State at Amherst, and the Bussey Institution, a department of Harvard University. In technological science there is special instruction given in the Massachusetts Institute of Technology (Boston), the Lawrence Scientific School (of Harvard University), the Free Institute of Industrial Science (Worcester), and the School of all Sciences (Boston University). In theology, nearly three hundred students in 1880 were divided among the schools at Andover (Congregational), at Boston (in connexion with the university, Methodist), at Cambridge (Harvard University, non-sectarian, and an independent Episcopal school), at Somerville (Tufts College, Universalist), at Newton (Baptist), and at Waltham (New Church). In law there are schools in connexion with both Boston and Harvard universities; and the same is true of medicine, that of the former being of homœopathic tendency. The State is also supplied with special schools of various other sorts, particularly those for deaf mutes, the blind, and the feeble-minded, in which noteworthy methods have been employed with success.

In 1880 the United States patent office issued letters to an average of one inhabitant of the State in every 1333, a degree of inventive energy only exceeded in Connecticut, where the proportion is one in 1020.

The total receipts of the post-office in 1880 were $2,484,692, an amount only exceeded by New York, Ohio, Pennsylvania, and Illinois, while the State stands seventh in population.

The Press.—The earliest printing in the British colonies was done at Cambridge in this State, where, in 1640, the first book was printed, which is known as the "Bay Psalm-Book," being a version of the Psalms, for singing, made in the colony. Cambridge still retains its pre-eminence in the University and Riverside presses. A printing-house was not set up in Boston till 1674. In the early part of this century book printing was done at various country presses; but at present it is all done in Boston, which, with New York and Philadelphia, is now a principal centre of the American book trade.

A single number of two separate ventures to scatter public intelligence had appeared in Boston in 1689 and 1690; but the first regular newspaper was not established till 1704, when the *Boston Newsletter* became the pioneer of the American newspaper press. There is at present no newspaper of much influence printed outside of Boston, except the *Springfield Republican*; and even the Boston newspapers are generally held to be behind those of New York and Chicago in enterprise and power.

In 1880 there were 35 daily newspapers, with 33 others (having an annual circulation for dailies of 86,304,851; for weeklies, &c., of 10,204,537), and 392 periodicals of all kinds issued.

Libraries.—The State is the most richly provided with public collections of books (apart from school libraries) of any in the Union. In the number of volumes the public library of Boston (404,201 in 1882) probably stands at the head of all in the country, though the library of Congress closely follows. Each of these libraries fills its enumeration, however, with large numbers of duplicates,—that at Washington from those received under the Copyright Act, and that of Boston from the extensive provision of extra copies for its ten popular departments, largely counterparts of each other. It is accordingly probable that the library of Harvard University (nearly 300,000 volumes), which has but few duplicates, outranks all others in the country in the count of titles, as it is much the largest of all American academic collections. Of the eight largest libraries in the United States, three are in Massachusetts, the Boston Athenæum, one of the best of the class of proprietary libraries, being counted with the two already named. The State led in the founding of city and town libraries, supported by public taxes, thirty years ago, and has instituted more of them than exist in all the other States combined. After the one at Boston, that at Worcester is the best-known. Collections of fair proportions are attached to the lesser colleges, Amherst, Williams, and Wellesley. The special historical libraries of the American Antiquarian Society at Worcester, the Massachusetts Historical Society, the New England Historic Genealogical Society, and Congregational Library, at Boston, added to the departments of the Harvard and Boston libraries, make Massachusetts exceedingly rich in books upon American history. No one of her libraries has the resources of the rarest of early Americana which will be found in the private collection of the late John Carter-Brown at Providence, and in the Lenox library at New York; but, with access to such private collections as that of Charles Deane at Cambridge, the student of American history is probably at less disadvantage in Massachusetts than in any other library centre in the States, though the value of the Peter Force collection in the library of Congress is not to be forgotten. In science, sections of the Boston public library and the Harvard library are of the most importance, though in physics and natural history the collections of the American Academy of Arts and Sciences (Boston) and of the Boston Society of Natural History may well supplement them. In private libraries the State may claim numbers, rather than individual richness, and is probably surpassed by New York in signal collections. The State itself, in the State House, has a collection of considerable value, confined for the most part to law, public documents, and American history.

Crime.—A board of prison commissioners (three men and two women) report in 1880 3821 persons in confinement, 2070 in county prisons, and 1751 in other institutions. In 1879 there were 16,211 sentences for drunkenness; and during the last twenty years 60 per cent. of all sentences for crime were traceable to liquor, or 340,814, in that time, out of 578,458 sentences. Of this aggregate, 332,495 were against chastity, morality, and decency; 55,327 against property; and 1656 (felonious) and 81,440 (not felonious) against persons. Seventy-five per cent. of criminals are between the ages of eighteen and forty-five.

Fires and Insurance.—The fires in 1880 were 1722 in number (of which 596 were total), causing an aggregate loss of $4,454,221, of which 71 per cent. was paid by insurance companies. The causes were in 383 cases reported unknown, and in 294 incendiary.

In life insurance, six Massachusetts companies have gross assets of $32,939,505 and gross liabilities of $27,546,554; while companies organized without the State and doing business within it have $369,996,657 assets and $328,105,152 liabilities.

Government, Militia, &c.—The State, under the federal constitution, sends two senators to the Congress of the United States, and the most eminent men who have thus represented the commonwealth have been John Quincy Adams, Daniel Webster, Rufus Choate, Edward Everett, and Charles Sumner. The State is also entitled to twelve members of the National House of Representatives.

The executive department of the State Government is confided to a governor, who is aided by a lieutenant-governor, and eight others, representing so many divisions of the State, who, with the governor and lieutenant-governor, constitute the executive council. They are chosen yearly. There are also a secretary of the commonwealth, a treasurer, and auditor. An attorney-general is the State's law officer. The governor, as commander-in-chief of the State militia, has a military staff.

The judges are all appointed by the governor, with the advice and consent of his council, and hold office during good behaviour. The highest court is the supreme judicial court, which has a chief justice and six associate justices. Among the eminent jurists who have been at the head of this court are John Adams, Theophilus Parsons, and Lemuel Shaw. A superior court, with a chief justice and ten associate justices, was established in 1859. Each county has its own courts of probate and insolvency. Various larger cities and towns have police and municipal courts; while groups of towns have district courts.

The legislative departments are the senate, of forty members, chosen by senatorial districts; and a house of representatives, of two hundred and forty members, chosen by districts within the counties. These two bodies form the general court so-called, which is chosen yearly, and it elects its own officers. It meets in the State House, at Boston, a structure prominently placed on the highest point of land in that city, its dome serving as an apex to the elevation of its sky-line. It was built in 1795–97, but has been enlarged since. Before it are statues of Daniel Webster, by Powers, and Horace Mann, by Miss Stebbins, and within are Chantrey's toga-draped statue of Washington (placed there in 1828), and Thomas Ball's statue of John A. Andrew,—the latter the most eminent of the recent governors, whose term of service covered the period of the civil war (1861–65), and who acquired the sobriquet of the "great war governor."

Of the incumbents of the twelve principal offices of the Federal Government, this State has furnished, since the organization under the constitution, 34,—a number exceeded by Virginia (40), Pennsylvania (36), and New York (35).

The enrolled militia (every able-bodied male between eighteen and forty-five years of age in 1880) were 238,762 in number,—the active volunteer militia numbering 334 officers and 4436 enlisted men, organized in two brigades, besides two unattached corps of cadets, one the governor's bodyguard.

History.—It is possible that the coasts of Massachusetts were visited by the Northmen, and by the earliest navigators who followed Cabot, but the evidence is that of conjecture only. Gosnold left the earliest trace of English acquaintance on its shores, when he discovered and named Cape Cod in 1602. Pring and Champlain later tracked them, but the map of Champlain is hardly recognizable. The first sufficient explorations for cartographical record were made by John Smith in 1614, and his map was long the basis—particularly in its nomenclature—of later maps. Permanency of occupation, however, dates from the voyage of the "Mayflower," which brought about a hundred men, women, and children, who had mostly belonged to an English sect of Separatists, originating in Yorkshire, but who had passed a period of exile for religion's sake in Holland. In the early winter of 1620 they made the coast of Cape Cod; they had intended to make their landfall farther south, within the jurisdiction of the Virginia Company, which had granted them a patent; but stress of weather prevented their doing so. Finding themselves without warrant in a region beyond their patent, they drew up and signed, before landing, a compact of government, which is accounted the earliest written constitution in history. After some exploration of the coast they made a permanent landing, December 21, 1620 (new style), at Plymouth, a harbour which had already been so named on Smith's map in 1616. A subsequent patent from the council for New England, upon whose territory they were, confirmed to them a tract of land which at present corresponds to the south-east section of the State. They maintained their existence as a colony, though never having a charter direct from the crown, till 1691, when, under what is termed the Provincial Charter, Plymouth colony was annexed to Massachusetts.

The Massachusetts Company had been formed in England in 1628 for the purpose of promoting settlements in New England. There had been various minor expeditions, during the few years since Smith was on the coast, before this company, in the Puritan interests, had sent over, in 1628, John Endicott, with a party, to what is now Salem. In 1630 the government of the company, with questionable right, transferred itself to their territory, and under the lead of John Winthrop laid the foundations anew of the Massachusetts colony, when they first settled Boston in the autumn of that year. Winthrop remained the governor of the colony, with some interruptions, till his death in 1649, his first rejection coming from a party of theological revolt which chose Henry Vane (later Sir Henry Vane) to the office. The early history was rendered unquiet at times by wars with the Indians, the chief of which were the Pequot War in 1637, and Philip's War in 1675–76; and for better combining against these enemies, Massachusetts, with Connecticut, New Haven, and New Plymouth, formed a confederacy in 1643, considered the prototype of the larger union of the colonies which conducted the War of the Revolution (1775–82). The struggle with the crown, which ended in independence, began at the foundation of the colony, with assumptions of power under the charter,—which the colonial government was always trying to maintain, and the crown was as assiduously endeavouring to counteract. Theological variances and differences of political views led to some emigration of the early colonists to Rhode Island. To secure "more room" led others to go to Connecticut, where they established a bulwark against the Dutch of New York. An inroad of the Quakers disturbed their peace for several years, and led to violent laws against all such aggressive dissentients. After more than a half century of struggle, the crown finally annulled the charter of the colony in 1685, and after a brief temporary sway of Joseph Dudley, a native of the colony, as president of a provisional council, Sir Edmund Andros was sent over with a commission to unite New York and New England under his rule. His government was espoused by a small church party, but was intensely unpopular with the bulk of the people; and, before news arrived of the landing of William of Orange in England, the citizens of Boston rose in revolution (1689), deposed Andros, imprisoned him, and re-established their old colonial form of government. Then came a struggle, carried on in England by Increase Mather as agent of the colony, to secure such a form of government, under a new charter, as would preserve as many as possible of their old liberties. Plymouth colony, acting through its agent in London, endeavoured to secure a separate existence by royal charter, but accepted finally union with Massachusetts when association with New York became the alternative. The province of Maine was also united in the new provincial charter of 1691, and Sir William Phips came over with it, commissioned the first royal governor. He was a native of Maine, a rough sailor, who had got his knighthood because he had raised treasure from a Spanish wreck in the West Indies. He was a parishioner of Mather in Boston, and, it was thought, received the appointment through Mather's influence.

Throughout the continuance of the government under the provincial charter, there was a constant struggle between the prerogative party, headed by the royal governor, and the popular party, who cherished recollections of their practical independence under the colonial charter, and who were nursing the sentiments which finally took the form of resistance in 1775. The popular majority kept up the feeling of hostility to the royal authority in recurrent combats in the legislative assembly over the salary to be voted to the governor. These antagonisms were from time to time forgotten in the wars with the French and Indians, and early in Phips's administration by the unfortunate austerities of the Salem witchcraft delusion. During the earl of Bellomont's administration, New York was again united with Massachusetts, under the same executive. The scenes of the recurrent wars were mostly distant from Massachusetts proper, either in Maine or on Canadian or Acadian territory, although some savage inroads of the Indians were now and then made on the exposed frontier towns, as, for instance, upon Deerfield in 1704, and upon Haverhill in 1708. Phips, who had succeeded in an attack on Port Royal, had ignominiously failed when he led the Massachusetts fleet against Quebec in 1690. The later expedition of 1711 was no less a failure. The most noteworthy administration was that of William Shirley (1741–49 and 1753–56), who at one time was the commanding officer of the British forces in North America. He made a brilliant success of the expedition against Louisburg in 1745, William Pepperell, a Maine officer, being in immediate command. Shirley with Massachusetts troops also took part in the Oswego expedition of 1755; and Massachusetts proposed, and lent the chief assistance in, the expedition to Nova Scotia in 1755, which ended in the removal of the Acadians. Her officers and troops played an important part in the Crown Point and second Louisburg expedition (1758).

The beginning of the active opposition to the crown may be placed in the resistance, led by James Otis, to the issuing of writs to compel citizens to assist the revenue officers, followed later by the outburst of feeling at the imposition of the Stamp Act, when Massachusetts took the lead in confronting the royal power. The governors put in office at this time by the crown were not of conciliatory temperaments, and the measures instituted in parliament served to increase bitterness of feeling. Royal troops sent to Boston irritated the populace, who were highly excited at the time, when an outbreak, known as the Boston massacre, occurred in 1770, and a file of the garrison troops, in self-defence, shot down a few citizens among the crowd which assailed them. The merchants combined to prevent the importation of goods which by law would yield the crown a revenue; and the patriots, as the anti-prerogative party called themselves, opened communication with those of the other colonies through "committees of correspondence," a method of the utmost advantage thereafter in forcing on the revolution, by intensifying the resistance of the towns in the colony, and by inducing the leaguing of the other colonies. In 1773 a party of citizens, disguised as Indians, and instigated by popular meetings, boarded some tea-ships in the harbour of Boston, and, to prevent the landing of their taxable cargoes, threw them into the sea,—an act known in history as the "Boston tea-party." Parliament in retaliation closed the port of Boston,—a proceeding which only aroused more bitter feeling in the country towns, and enlisted the sympathy of the other colonies. The governorship was now given to General Thomas Gage, who commanded the troops which had been sent to Boston. Everything foreboded an outbreak. Most of the families of the highest social position were averse to extreme measures, and a large number were not won over and became expatriated loyalists. The popular agitators, at whose head was Samuel Adams,—with whom John Hancock, an opulent merchant, and one of the few of the richer people who deserted the crown, leagued himself,—forced on the movement, which became war in April 1775, when Gage sent an expedition to Concord and Lexington to destroy military stores accumulated by the patriots. This detachment, commanded by Lord Percy, was assaulted, and returned with heavy loss. The country towns now poured in their militia to Cambridge, opposite Boston; troops came from neighbouring colonies, and a Massachusetts general was placed in command of the irregular force which, with superior numbers, at once shut the royal army up in Boston. An attempt of the provincials to seize a commanding hill in Charlestown brought on the battle of Bunker Hill (June 17, 1775), in which the provincials were driven from the ground, although they lost much less heavily than the royal troops. Washington, chosen by the continental congress to command the army, arrived in Cambridge in July 1775, and, stretching his lines around Boston, forced its evacuation in March 1776. The State was not again the scene of any conflict during the war. Generals Knox and Lincoln were the most distinguished officers contributed by the State to the revolutionary army. Out of an assessment at one time upon the States of $5,000,000 for the expenses of the war, Massachusetts was charged with $820,000, the next highest being $800,000 for Virginia. Of the 231,791 troops sent by all the colonies into the field, reckoning by annual terms, Massachusetts sent 67,907, the next highest being 31,939 from Connecticut, Virginia only furnishing 26,678.

After the outbreak of the war a provisional government was in power till a constitution was adopted in 1780, when John Hancock became the first governor. His most eminent successors have been Samuel Adams (1794–97), Elbridge Gerry (1810–12), Edward Everett (1836–40), and John A. Andrew (1861–66). Governor Bowdoin in 1786 put down an insurrection known as Shay's Rebellion. The Federal Constitution was accepted by Massachusetts by a small majority, and its rejection was at one time imminent. But Massachusetts became a strong Federal State, and suffered heavily under the Embargo Act of 1807, which was laid in the interests of the democratic party. The sentiment of the State was also against the war with England in 1812–14; but much of the naval success of the war was due to Massachusetts sailors. In an apportionment of troops at the time, out of 100,000 Massachusetts was to furnish 10,000,—Pennsylvania with 14,000, New York 13,500, and Virginia 12,000, now exceeding her quota.

During the interval till the outbreak of the civil war of 1861, Massachusetts was foremost in political change or progress. She opposed the policy which led to the Mexican War; but the State sent one regiment (1057 men) into the field, under the command of Caleb Cushing. The Liberty party, forerunner of the Freesoil and Republican parties, arose among her people, led on by such men as William Lloyd Garrison and Wendell Phillips. The Federal domination had been succeeded by the Whig rule in the State, and when its greatest exponent, Daniel Webster, died in 1852, the Freesoil party was gathering force, and after an interval became the Republican party, with new affiliations, which drew off a majority of the old Whig party. This last political organization expired under the operation,—as it lost also its minority by their joining the Democratic ranks. Charles Sumner became the most eminent exponent of the new party, and he became the State's senator in the Federal Congress. The feelings which grew up and the movements that were fostered, till they rendered the civil war inevitable, received something of the same impulse from Massachusetts which she had given a century before to the feelings and movements forerunning the revolution. When the war broke, it was her troops who first received hostile fire in Baltimore, and, turning their mechanical training to account, opened the obstructed railroad to Washington. In the war which was thus begun, she built, equipped, and manned many vessels for the Federal navy, but during the early years of the conflict she was not allowed any credit for these sailors on her quota of men; and, when allowance was finally made in 1864, she showed a record of 22,360 men who had since 1861 enlisted in the navy. In 1862, out of 300,000 men called for, Massachusetts was required to furnish 15,000. During the war all but twelve small towns furnished troops in excess of what was called for, the excess throughout the State amounting in all to over 15,000 men, while the total recruits to the Federal army were 159,165 men, of which less than 1200 were raised by draft. The State, as such, and the towns spent $42,605,517·19 in the war; and private contributions of citizens are reckoned in addition at about $9,000,000. This does not include the aid to families of soldiers, paid then and later by the State.

Since the close of the war the State has remained generally steadfast in adherence to the principles of the Republican party, and has continued to develop its resources. Navigation, which was formerly the distinctive feature of its business prosperity, has, under the pressure of laws and circumstances, given place to manufactures, and the developing of carrying facilities on the land rather than on the sea. (J. WI.)

MASSÉNA, ANDRÉ (1758–1817), duke of Rivoli, prince of Essling, and marshal of France, the greatest soldier and greatest general of all Napoleon's marshals, and the one man who with education and ambition might have been Napoleon's rival, was the son of a small wine merchant, it is said of Jewish origin, and was born at Nice on May 6, 1758. His parents were very poor, and he began life as a cabin boy. He did not care much for the sea, and in 1775 enlisted in the Regiment Royal Italien, a regiment of Italians in the pay of France. He quickly rose to be under-officer-adjutant; but, finding his birth would prevent his ever getting a commission, he left the army in 1789, retired to his native city, and married. At the sound of war, however, and the word republic, his desire to see service increased, and he once more left Italy, and joined the 3d battalion of the volunteers of the Var in 1792. In those days when men elected their officers, and nearly all the old commissioned officers were dead or had emigrated, promotion to a man with a knowledge of his drill was rapid, and by April 1793 Masséna was chef de bataillon, or colonel. His regiment was one of those in the army of General Anselme, which was ordered to occupy Nice, and his knowledge of the country, of the language, and of the people was so useful that in December he was already general of division. In command of the advanced guard he won the battle of Saorgio in August 1794, capturing ninety guns, and after many successes he at last, on November 23, 1795, with the right wing of the army of Italy, won the great victory of Loano, in which four thousand Austrians and Sardinians were put hors de combat. In Bonaparte's great campaigns of 1796 and 1797 Masséna was his most trusted general of division; in each battle he won fresh laurels, until the crowning victory of Rivoli, from which he afterwards took his title. It was during this campaign that Bonaparte gave him the title of *enfant chéri de la victoire*, which he was to justify till he met the English in 1810. Masséna's next important service was in command of the army in Switzerland, which united the army in Germany under Moreau, and that in Italy under Joubert. There he proved himself a great general; the archduke Charles and Suwaroff had each been successful in Germany and in Italy, and now turned upon Masséna in Switzerland. That general held his ground well against the archduke, and then suddenly, leaving Soult to face the Austrians, he transported his army to Zürich, where, on September 26, 1799, he entirely defeated Suwaroff, taking two hundred guns and five thousand prisoners. His campaign and battle placed his reputation on a level with that of his compatriot Bonaparte, and he might have made the revolution of Brumaire, but he was sincerely attached to the republic, and had no ambition beyond a desire to live well and have plenty of money to spend. Bonaparte, now first consul, sent him to Genoa to command the débris of the army of Italy, and he nobly defended Genoa from February to June to the very last extremity, giving time for Bonaparte to strike his great blow at Marengo. He now went to Paris, where he sat in the Corps Législatif in 1803, and defended Moreau, but where Napoleon took his measure, and did not interfere with him. In 1804 he was made one of the first marshals of France of the new régime, and in 1805 was decorated with the Grand Eagle of the Legion of Honour. In that year Napoleon needed an able general to keep in check the archduke Charles in Italy, while he advanced through Germany with the grand army. Masséna was chosen; he kept the archduke occupied till he got news of the surrender of Ulm, and then on October 30th utterly defeated him in the battle of Caldiero. After the peace of Pressburg had been signed, Masséna was ordered to take possession of the kingdom of Naples, and to place Joseph Bonaparte on the throne. This task done, Napoleon summoned Masséna to Poland, where he as usual distinguished himself, and where he for the time gave up his republican principles, and was made duke of Rivoli. In the campaign of 1809 he covered himself with glory at Landshut and at Eckmühl, and finally at the little village of Essling, which he held with such determination that Napoleon had some right to call his otherwise complete defeat of Aspern a victory. When the retreat to the island of Lobau was ordered, it was Masséna who covered the broken regiments, and held the *tête du pont*; and on the field of Wagram it was Masséna who, though too ill to ride, directed from his carriage the movements of the right wing, and recovered the honour of France. For his great services he was created prince of Essling, and given the princely castle of Thouars. He was then ordered to Spain to "drive the English into the sea." The campaigns of 1810 and 1811, the advance to and the retreat from Torres Vedras, are well known from Napier's history, who does full justice to Wellington's great opponent. Masséna himself ascribed his failure to the frequent disobedience of his three subordinate generals Ney, Reynier, and Junot, and with some justice; but he alone could have stayed so long before the lines, and could have made the long halt at Santarem, which checked Wellington so thoroughly. The retreat was as finely conducted as the advance, and would have been even more triumphant had Ney obeyed orders. Even then he was again ready to try his fortune, and nearly defeated Wellington at Fuentes d'Oñoro, though much hampered by Bessières. Recalled with ignominy, his prestige gone, the old marshal felt he had a right to complain of Ney and of Napoleon himself, and, it is said, opened communications with Fouché, and the remnant of the republican party. Whether this be true or not, Napoleon gave his greatest marshal no more employment in the field, but made him merely commandant of the 8th military division, with his headquarters at Marseilles. This command he still held at the restoration of the Bourbons, when Louis XVIII. confirmed him in it, and gave him letters of naturalization, as if the great leader of the French armies had not ceased to be an Italian. When Napoleon returned from Elba, Masséna, probably by the advice of Fouché, kept Marseilles quiet to await events, the greatest service he could do the royalists, but afterwards imputed to him as a fault. After the second restoration Masséna was summoned to sit on the court martial which tried Marshal Ney, but, though he had been on bad terms with that general, and attributed his own disgrace to him, the old soldier would not be his comrade's judge. This refusal was used by the royalists to cruelly attack the marshal, against whom they raked up every offence they could think of, and whose victories they forgot. This annoyance shortened his life, and on the 4th April 1817 the old hero died. He was buried in Père-la-Chaise, with only the word "Masséna" upon his tombstone.

In private life indolent, greedy, rapacious, ill-educated, morose, on the field of battle Masséna was a man of genius, prompt in resource, indefatigable, perfectly brave, and never knowing when he was beaten. Italian he always was in his indolence, but in his quickness of resource a real compatriot of Napoleon himself.

See Thiébault's *Éloge funèbre*, and Koch's *Mémoires de Masséna*, 4 vols., 1849, a most valuable work, and most carefully compiled. See also the military histories of the epoch, but in reading Napier's pictures of him and Soult it is well to remember that author's personal friendship with the latter.

MASSILLON, a city of the United States, in Stark county, Ohio, is situated on the Tuscarawas, a head stream of the Muskingum, communicates with Lake Erie by the Ohio canal, and forms an important junction for various lines of railway. It is well known for its coal-mines and white sandstone quarries; and it also contains blast furnaces, rolling mills, foundries, machine-shops, grist mills, and extensive establishments for the manufacture of agricultural implements, glass, and paper. The population, 3819 in 1860, was 6838 in 1880.

MASSILLON, Jean Baptiste, was born at Hyères on June 24, 1663, and died at Clermont on September 28, 1742. He was thus, except Saint-Simon and Fontenelle, the longest-lived of the men of the Siècle de Louis Quatorze. It is noteworthy that, like the majority of the great pulpit orators of his own and the preceding generation, he was a southerner. His father, François Massillon, was a notary, and he appears to have been well educated. In 1681 he joined the congregation of the Oratory, which at that time had a high reputation. But, although he had thus chosen an order where the rules were by no means strict, he was not anxious for easy living or secular renown. The credit which he received for his first efforts at preaching startled him, and he sought a much more severe discipline, one indeed which is said to have been of Trappist rigour. Accident, however, made his literary and oratorical talents known to the Cardinal de Noailles, who determined that the church should not lose so well qualified a defender. In obedience to the cardinal, Massillon left the abbey of Septfonds, rejoined the Oratory, and was introduced to the Parisian seminary of Saint Magloire in 1696 He was soon set to work to preach in the Paris churches, and his reputation spread rapidly from city to court. He preached before Louis XIV. for the first time in Advent 1699. He made a profound impression, and it is reported that his generous elder, Bourdaloue, from whom Massillon himself had learnt much, said of him, "He must increase, but I must decrease." His fame, however, did not lead to immediate preferment. In the first place, the Oratorians were on bad terms with the Jesuits, and were considered too liberal to suit the reign of gloomy pietism and severe orthodoxy in which Louis's dissolute life closed. In the second, Massillon was neither a flatterer, nor did he resort to the abrupt denunciation of vice which had succeeded in the case of some of his predecessors. Indeed, in the last years of the reign there was nothing (so far as the king was concerned) to denounce, unless it were an excess of orthodoxy. Louis's famous saying that other preachers made him pleased with them, but that Massillon made him displeased with himself, may have been merely a *mot*, but it may also have expressed an involuntary truth. However this may be, Massillon, who perhaps desired no office, received none as long as the old king lived. The regency was much more favourable to him, and in 1717 he was nominated to the see of Clermont, with the additional honour of being commissioned to preach the next year's *Petit Carême* or series of short Lent sermons before the young Louis XV. Bishop in 1717, Lent preacher in 1718, Massillon received in 1719 a yet further honour, though this time a secular one, by being elected to the Academy. Various causes, however, combined to remove him from Paris. His own standard of duty was high, and he was not likely in any case to have acquiesced in the position of a non-resident bishop; the court grew more and more dissolute; and his advance in years must have somewhat disqualified him from preaching and travelling. He delivered but few sermons in Paris after the *Petit Carême*, and preached there for the last time in 1723, when he pronounced the funeral oration of the duchess-dowager of Orleans. The twenty years of life which remained to him were spent at Clermont, where he was distinguished for all good works, especially for exacting the minimum of episcopal dues and expending the maximum on charity.

Massillon's works are made up for the most part of sermons, lectures, synodal addresses, and the like. They have been repeatedly edited, and are easily accessible in two large volumes published by Didot. As a pulpit orator, if not as a theologian, Massillon probably deserves the highest rank among Frenchmen. His style is very nearly perfect, uniting the polish of the later age of Louis XIV. with the vigour of the earlier. His thoughts are original and just, and the arrangement of his discourses lucid and orderly without being unduly scholastic. He has usually been contrasted with his predecessor Bourdaloue, the latter having the credit of vigorous denunciation, Massillon of gentle persuasiveness. But few preachers can have excelled him in vigour when he chose to be stern. Besides the *Petit Carême*, his sermons on the Prodigal Son, on Death, for Christmas Day, for the Fourth Sunday in Advent, may be cited as perhaps his masterpieces. But in truth Massillon is singularly free from inequality. His great literary power, his reputation for benevolence, and his known toleration and dislike of doctrinal disputes caused him to be much more favourably regarded than most churchmen by the *philosophes* of the 18th century. He acquired the surname of the Racine of the pulpit, but extreme purity of style is almost the only point of contact between the two writers.

MASSINGER, Philip (1584-1640), one of the most prolific, scholarly, and powerful dramatists among the immediate successors of Shakespeare. He was born in 1584, went to Oxford (St Alban's Hall) in 1602, and left in 1606. This is all that is known of his early life, except that his father, as appears from the dedication of one of his plays (*The Bondman*), was in the service of the Herberts. That his father's service was not menial is proved by his having once been the bearer of letters from the earl of Pembroke to the queen. The industry of antiquaries has discovered only one little fact about Massinger between his leaving Oxford in 1606 and his having a comedy performed at court in 1621. This fact is that he joined with two dramatists, Field and Daborne, in asking an advance of £5 from the theatrical capitalist, Henslowe. This painful request, the date of which is conjectured to be about 1614, sets forth that the three petitioners were "in unfortunate extremitie." In his part of the document Massinger says that he has "ever found" Henslowe "a true loving friend." The expression seems to point to his having been connected with plays and players for some considerable time. After 1621 many of his plays were acted and published; but from the tone of his dedications it is to be inferred that he was often in straits. The entry in the parish register of St Saviour's—"March 20, 1639-40—buried Philip Massinger, a stranger"—may mean only that Massinger was not a resident in the parish; but it is sadly out of keeping with the dramatist's place in the respect of posterity.

In the barrenness of authentic fact, conjecture has been busy with Massinger's life and character. One of the questions that have been raised about him,—whether or not he was a Roman Catholic,—leads to other questions that have more than a personal interest. Attempts to fix the political or the religious creed of a dramatist are generally fanciful; as a rule, when a critic finds an opinion expressed by one of a dramatist's personages with exceptional and striking force, he jumps to the conclusion that the dramatist must have held this opinion himself as a ruling conviction. The evidence that Massinger was a Roman Catholic at a time when the creed was held under pains and penalties is of a more serious kind, though not conclusive. It rests upon three of his plays, *The Virgin Martyr* (printed in 1622, acted before 1620), *The Renegado* (acted in 1624), and *The Maid of Honour* (printed in 1632, but probably acted earlier). In the first of these Massinger was assisted by Dekker. Whether or not the author was a Roman Catholic, it is certain that only a Roman Catholic audience could be expected to enter into the spirit of these plays and applaud at the end; and they are very remarkable theatrical phenomena to have appeared in the reign of James.

The *Virgin Martyr*, founded on the martyrdom of Dorothea in the time of Diocletian, is, in effect, an old miracle play in five acts. The devil himself appears on the stage,—first in human shape as the servant of a persecutor, hunting out victims and instigating the most cruel tortures; afterwards in "a fearful shape" with fire flashing round him. The page of the martyr Dorothea is an angel in disguise, who also appears in his own proper shape before the end of the play. Dorothea is tortured on the stage in the most revolting fashion, dragged about by the hair, kicked, beaten with cudgels, but her page Angelo stands by, and she is miraculously preserved from hurt. Other miracles are performed on the stage. A persecutor falls down in a fit when about to proceed to subject the martyr's constancy to the foulest trials. In the last act a basket of fruit from paradise is brought on, and the chief persecutor eating of it is wholly changed in spirit, and drives away his diabolic servant by holding up a cross of flowers. At the close the martyrs appear in white robes, transfigured. The *Virgin Martyr* further resembles the miracle play in the coarseness of the comic scenes intended to illustrate the power of the devil over the most base and grovelling natures. The tone of the play throughout is serious and lofty; the passions of the persecutors and the heroic devotion of the martyrs are given with great dramatic force. This is a very remarkable play to have appeared suddenly amidst the run of secular pieces. It seems to have been popular, and was several times reprinted before the Restoration. That the *Renegado* should have found favour is still more remarkable. In itself it is a powerfully constructed play, strong in character and incident. Massinger's leaning to Roman doctrine is supposed to be shown by his making one of his heroines—a converted Turk, a sultan's sister—experience complete spiritual transformation after receiving the rite of baptism. But there is a more suggestive and stranger fact than this. The hero of the piece, Francisco, is a Jesuit priest, treated with profound respect throughout, a man of noble unselfish aims, running all risks to save and gain souls, exercising the strongest moral influence for the wisest and most benevolent purposes. Francisco's influence pervades the play, and is crowned with triumph at the end. He sails back to Venice with a noble lady rescued from the infidel, her virtue protected by an amulet during her captivity, a renegade military hero restored to his country and the church, a noble Venetian rescued from spiritual and physical perils, the beautiful sister of the sultan converted to Christianity. That a London audience should have tolerated this glorification of a Jesuit within twenty years of the Gunpowder Plot is an extraordinary fact, of which the explanation is still to seek. In the *Maid of Honour* the heroine relieves a highly complicated situation at the end by taking the veil, giving a third of her property to a nunnery, a third for pious uses, and a third to an honest, faithful, but to her unattractive lover. For this she is held up as "to all posterity a fair example for noble maids to imitate." Only an audience of very pious Catholics could have sympathized with such a conclusion.

Such plays show that Massinger, if not a Roman Catholic, was at least not blinded by the popular hatred of them, but could dwell in rapt admiration on what was noble and lofty in the motives supplied by the Roman Church. The strange thing is that he found a manager to produce these plays, or an audience to tolerate them. It may be doubted whether Massinger was ever a popular dramatist. His poverty is not indeed conclusive on this point, for the prices paid for plays were so small that a dramatist could hardly make a livelihood by play writing, unless he was also an actor or a theatrical manager. But the best qualities of his plays appeal rather to thoughtful politicians, moralists, and students of character than to the simple feelings of the ordinary playgoer Only one of them, *A New Way to Pay Old Debts* (printed 1633), has kept the stage, and that chiefly because the leading character, Sir Giles Overreach, a sort of commercial Richard III., a compound of "the lion and the fox," provides many opportunities for a great actor. Like all Massinger's plays, it is most ingenious and effective in construction, but in this as in others he has been more intent upon the elaboration of a plot and the exhibition of a ruling passion than upon winning the love and admiration of his audience for heroes and heroines. The other personages besides Sir Giles are either conventional comic figures, or dim, feebly outlined, uninteresting characters. The reformed prodigal and the two pairs of lovers who outwit the cunning diplomatist by simple means seem poor, joyless, bloodless phantoms when put side by side with the rich life of Shakespeare's youthful lovers and reckless scapegraces; they are mere foils to Overreach; their life is not displayed, it is only indicated in the dialogue. With the exception of this play, all Massinger's have been relegated to the study since his own time. The *Fatal Dowry* (printed 1632), in which Massinger had the assistance of Field, was partially resuscitated by Rowe, being made the basis of the *Fair Penitent*. In Massinger's own judgment, the *Roman Actor* was "the most perfect birth of his Minerva." It is in effect a study of the tyrant Domitian, and of the results of despotic rule on the despot himself and his court; the intrigues and counter intrigues, the rise of sycophancy, the fall of honesty, the growth of the appetite for blood, the growth and final triumph of the spirit of revenge, are exhibited with great power. Among the dramatists of that great period, Massinger comes next to Shakespeare in the art of opening and developing a plot. The *Bondman*, the *Duke of Milan*, and the *Great Duke of Florence* are also favourable specimens of Massinger's power. But what was said by one of his admirers in the dedication of the *City Madam* is perfectly true, that, "though he composed many plays, he wrote none amiss." The manners and the characters are always clearly conceived, although the dramatist's strength is put forth in the portrayal of some one ruling passion. The action always marches forward steadily, with as little as possible of irrelevant digression; so steadily in fact is the main purpose pursued as to produce a certain air of labour and constraint. The language is never mean, and never turgid; in impassioned situations it wants fire and directness. If the stage were ever deliberately employed as an historical school, frequented by audiences anxious to get a clear and vivid impression of important situations, going to the theatre not to be interested against their will but willing to be interested, the dramas of Massinger would furnish excellent models.

Several of Massinger's plays are no longer extant. Eight of them were among those destroyed by Warburton's cook. The most recent edition of those remaining, nineteen in number, is Cunningham's (1870). Gifford edited Massinger with great care. (W. M.)

MASSORAH (מַסֹּרָה), better MASSORETH (מַסֹּרֶת), a late Hebrew word meaning "tradition," is the technical term specially applied to the tradition by which Jewish scholars (Massorets, בַּעֲלֵי הַמַּסֹּרֶת) sought to fix the correct writing and reading of the text of the Old Testament. An oral tradition on disputed points of this sort naturally existed from the early days of the Jewish schools, but the use of a written Massorah in notes on the margin of Bibles, at the end of Biblical codices or of the individual books contained in them, or in separate works appears to have followed the introduction of the vowel points, and to have been influenced by similar labours of Syrian scholars. See HEBREW LANGUAGE, vol. xi p. 600

MASSOWAH, or MESOWAH, a town on the Abyssinian coast of the Red Sea, on a small coral island of the same name, in 15° 30′ N. lat. and 39° 30′ E. long. The height of the island is from 20 to 25 feet above the sea, the length does not exceed $\frac{1}{2}$ mile, and the breadth is about $\frac{1}{4}$ mile The western half is occupied by the town; in the eastern half are Mohammedan burying-grounds and dismantled cisterns. Most of the dwelling-houses are mere straw huts; the mosque, the Roman Catholic church, the Government buildings and custom-house, and the residences of the principal merchants are of stone. Water was formerly scarce, and had for the most part to be carried from the mainland; but in 1872 an ancient aqueduct from Mokullu was restored, and continued by an embankment to the town. Besides the original Ethiopians, who speak a Tigré dialect corrupted with Arabic, the population, estimated at from 5000 to 6000, comprises Arabs from Yemen and Hadramaut, Gallas and Somalis, and Hindus from Surat. The trade, which consists mainly in exporting hides, butter, Abyssinian coffee, and civet, and importing European and Indian cotton goods and silks, increased in value from about £65,000 per annum in 1865 to from £240,000 to £280,000 between 1879 and 1881.

The island of Massowah (locally Base) has probably been inhabited from a very early date. It was at Massowah (Matzua, as they called it) that the Portuguese landed in 1542 under Christovão da Gama. Captured by the Turks in 1557, the island has remained more or less strictly a Turkish possession ever since. A military colony of Bosnians settled at Arkiko was appointed, not only to defend it in case of attack from the mainland, but to keep it supplied with water in return for $1400 per month from the town's customs. For some time in the close of last century Massowah was held by the sherif of Mecca, and it afterwards passed under Mehemet Ali of Egypt. The Turks were reinstated about 1850, but in 1865 they handed the island back to Egypt for an annual tribute of $2\frac{1}{2}$ million piastres.

See *Bruce's Travels*, vol. iv.; Heuglin in Petermann's *Mittheilungen*, 1860; Rassam, *Brit. Mission to Abyssinia*, 1869; Pennazzi in *Nuova Antologia*, July 1880.

MASSYS, or MATSYS, QUINTIN (1466–1530), was born at Louvain, where he first learned a mechanical art. During the greater part of the 15th century the centres in which the painters of the Low Countries most congregated were Bruges, Ghent, and Brussels. Towards the close of the same period Louvain took a prominent part in giving employment to workmen of every craft. It was not till the opening of the 16th century that Antwerp usurped the lead which it afterwards maintained against Bruges and Ghent, Brussels, Mechlin, and Louvain. Quintin Massys was one of the first men of any note who gave repute to the guild of Antwerp. A legend still current relates how the smith of Louvain was induced by affection for the daughter of an artist to change his trade and acquire proficiency in painting. A less poetic but perhaps more real version of the story tells that Quintin had a brother with whom he was brought up by his father Josse Massys, a smith, who held the lucrative offices of clockmaker and architect to the municipality of Louvain. It came to be a question which of the sons should follow the paternal business, and which carve out a new profession for himself. Josse the son elected to succeed his father, and Quintin then gave himself to the study of painting. But it is not improbable that as he lived in an age when single individuals were cunning in various branches of design, Quintin was equally familiar with the chisel and file or the brush and pencil. We are not told expressly from whom Quintin learned the profession in which he acquired repute, but his style seems necessarily derived from the lessons of Dierick Bouts, who took to Louvain the mixed art of Memling and Van der Weyden. When he settled at Antwerp, at the age of twenty-five, he probably had a style with an impress of its own, which certainly contributed most importantly to the revival of Flemish art on the lines of Van Eyck and Van der Weyden. What particularly characterizes Quintin Massys is the strong religious feeling which he inherited from earlier schools. But that again was permeated by realism which frequently degenerated into the grotesque. Nor would it be too much to say that the facial peculiarities of the boors of Van Steen or Ostade have their counterparts in the pictures of Massys, who was not, however, trained to use them in the same homely way. From Van der Weyden's example we may trace the dryness of outline and shadeless modelling and the pitiless finish even of trivial detail, from the Van Eycks and Memling through Dierick Bouts the superior glow and richness of transparent pigments, which mark the pictures of Massys. The date of his retirement from Louvain is 1491, when he became a master in the guild of painters at Antwerp. His most celebrated picture is that which he executed in 1508 for the joiners' company in the cathedral of his adopted city. Next in importance to that is the Maries of Scripture round the Virgin and Child, which was ordered for a chapel in the cathedral of Louvain. Both altar-pieces are now in public museums, one at Antwerp, the other at Brussels. Both challenge attention for the qualities which have already been described. They display great earnestness in expression, great minuteness of finish, and a general absence of effect by light or shade. As in early Flemish pictures, so in those of Massys, superfluous care is lavished on jewellery, edgings, and ornament. To the great defect of want of atmosphere such faults may be added as affectation, the result of excessive straining after tenderness in women, or common gesture and grimace suggested by a wish to render pictorially the brutality of jailers and executioners. Yet in every instance an effort is manifest to develop and express individual character. This tendency in Massys is chiefly illustrated in his pictures of male and female market bankers (Louvre and Windsor), in which an attempt is made to display concentrated cupidity and avarice. The other tendency to excessive emphasis of tenderness may be seen in two replicas of the Virgin and Child at Berlin and Amsterdam, where the ecstatic kiss of the mother is quite unreal. But in these examples there is a remarkable glow of colour which takes us past many defects. Expression of despair is strongly exaggerated in a Lucretia at the museum of Vienna. On the whole the best pictures of Massys are the quietest; his Virgin and Christ or Ecce Homo and Mater Dolorosa (London and Antwerp) display as much serenity and dignity as seems consistent with the master's art. A telling example of his partiality for grotesque character in face is an Epiphany in the collection of Mr H. R. Hughes in England. His skill as a portrait painter has not been sufficiently admired, probably because most of his likenesses have ceased to be identified with his name. Egidius at Longford, which drew from Sir Thomas More a eulogy in Latin verse, is but one of a numerous class, to which we may add the portrait of Maximilian of Austria in the gallery of Amsterdam, a masterpiece which at some future period may afford a clue to other works of similar treatment in English and Continental galleries. Massys in this branch of practice was much under the influence of his contemporaries Lucas of Leyden and Mabuse. His tendency to polish and smoothness excluded to some extent the subtlety of modulation remarkable in Holbein and Dürer. There is reason to think that he was well acquainted with both these German masters. He probably met Holbein more than once on his way to England. He saw Dürer at Antwerp in 1520. Quintin died at Antwerp in 1530. The puritan feeling which slumbered in him was fatal to some of his relatives. His sister Catherine and her husband suffered at Louvain in 1543 for the then capital offence of reading the Bible, he being decapitated, she buried alive in the square fronting the cathedral.

Quintin's son, Jan Massys, inherited the art but not the skill of his parent. The earliest of his works, a St Jerome, dated 1537, in the gallery of Vienna, the latest, a Healing of Tobias, of 1564, in the museum of Antwerp, are sufficient evidence of his tendency to substitute imitation for original thought.

MASTER AND SERVANT. These are scarcely to be considered as technical terms in law. The relationship which they imply is created when one man hires the labour of another for a term. Thus it is not constituted by merely contracting with another for the performance of a definite work, or by sending an article to an artificer to be repaired, or engaging a builder to construct a house. Nor would the employment of a man for one definite act of personal service—*e.g.*, the engagement of a messenger for a single occasion—generally make the one master and the other servant. It was held, however, in relation to the offence of embezzlement, that a drover employed on one occasion to drive cattle home from market was a servant within the statute. (See article EMBEZZLEMENT for definition of "clerk" or "servant" in that connexion.) On the other hand, there are many decisions limiting the meaning of "servants" under wills giving legacies to the class of servants generally. Thus "a person who was not obliged to give his whole time to the master, but was yet in some sense a servant," was held not entitled to share in a legacy to the servants. These cases are, however, interpretations of wills where the intention obviously is to benefit domestic servants only. And so in other connexions questions may arise as to the exact nature of the relations between the parties—whether they are master and servant, or principal and agent, or landlord and tenant, or partners, &c.

The terms of the contract of service are for the most part such as the parties choose to make them, but in the absence of express stipulations terms will be implied by the law. Thus, "where no time is limited either expressly or by implication for the duration of a contract of hiring and service, the hiring is considered as a general hiring, and in point of law a hiring for a year." But "in the case of domestic and menial servants there is a well-known rule, founded solely on custom, that their contract of service may be determined at any time by giving a month's warning or paying a month's wages, but a domestic or other yearly servant, *wrongfully* quitting his master's service, forfeits all claim to wages for that part of the current year during which he has served, and cannot claim the sum to which his wages would have amounted had he kept his contract, merely deducting therefrom one month's wages. Domestic servants have a right by custom to leave their situations at any time on payment of a calendar month's wages in advance, just as a master may discharge them in a similar manner" (Manley Smith's *Law of Master and Servant*, chaps. ii. and iii.). The master's right to chastise a servant for dereliction of duty (which appears to be still recognized in some American cases) is no longer sustained in English law, unless perhaps in the case of servants under age, to whom the master stands *in loco parentis*.

The following are assigned by Manley Smith as in general sufficient grounds for discharging a servant:—(1) wilful disobedience of any lawful order; (2) gross moral misconduct; (3) habitual negligence; (4) incompetence or permanent disability caused by illness.

A master has a right of action against any person who deprives him of the services of his servant, by enticing him away, harbouring or detaining him after notice, confining or disabling him, or by seducing his female servant. Indeed the ordinary and only available action for seduction in English law is in form a claim by a parent for the loss of his daughter's services.

The death of either master or servant in general puts an end to the contract. A servant wrongfully discharged may either treat the contract as rescinded and sue for services actually rendered, or he may bring a special action for damages for the breach. A master is bound to provide food (but apparently not medical attendance) for a servant living under his roof, and wilful breach of duty in that respect is a misdemeanour under 24 & 25 Vict. c. 100.

A servant has no right to demand "a character" from an employer, and if a character be given it will be deemed a privileged communication, so that the master will not be liable thereon to the servant unless it be false and malicious. A master by knowingly giving a false character of a servant to an intending employer may render himself liable—should the servant for example rob or injure his new master.

For penalties incurred by personating masters and giving false certificates of character, or by persons offering themselves as servants with false or forged certificates, see 32 Geo. III. c. 56.

Reference may be made to the article on LABOUR AND LABOUR LAWS for the cases in which special terms have been introduced into contracts of service by statute (*e.g.*, Truck Act), and for the recent legislation on the subject generally, including the Employers' Liability Act, 1880.

The master's liability on the contracts of his servant depends on altogether different principles from those on which his liability for negligence has been justified. It is substantially a case of liability as principal for the acts of an agent. The main question in all cases is whether the alleged agent had authority to make a contract for his principal, and in the relation of master and servant there may be any variety of circumstances giving rise to that presumption. Here the rights of third persons have to be considered, and the master will be held liable to them wherever he has "by words, conduct, or demeanour held out his servant as a general agent, whether in all kinds of business or in transacting business of a particular kind,"—even if the servant should act contrary to express orders. For example, a horse-dealer sending his servant to market with a horse to sell will be liable on the servant's warranty, although he has been positively ordered not to warrant; whereas an owner sending a stranger to sell would not be liable on a warranty given contrary to express directions.

MASTIC, or MASTICH, a resinous exudation obtained from the lentisk, *Pistacia Lentiscus*, an evergreen shrub of the natural order *Anacardiaceæ*. The lentisk or mastic plant is indigenous to the Mediterranean coast region from Syria to Spain, but grows also in Portugal, Morocco, and the Canaries. Although experiments have proved that excellent mastic might be obtained in other islands in the archipelago, the production of the drug has been, since the time of Dioscorides, almost exclusively confined to the island of Scio. The mastic districts of that island are for the most part flat and stony, with little hills and few streams. The shrubs are about 6 feet high. The resin is contained in the bark and not in the wood, and in order to obtain it numerous vertical incisions are made, during June, July, and August, in the stem and chief branches. The resin speedily exudes and hardens into roundish or oval tears, which are collected, after about fifteen days, by women and children, in little baskets lined with white paper or cotton wool. The ground around the trees is kept hard and clean, and flat pieces of stone are often laid beneath them to prevent any droppings of resin from becoming contaminated with dirt. The collection is repeated three or four times between June and September, a fine tree being found to yield about 8 or 10 ℔ of mastic during the season. Besides that obtained from the incisions, mastic of very fine quality spontaneously exudes from the small branches. The harvest is affected by showers of rain during the period of collection, and the trees are much injured by frost, which is, however, of rare occurrence in the districts where they grow.

Four qualities of mastic are recognized by the dealers in Scio.

1. *Cake*, consisting of large pieces, sold chiefly for use in the seraglios, being chewed by women of all ranks throughout the Turkish empire, for the purpose of imparting an agreeable odour to the breath. This quality is worth 120 to 130 piastres per oke (of 2·83 ℔) or even more.
2. *Large tears*, worth 90 to 100 piastres.
3. *Small tears*, valued at 75 to 80 piastres.
4. Mastic mixed with fragments of leaves and sand, chiefly consumed in the manufacture of the Turkish liqueur, or mastic brandy, called *raki*, and other cordials.

The third sort, in small tears, is that which is chiefly exported to England, the first and second qualities being sent to Turkey, especially Constantinople, also to Trieste, Vienna, and Marseilles. These varieties are known to the dealers as κυλιστό, φλισκάρι, πῆττα, and φλοῦδα respectively.

Mastic still forms the principal revenue of Scio. In 1871, 28,000 ℔ of picked and 42,000 ℔ of common were exported from that island, the former being worth 6s. 10d. and the latter 2s. 10d. per ℔. The average price in London varies from 2s. 6d. to 4s. 6d. per ℔.

During the 15th, 16th, and 17th centuries mastic enjoyed a high reputation as a medicine, and formed an ingredient in a large number of medical compounds, but its use in medicine is now almost obsolete.

Mastic occurs in English commerce in the form of roundish tears about the size of peas, some of them, however, being oblong or pear-shaped. They are transparent, with a glassy fracture, of a pale yellow or faint greenish tinge, which darkens slowly by age. When chewed they rapidly soften, by which character they are easily distinguished from Sandarac resin, which while bearing a strong resemblance to mastic occurs in tears of a more cylindrical shape. The mastic which has been imported of late years presents a bright glassy appearance from having been washed free from dust.

Mastic is soluble in turpentine, chloroform, ether, acetone, and oil of cloves; but cold alcohol dissolves only 90 per cent. of it. The soluble portion is called *Alpha resin* ($C^{20}H^{32}O^{3}$), and possesses acid properties. The insoluble portion, *Beta resin* or *Masticin*, is somewhat less rich in oxygen, and is a translucent colourless tough substance insoluble in caustic alkali.

Pistacia Khinjuk, Stocks, and *P. cabulica*, St., trees growing throughout Sindh, Baluchistan, and Cabul, yield a kind of mastic which is met with in the Indian bazaars under the name of *Mustagi-rúmi*, *i.e.*, Roman mastic. This when met with in the European market is known as East Indian or Bombay mastic. In Algeria *P. atlantica*, Desf., yields a solid resin, which is collected and used by the Arabs as a masticatory. Cape mastic, used by the colonists, but not exported to England, is the produce of *Euryops multifidus*, the resin bush, or *harpuis bosch*, of the Boers,—a plant of the composite order growing abundantly in the Clanwilliam district. Dammar resin is sometimes sold under the name of mastic. The West Indian mastic tree is the *Bursera gummifera*, and the Peruvian mastic is *Schinus Molle*; but neither of these furnishes commercial resins.

MASTODON (from *μαστός*, "nipple," and *ὀδούς*, "tooth"), a name, suggested by the conical or papillary form of the projections on the molar teeth of some of the species, given by Cuvier to a genus of extinct elephant-like animals. Their position in the suborder *Proboscidea* of the great order *Ungulata* has been indicated in the article MAMMALIA (p. 425 of the present volume).

In size, general form, and principal osteological characters the Mastodons resembled the Elephants. It is by the teeth alone that the two groups are to be distinguished, and, as shown in the article just referred to, so numerous are the modifications of these organs in each, and so insensibly do they pass by a series of gradations into one another, that the distinction between the two is an arbitrary and artificial one, though convenient and even necessary for descriptive purposes.

As in other Proboscideans, the teeth of Mastodons consist only of incisors and molars. The incisors or tusks are never more than a single pair in each jaw. In the upper jaw they are always present and of large size, but apparently never so much curved as in some species of Elephant, and they often have longitudinal bands of enamel, more or less spirally disposed upon their surface, which are not met with in Elephants. Lower incisors, never found in true Elephants, are present throughout life in some species of Mastodon, which have the symphysis of the lower jaw greatly elongated to support them (as in *M. angustidens*, *M. pentelici*, and *M. longirostris* (see fig. 1, *C*). In the common American species (*M. ohioticus*, Blumenbach) there were two tusks in the lower jaw in the young of both sexes; these were soon shed in the female, but one of them was retained in the male. In other species no inferior tusks have been found, at all events in adult life (see figure of *M. turicensis*).

The molar teeth are six in number on each side, increasing in size from before backwards, and, as in the Elephants, with a horizontal succession, the anterior teeth being lost before the full development of the posterior teeth, which gradually move forward, taking the place of those that have been destroyed by wear. This process is, however, not so complete as in the true Elephants, and as many as three teeth may be in place in each jaw at one time. There is, moreover, in many species a true vertical succession, affecting either the third, or the third and second, or (in one American species, *M. productus*) the first, second, and third of the six molariform teeth. These three

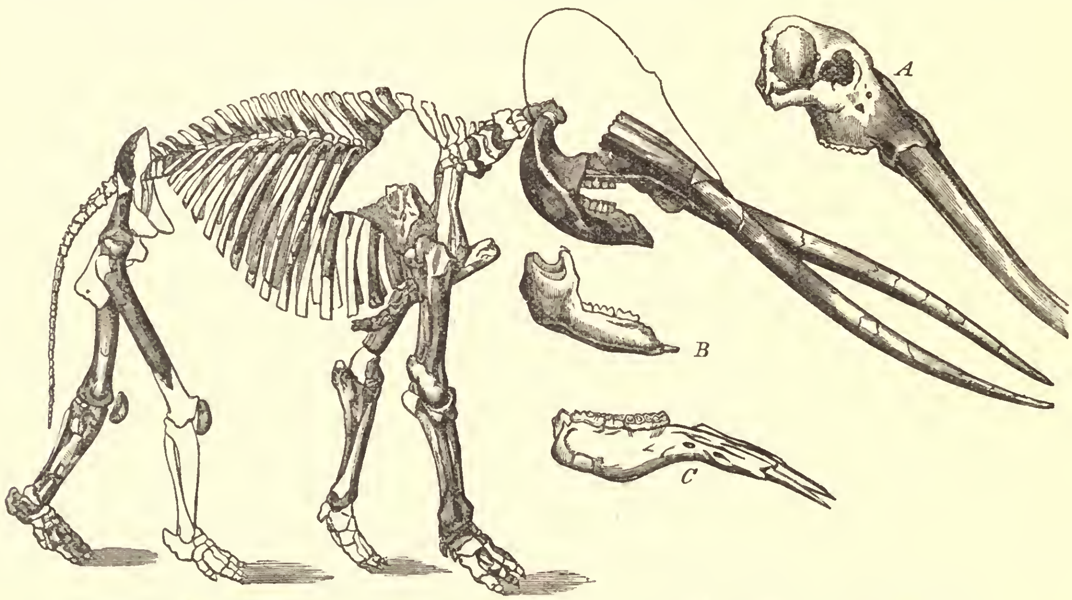


FIG. 1.—*Mastodon turicensis* (Pliocene). From Sismonda. A, B, *M. ohioticus*; C, *M. longirostris*.

are therefore reckoned as milk molars, and their successors as premolars, while the last three, which are never changed, correspond to the true molars of those animals in which the typical dentition is fully developed. The study of the mode of succession of the teeth in the different species of Mastodons is particularly interesting, as it exhibits so many stages of the process by which the very anomalous dentition of the modern Elephants may have been derived by gradual modification from the typical heterodont and diphyodont dentition of the ordinary Mammal. It also shows that the anterior molars of Elephants do not correspond to the premolars of other Ungulates, but to the milk molars, the early loss of which in consequence of the peculiar process of horizontal forward-moving succession does not require, or allow time for, their replacement by premolars. It must be noted, however, that, in the Mastodon in some respects the least specialized in tooth-structure, the *M. ohioticus* of North America, no vertical succession of the molars has yet been observed, although vast numbers of specimens have been examined.

The Mastodons have, generally speaking, fewer ridges on their molar teeth than the Elephants; the ridges are also less elevated, wider apart, have a thicker enamel covering, and scarcely any cementum filling up the space between them. Sometimes (as in *M. ohioticus*) the ridges are simple transverse wedge-shaped elevations, with straight or

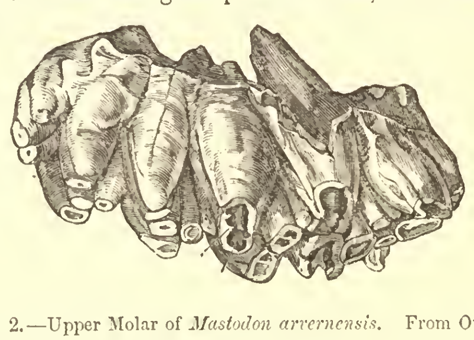


FIG. 2.—Upper Molar of *Mastodon arvernensis*. From Owen.

concave edges. In other species the summits of the ridges are more or less subdivided into conical cusps, and may have accessory cusps clustering around them (as in *M. arvernensis*, see fig. 2). When the apices of these are worn by mastication, their surfaces resemble circles of dentine, surrounded by a border of enamel, and as the attrition proceeds different patterns are produced by the union of the bases of the cusps, a trilobed or trefoil form being characteristic of some species.

Certain of the molar teeth of the middle of the series in both Elephants and Mastodons have the same number of principal ridges, and those in front of them have fewer and those behind a greater number. These teeth were distinguished as "intermediate" molars by Dr Falconer, to whose extensive and conscientious researches we owe much of our knowledge of the structure of this group of animals. In the restricted genus *Elephas* there are only two, the last milk molar and the first true molar (or the third and fourth of the whole series), which are alike in the number of ridges; whereas in the Mastodons there are three such teeth, the last milk molar and the first and second true molars (or the third, fourth, and fifth of the whole series). In the Elephants the number of ridges on the intermediate molars always exceeds five, but in the Mastodons it is nearly always three or four, and the tooth in front has usually one fewer and that behind one more, so that the ridge formula (*i.e.*, a formula expressing the number of ridges on each of the six molar teeth) of most Mastodons can be reduced either to 1, 2, 3, 3, 3, 4 or 2, 3, 4, 4, 4, 5. The former characterizes the section called *Trilophodon*, and the latter that called *Tetralophodon* by Dr Falconer. These divisions are very useful, as under one or the other all the present known species of Mastodon can be ranged, but observations upon a larger number of individuals have shown that the number of ridges upon the teeth is by no means so constant as implied by the mathematical formulæ given above. Their exact enumeration is even difficult in many cases, as "talons" or small accessory ridges at the hinder end of the teeth occur in various stages of development, until they take on the character of true ridges. Transitional conditions have also been shown, at least in some of the teeth, between the trilophodont and the tetralophodont forms, and again between the latter and what has been called a "pentalophodont" type, which leads on towards the condition of dental structure characteristic of the true Elephants.

The range of the genus *Mastodon* in time was from the middle of the Miocene period to the end of the Pliocene in the Old World, when they became extinct; but in America several species—especially the best-known, owing to the abundance of its remains, which has been variously called *M. ohioticus*, *M. americanus*, and *M. giganteus*—survived quite to a late Pleistocene period.

The range in space will be best indicated by the following list of the generally recognized species. 1. Trilophodont series—*M. angustidens, borsoni, pentelici, pyrenaicus, tapiroides* (or *turicensis*), *virgatidens*, from Europe; *M. falconeri* and *pandionis*, from India; *M. ohioticus, obscurus*, and *productus*, North America; and *M. andium* and *humboldtii*, South America. 2. Tetralophodont series—*M. arvernensis, M. dissimilis* and *longirostris*, from Europe; *M. latidens, sivalensis*, and *peramensis*, from India; *M. mirificus*, from North America. The only two of which remains have been found in Great Britain are *M. arvernensis* and *M. borsoni*, both from the crags of Norfolk and Suffolk.

The range of the genus was thus very extensive, and it has even been supposed to reach to Australia, where no Ungulate mammal has ever been proved to exist. This supposition until very recently has been based upon the evidence of a single molar tooth of an animal undoubtedly belonging to *Mastodon*, and alleged to have been brought from near Boree Creek, an affluent of the Lachlan river in the Ashburnham district, New South Wales, by the late Count Strzelecki, and described by Professor Owen in 1844 under the name of *M. australis*. Its identity with the South American *M. andium* has, however, been shown by Dr Falconer, who has thrown grave doubts upon the locality assigned to the specimen. A fragment of a tusk, of the Australian origin of which there is less question, and which presents the characteristic structure only known at present in Elephants and Mastodons, has been lately described by Professor Owen (*Proc. Roy. Soc.*, March 30, 1882). It was found in a drift-deposit of a ravine in a district of Darling Downs, 60 miles to the eastward of Moreton Bay, Queensland. Unfortunately no other portions of the remains of the animal to which it belonged have been discovered.

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MASʻÚDY. Abú'l-Ḥasan ʻAlí ibn Ḥosein ibn ʻAlí el-Masʻúdy,[1] was born at Baghdad towards the close of the 9th Christian century. Great part of his life was spent in travel; in 912–13 A.D. he was at Múltán in the Punjab, and also visited Manṣúra. Three years later he was at Baṣra and met Abu Zeid, the geographer whose remarks on the extreme East are comprised in Reinaud's *Relation des Voyages* (Paris, 1845). His writings and those of Masʻúdy are indebted each to the other. In the interval it would seem our traveller had gained that personal acquaintance with Fars and Susiana, and that knowledge of the books of the Persians, of which he speaks in his writings. Once more turning eastward he was at Cambay in 915–16, and soon after at Ṣaimúr. Hence he pushed on to Ceylon and sailed to Madagascar, returning to ʻOmán in 916–17. In the introduction to the *Meadows* he seems also to say that he had journeyed as far as China. A northern journey carried Masʻúdy as far as the Caspian Sea. In 926 he was at Palestine, where his curiosity, not limited by religious prejudice, led him to visit the Christian church and describe its relics. In 943–44 he made a careful study of the ruins of Antioch, and subsequently proceeded to Baṣra. In the same year he composed the *Meadows of Gold*. The last ten years of his life were passed in Syria and Egypt. His last work, *The Indicator and Monitor*, was written 345 A.H., and his death took place in Egypt the same year (956–57 A.D.).[2] The vast journeys of Masʻúdy did not pass beyond the lines of commercial enterprise among the Moslems of those days, when ʻIráḳ was not unjustly held to be the centre of the world, and the arms, the trade, and the religion of Islám penetrated to the remotest parts of Asia and Africa. But Masʻúdy did not travel for gain. His object was to study with his own eyes the peculiarities of every land, and to collect whatever was of interest for archæology, history, and manners. Singularly free from bigotry—he was himself a Moʻtazilite, one of the heretical sect, as they were reckoned, who held the doctrine of man's free will—he was ready to derive information even from the writings of infidel Persians or of a Christian bishop.[3] In the range of his observations and the naive uncritical honesty with which he records them he has naturally suggested comparison with Herodotus, and so competent a judge as Ibn Khaldún gives him the title of imám of Eastern historians, an epithet precisely parallel to that borne by Herodotus among the historians of the West. The parallel, however, must be taken with great deductions. Of the *Meadows*, the work by which Masʻúdy is chiefly known, by far the greater part is an historical compilation, enlivened indeed in some parts by personal recollection of places and the like, but mainly drawn from a vast mass of earlier books[4] which are used in the common paste-and-scissors fashion of Eastern history. Even in the earlier cosmographical chapters the author's vast and miscellaneous reading, which included the Arabic translations of Ptolemy and other Greek writers, is mingled with his original observa-

1 The surname is derived from an ancestor Masʻúd, a Meccan, whose son ʻAbdalla accompanied Mohammed on his flight to Medína, and is often mentioned in the history of the prophet. Details as to the family are given by Reiske, *Ann. Mos.*, vol. i., note 208.

2 See De Sacy, *Chrest.*, 1st ed., ii. 490.

3 In the *Meadows*, iii. 69, he tells us that at Fosṭáṭ (Old Cairo), in 336 A.H., there fell into his hands a chronicle (now lost) by Godmer, bishop of Gironne, which he uses for his narrative.

4 Of these the first chapter gives an interesting catalogue.

tions in that ill-digested style so often characteristic of men of prodigious acquisitive power; and the presentation of facts falls as far short of freshness and the artistic charm of the inimitable Grecian *raconteur* as the shapeless details of universal history, as it appeared to the Moslem, fall short of the epic interest of the great struggle for supremacy between Eran and Hellas.

Mas'údy has himself sketched his literary activity in the opening chapter of the *Meadows* and in his last book *The Indicator*. In his huge *Annals* (*Akhbár el-Zemán*) and in a second work of less extent (*Kitáb el-Awsat*) which followed it he summed up the whole cosmographical and geographical science of his age. These works are lost or known only by fragments, but we possess an abridgment in the author's third great work *The Meadows of Gold and Mines of Precious Stones*, of which there are many MSS. in European libraries. It was printed by Barbier de Meynard with a French translation, 9 vols. 8vo, Paris, 1861-77, and at Búlák in 1867 (2 vols. folio). The first volume of an English translation by Sprenger appeared at London in 1841; but the work was not continued. The Kitáb-el-Tanbíh (*Indicator and Monitor*) exists in MS. at Paris, and has been fully described by De Sacy in *Notices et Extraits*, vol. viii., 1810 (reprinted at the end of the Paris edition of the *Meadows*, where a list of other works of our author is given). See also Quatremère in *Jour. As.* for January 1839, and the article "Masoudy," by Reinaud, in the *Nouv. Biog. Générale*.

MASULIPATAM, the chief town of Kistna district, Madras, India, and a seaport, is situated in 16° 9′ N. lat., 81° 11′ E. long., with a population in 1871 of 36,316. The export trade is partly to Europe; imports are chiefly local. In 1874-75 235 vessels of 106,000 tons burthen visited the port; the exports (oil-seeds and cotton) amounted to £171,400, the imports to £119,600. The town contains the usual district offices, a jail, and several schools, the chief being the high school. It is a flourishing station of the Church Missionary Society.

Masulipatam was the earliest British settlement on the Coromandel coast. An agency was established there in 1611, and a fortified factory in 1622. During the wars of the Carnatic, the English were temporarily expelled the town, which was held by the French for some years. In 1759 the town and fort were carried by storm by Colonel Forde, and it has been held by the British ever since. Weavers form a large portion of the inhabitants of the town, though their trade has greatly declined since the beginning of this century. Their operations, besides weaving, include printing, bleaching, washing, and dressing. In former days the chintzes of Masulipatam had a great reputation abroad for the freshness and permanency of their dyes, the colours becoming brighter after washing than before. There is still a small demand for these articles in Burmah, the Straits, and the Persian Gulf; but steam machinery has nearly beaten the hand-loom out of the field. Another speciality was *metapollams* or kerchiefs for the head; but this industry was ruined by the refusal of the West Indian negroes to wear these kerchiefs after their emancipation. Tartans, ginghams, towels, and table linen are still manufactured to some extent. The importance of the place is now declining, and the garrison was withdrawn in 1865. The heaviest blow to the prosperity of the town was given by the great storm-wave of 1864, which swept over the entire town, and is said to have destroyed 30,000 lives.

MATAMOROS, a city of Mexico, in the province of Tamaulipas, on the southern bank of the Rio Grande, about 35 miles from its mouth, and directly opposite Brownsville in Texas. Built in an open plain, Matamoros has its streets laid out with great regularity; and the general appearance gives evidence at once of its recent rise into importance and of the influence of the architectural fashions of the United States. The principal building is the large but heavy-looking cathedral. An extensive traffic, both legitimate and contraband, is carried on between Matamoros and Brownsville, and in spite of the bar at the mouth of the river, which in foul weather prevents the entrance even of small schooners, the place is not without its value to Mexico as a foreign port. The imports of American and of European goods are valued each at about $1,100,000, with a growing preponderance on the side of the American. Cotton, flax, silk, and woollen goods are the main items in the European list; cottons, leaf tobacco, wheat-flour, machinery, and preserved meats in the American. Hides and skins, live animals, and wool are the principal exports apart from coin and bullion, which are largely smuggled to avoid the export duty. The population is about 20,000.

Founded in the beginning of the century, and named in honour of the Mexican patriot Mariano Matamoros, the city has played a part in all the more recent wars. It was captured by General Taylor of the United States in 1846, was in the hands of the imperialists under Majia in 1864, and was occupied by the French in 1866.

MATANZAS, or SAN CARLOS DE MATANZAS, a city and seaport on the north coast of Cuba, and the chief town of a province, lies 52 miles east of Havana, with which it is connected by rail. It is a well-built place of from 36,000 to 40,000 inhabitants, occupying a fine site at the head of the Bay of Matanzas, and separated from its suburbs Pueblo Nuevo and Versailles by the San Juan on the one hand and the Yamurri on the other. In the centre of the principal square is a statue of Ferdinand VII., and along the east side runs the residence of the commandant. The new theatre is the handsomest building of its kind in Cuba, and the Empresa Academy has the repute of being one of the best educational institutions in the West Indies. As a commercial centre Matanzas ranks next to Havana, having risen rapidly after the removal of the old trade restrictions in 1809. The exports are mainly sugar and molasses. The harbour has been deteriorated by the mud brought down by the San Juan; but the bay is well sheltered from all winds except the north-east, which brings in a heavy sea. Matanzas was founded in 1693 by a number of immigrants from the Canary Islands, and in the same year Bishop Compostello laid the first stone of the cathedral. The city suffered severely from a conflagration in 1845. About 2½ miles to the east are the beautiful stalactite caves of Bellamar, about 3 miles in extent.

MATARÓ, a Mediterranean seaport of Spain, in the province of Barcelona, 21 miles to the north-east of that city, is beautifully situated on the lower slopes and at the foot of the range of hills which skirt the coast, and shelter the town from the cold northern winds. The streets of the new town, lying next the sea, are wide and regularly built; those of the old town, farther up the hill, still preserve much of their ancient character. The parish church of Santa Maria has some good pictures and wood carvings; other prominent public buildings are the theatre, the civil hospital, and the establishments of the Padres Escolapios. There are small schools of navigation and the fine arts. The wine of the neighbourhood, which somewhat resembles port, is shipped in large quantities from Barcelona; and the district furnishes fine roses, strawberries, and similar produce for the Barcelona market. There is a considerable fishery, the products of which are sent inland to Manresa and other places. The leading industries of Mataró are its linen, woollen, and cotton manufactures, especially of canvas and tarpaulin; several hundreds of women are employed in the town and neighbourhood in lace-making; there are also potteries, machine-making, and chemical works, and shipbuilding is carried on to some extent. The railway to Barcelona, opened in October 1848, was the first to be constructed in Spain. Mataró has no artificial harbour, several attempts to make one having failed; the trade is carried on chiefly through Barcelona. The population in 1877 was 17,405. Outside the town is the much-frequented carbonated mineral spring of Argentona.

MATCHES. Till the close of the 18th century flint and steel with tinder box and sulphur-tipped splints of wood—"spunks" or matches—were the common means of obtaining fire for domestic and other purposes. The sparks struck off by the percussion of flint and steel were made to fall among the tinder, which consisted of carbonized fragments of cotton and linen; the entire mass of the tinder was set into a glow, developing sufficient heat to ignite the sulphur with which the matches were tipped, and thereby the splints themselves were set on fire. Instead of tinder, match-paper or touch-paper, a thick bibulous paper impregnated with saltpetre (nitrate of potash), and amadou or German tinder, a thick leathery and porous preparation from the fungus *Polyporus fomentarius*, were often used.

It was not till 1805 that any attempt was made to use chemical agency for the ordinary production of fire. In that year M. Chancel, assistant to Professor Thenard of Paris, introduced an apparatus consisting of a small bottle containing asbestos, saturated with strong sulphuric acid, with splints or matches coated with sulphur, and tipped with a mixture of chlorate of potash and sugar. The matches so prepared, when brought into contact with the sulphuric acid in the bottle, ignited, and thus, by chemical action, fire was produced. It appears also that in the same year phosphorus matches were known in Paris, and in 1809 Derepas proposed to lessen the dangerously great inflammability of the phosphorus match by making an igniting mixture of that element with magnesia. It is also said that M. Derosne made a friction match with a phosphorus tip in 1816. Again in 1823 a phosphorus match was proposed, but it came into little use. In this case the composition consisted of equal parts of phosphorus and sulphur cautiously melted together in a glass tube. The tube was then securely corked, and, to obtain a light, a splint was introduced into the mixture, and a small pellet detached, which on withdrawal and exposure almost spontaneously ignited. In that year (1823) a decided impetus was given to the artificial evolution of fire by the introduction of the Döbereiner lamp, so called after its inventor Professor Döbereiner of Jena. The action of this elegant invention depends on the remarkable property possessed by spongy or highly porous platinum of determining the combination of hydrogen and oxygen and the formation of water at common atmospheric temperatures. In the Döbereiner lamp hydrogen is evolved in a suitable vessel by the action of zinc on acidulated water. The gas so liberated, when required, is passed through a fine orifice by means of a stop-cock, and impinging on a mass of spongy platinum mounted in a frame it combines with oxygen of the air, thereby developing an intense heat, which quickly causes the platinum to glow, and ultimately is sufficiently intense to set the stream of hydrogen itself on fire. The Döbereiner lamp is still occasionally seen, but it is chiefly used in connexion with chemical lectures.

The first really practical friction matches were made in England in 1827, by Mr John Walker, a druggist of Stockton-on-Tees. These were known as "Congreves" after Sir William Congreve, Bart., the inventor of the Congreve rocket, and consisted of wooden splints or sticks of cardboard coated with sulphur and tipped with a mixture of sulphide of antimony, chlorate of potash, and gum. With each box of eighty-four, which was retailed at a shilling, there was supplied a folded piece of glass paper, the folds of which were to be tightly pressed together, while the match was drawn through between them. In 1830 the so-called "Prometheans" were patented by Mr S. Jones of London. These consisted of a short roll of paper with a small quantity of a mixture of chlorate of potash and sugar at one end, a thin glass globule of strong sulphuric acid being attached at the same point. When the sulphuric acid was liberated by pinching the glass globule, it acted on the mixed chlorate and sugar, producing fire.

The phosphorus friction match of the present day was first introduced on a commercial scale in 1833; and it appears to have been made almost simultaneously in several distinct centres. The name most prominently connected with the early stages of the invention is that of Preschel of Vienna, who in 1833 had a factory in operation for making phosphorus matches, fusees, and amadou slips tipped with igniting composition. At the same time also matches were being made by Moldenhauer in Darmstadt; and for a long series of years Austria and the South-German states were the principal centres of the new industry. Improvements in the manufacture have been numerous; and the industry is now carried on with a complete system of ingenious labour-saving machinery. The use of phosphorus as a principal ingredient in the igniting mixture of matches has not been free from very serious disadvantages. It is a deadly poison, the free dissemination of which has led to many accidental deaths, and also to numerous cases of wilful poisoning and suicides. Workers also who are exposed to phosphoric vapours are subject to a peculiarly distressing disease which attacks the jaw, and ultimately produces necrosis of the jaw-bone; it appears, however, that, with scrupulous attention to ventilation and cleanliness, almost all risk of the disease may be avoided. Strenuous efforts have been made by numerous inventors to introduce matches having no phosphorus in their igniting mixture, but hitherto with indifferent success. The most serious objections to the use of phosphorus have, however, been overcome by the discovery of the modified condition of that body known as red or amorphous phosphorus, made by Professor Anton Von Schrötter of Vienna in 1845, and the utilization of that substance in the now well-known "safety matches" invented by Lundström of Sweden in 1855, and first manufactured in the United Kingdom by Bryant & May of London. Red phosphorus is, in itself, a perfectly innocuous substance, and no evil effects arise from freely working the compositions of which it forms an ingredient. The fact again that safety matches ignite only in exceptional circumstances on any other than the prepared surfaces which accompany the box—which surfaces and not the matches themselves contain the phosphorus required for ignition—makes them much less liable to cause accidental fires than the kinds more commonly in use.

Manufacture.—The operations carried on in a match factory may be grouped under the four heads of preparing the splints, dipping the matches, box-making, and filling. The varieties of wood principally used for matches are poplar, aspen, yellow pine, and white pine. Splints are either round or quadrangular, the former having been at one time exceedingly common, when Austrian manufactures ruled the markets; but, now that Sweden is the principal match-manufacturing country, matches are nearly all square in section. For cutting square splints many ingenious machines have been devised, some of which, worked by engine-power, can turn out from 15,000,000 to 17,000,000 splints per day. In Sweden the manufacturers use principally aspen or clean-grained pine wood, preferring sections 12 to 20 inches in diameter, newly felled and full of sap. If dry, the wood must be soaked before it is fit for the operations through which it passes. The timber is cut into blocks about 15 inches long—sufficient for seven matches—and being freed from bark it is fixed in a special form of turning lathe, and by means of a fixed cutting tool acting on its entire length a continuous veneer or band the thickness of a match is cut off. With each revolution of the block the knife advances proportionately to the thickness of the band cut off, and thus a uniformly thick slice is obtained continuously. At the same time eight small knives cut the veneer into seven separate bands each the length of a match, and thus in one operation seven long ribbons of wood the length and thickness of a match are obtained. These ribbons are next broken into lengths of from 6 to 7 feet, knotty pieces are removed, and to cut them into single matches they are fed into a machine which acts somewhat like a straw-chopper. From 120 to 140 bands are acted on in the apparatus, and a ratchet arrangement feeds them forward the thickness of a match at each stroke of the cutter, which thus cuts off 120 to 140 matches per stroke. Worked by hand the machine delivers about 5,000,000 splints per day, and by power it can be run to turn out double that number. The matches are next dried in revolving drums in a heated chamber or stove, and thereafter they are sifted in a kind of partitioned sieve to free them from fragments and splinters. The sifting process also arranges all the splints in parallel order and in uniform quantities, whereby they may be conveniently bundled and prepared for the dipping which next follows. For the dipping process it is necessary to keep each match free from contact with its neighbour, and indeed allow it such a space that each may be fully coated and yet there be no danger of the igniting composition clotting the heads into one mass. To effect this the splints are by an ingenious machine separately arranged at uniform intervals between the lathes of a dipping frame. The dipping frames are made about 18 inches square, and are fitted with 44 movable lathes. Between each pair of lathes 50 splints are inserted by the machine, and when tightened up by screws each frame thus contains $44 \times 50 = 2200$ splints placed at regular intervals, the heads of which are all on the same level. A single attendant can place, by aid of the machine, about 1,250,000 matches in the dipping frames per day. The dipping is done in a stove of masonry which contains three square flat-bottomed shallow pans. In the first the splints are heated so as to facilitate the absorption of paraffin; in the second their points are dipped into molten paraffin scale; and in the third they receive their heads or tips of igniting composition, that mixture being kept in a uniform thin stratum in the pan, or in some cases it is supplied by an endless india-rubber belt which revolves and dips into the composition. A skilful workman can dip from 3500 to 4000 frames, or about 8,000,000 matches, a day. The frames so dipped are afterwards arranged in a heated apartment till the igniting composition is dried, after which the matches are taken out and put up in boxes by hand.

Match splints in the factories of the United Kingdom are generally cut in lengths suitable for two matches, and dealt with in that form throughout. The splint-cutting machine patented by John Jex Long of Glasgow in 1871 differs essentially from the Swedish splint-making machinery above alluded to; it acts on squared blocks two-match length, and is capable of producing up to 17,000,000 matches per day.

The object of dipping in melted paraffin is, of course, to secure more ready ignition of the wood. Sulphur was formerly employed for that purpose; and enormous quantities of the cheaper matches made on the Continent and in America continue to be sulphur dipped. The cheaper kinds are frequently "bundle dipped" in the molten sulphur, after which their points are merely pressed against the igniting composition.

The chief element in the igniting mixture of ordinary matches is still common phosphorus, combined with one or more other bodies which readily part with oxygen under the influence of heat. Chief among these latter substances is chlorate of potash, the body which causes the sharp explosive sound when a common match is struck, and to the use of which there is a strong objection on the Continent from the fear of explosions in dealing with the substance in large quantities. The other oxygen-yielding bodies commonly found in matches are red lead, nitrate of lead, bichromate of potash, and peroxide of manganese. The proportions in which any of these bodies is present in various igniting compositions are kept trade secrets; they vary greatly, as special regard must be given to matches for damp climates, or for ocean transport, and to other considerations. The igniting agents are made into a paste with glue or gum as an adhesive agent, a little fine sand or powdered glass, and some colouring ingredient such as cinnabar, smalt, magenta, or Prussian blue. Matches in which amorphous phosphorus takes the place of the common variety, notwithstanding several obvious advantages, have never come into general use. They were shown in the Great Exhibition of 1851 by Bell & Black of London; and Foster & Warwa of Vienna, one of the earliest match-making firms, long continued to make them, as did also Coigniet Père et Fils of Paris. As made by these and other makers they were difficult to strike, requiring a special rough rubbing surface; the head frequently broke away in the attempt to light them, and when they did inflame it was with explosive violence and a loud spluttering noise. Dr Von Schrötter, the discoverer of amorphous phosphorus, claims to have found a means of preparing combinations of amorphous phosphorus with chlorate of potash and other oxygen-yielding compounds of all degrees of combustibility, and he states that Hochstätter of Frankfort now manufactures matches with amorphous phosphorus composition which may be ignited by rubbing on a cloth surface, which inflame quietly, burn without smell or sparking, are not influenced by damp, and are cheaper than common phosphorus matches. The use of amorphous phosphorus—but on the rubbing surface only and not in the dipping composition (safety matches)—was first suggested by Böttger, but it was not till a patent was secured by Lundström in 1855 that the matches were brought into the market. According to J. G. Gentele, the elements of the dipping mixture for the heads are—chlorate of potash, 32 parts; bichromate of potash, 12; red lead, 32; sulphide of antimony, 24; and the ingredients of a suitable rubbing surface are eight parts of amorphous phosphorus to nine of sulphide of antimony. There is no doubt, however, that here too there is considerable diversity in the composition of the mixtures. Igniting compositions entirely free from phosphorus depend for their moderate degree of efficiency on the use of such agents as chlorate of potash, sulphide of antimony, bichromate of potash, and red lead.

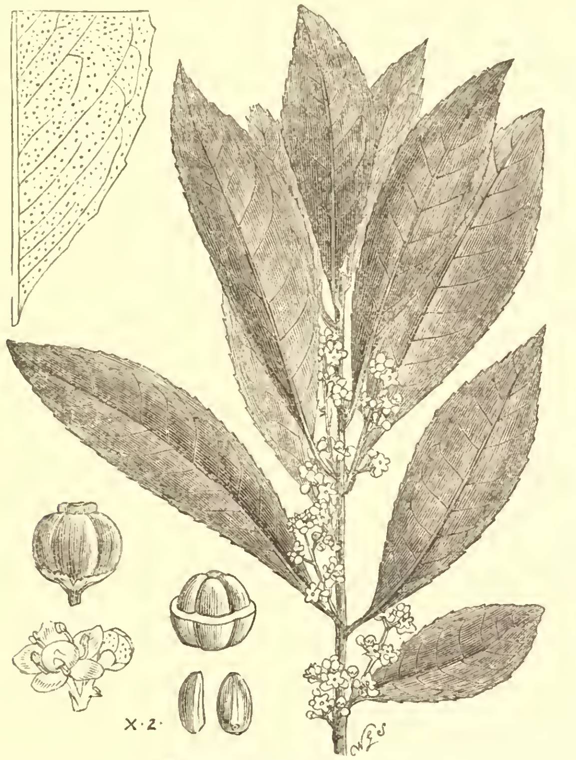
"Vestas" are matches in which short pieces of "wax taper" are used in place of wooden splints. The taper is prepared by drawing a series of wicks or strands of twenty to thirty fine cotton threads through molten stearin, with some proportion of paraffin. The wax quickly hardens on the threads, agglutinating them to irregular hard strands, which are smoothed and rounded to the required size by being drawn through iron plates perforated with holes the size of the required taper. The tapers are cut to the match lengths, and set in dipping frames by special machines. The making of vestas is an industry only second in extent to the wooden match manufacture,—its headquarters being London, Manchester, Marseilles, and the north of Italy. Fusees for the use of smokers are made of strips of thick porous paper saturated with saltpetre and bichromate of potash, and tipped with ordinary composition. They are now almost entirely supplanted by vesuvians, which consist of large oval heads on both ends of a round splint. These heads, made by repeated dipping, consist of a porous mixture of charcoal, saltpetre, cascarilla or other scented bark, glass, and gum, and they also are tipped with common igniting composition.

Ordinary match boxes are made of thin veneers or skillets of wood the same as used in splint making. The blocks used yield skillets the exact size of the box or cover to be made, and the machine which shaves skillets off the block also scores them along the lines by which they must be bent to form the box. The folding, covering with paper, and labelling are operations performed by young girls with remarkable rapidity. In dealing with double splints, the matches are at the boxing stage cut asunder in small bundles with a lever knife by the box filler, who acquires such delicacy of perception that at each operation she seizes and divides the exact quantity required to fill two boxes. A good hand will in this way fill 35 to 40 gross of boxes per day.

It is calculated that in the principal European countries from six to ten matches are used for each inhabitant daily. There is no way by which an exact estimate of the extent of the trade in the United Kingdom can be obtained; but competent authorities believe the yearly value of the matches made to be not less than £1,500,000, and that the makers turn out about 300,000,000 matches daily. Of all the makers Messrs Bryant & May are by far the most extensive; and next comes the Bell & Black company, formed of a combination of makers in London, Glasgow, Manchester, and York. In France the right to manufacture matches is a Government monopoly farmed to the *Compagnie générale des allumettes chimiques* for an annual payment of 16,000,000 francs, with 6 centimes extra per hundred matches in excess of forty milliards sold yearly. The company has concentrated the whole of the manufacture into twelve establishments, the largest of which are at Marseilles. The effect of the monopoly in France is that matches are very costly, and the average consumption per head throughout the country is considerably less than in other countries. Sweden is the country which in recent years has been most intimately identified with the growth of the industry. In that country, including with it Norway, there were in 1880 forty-three match factories, many of them large, that of Jönköping being among the most extensive in the world. The quantity of matches exported that year was about 19,000,000 lb (22,900,000 skal-punds), probably representing 50,000,000,000 matches. The yearly exports have increased four-fold since 1870, and are still rapidly extending. In Germany there are two hundred and twelve factories, which are estimated to make yearly about 60,000,000,000 matches; and Austria-Hungary—the original seat and centre of the manufacture—possesses one hundred and fifty establishments, whence large quantities of matches are exported to Russia, Turkey, Asia Minor, and the neighbouring states of Italy. Throughout Europe about 1200 tons of phosphorus are annually consumed in the manufacture of matches, the greater proportion being produced in England

In the United States a tax of 1 cent per box containing one hundred is levied on matches manufactured in the country, in addition to which there is an *ad valorem* duty of 35 per cent. on all matches imported. The internal revenue tax of a cent per box is subject to a reduction of 10 per cent. to manufacturers, with an additional discount of 5 per cent. on the purchase of the stamps used for the boxes when quantities exceeding in value $50 are purchased at one time. The result of these fiscal arrangements has been to favour large monopolizing companies. Although there are nearly thirty manufactories in the States at present, practically the match trade of the country is in the hands of, or entirely controlled by, the Diamond Match Company of New York, consisting of a combination of large manufacturers. During the year 1881 the revenue derived from the internal tax amounted to $3,272,258, while the customs duty on imported matches yielded no more than $6186, these receipts representing probably a consumption of 40,000,000,000 matches. (J. PA.)

MATÉ, or Paraguay Tea, consists of the dried leaves of *Ilex paraguayensis*, St Hil.,[1] an evergreen shrub or small tree belonging to the same natural order as the common holly, a plant to which it bears some resemblance in size and habit. The leaves are from 6 to 8 inches long, shortly-stalked, oblong wedge-shaped, rounded at the upper end, and finely toothed at the margin. The small white flowers



Maté (*Ilex paraguayensis*).
Portion of plant, half natural size. Flower drupe and nuts, twice natural size. Part of underside of leaf showing minute glands, natural size.

grow in forked clusters in the axils of the leaves; the sepals, petals, and stamens are four in number; and the berry is 4-seeded. The plant grows abundantly in Paraguay, Corrientes, Chaco, and the south of Brazil, forming woods called *yerbales.* One of the principal centres of the maté industry is the Villa Real, a small town above Asuncion on the Paraguay river; another is the Villa de San Xavier, in the district between the rivers Uruguay and Parana.

Although maté appears to have been used from time immemorial by the Indians, the Jesuits were the first to attempt its cultivation. This was commenced at their branch missions in Paraguay and the province of Rio Grande de San Pedro, where some plantations still exist, and furnish the best tea that is made. From this circumstance the names Jesuits' tea, tea of the Missions, St Bartholomew's tea, &c., are sometimes applied to maté. Under cultivation the quality of the tea improves, but the plant remains a small shrub with numerous stems, instead of forming, as in the wild state, a tree with a rounded head. From cultivated plants the leaves are gathered every two or three years, that interval being necessary for restoration to vigorous growth. The collection of maté is, however, chiefly effected by Indians employed for that purpose by merchants, who pay a money consideration to Government for the privilege.

When a yerbal or maté wood is found, the Indians, who usually travel in companies of about twenty-five in number, build wigwams and settle down to the work for about six months. Their first operation is to prepare an open space, called a *tatacua*, about 6 feet square, in which the surface of the soil is beaten hard and smooth with mallets. The leafy branches of the maté are then cut down and placed on the tatacua, where they undergo a preliminary roasting from a fire kindled around it. An arch of poles, or of hurdles, is then erected above it, on which the maté is placed, a fire being lighted underneath. This part of the process demands some care, since by it the leaves have to be rendered brittle enough to be easily pulverized, and the aroma has to be developed, the necessary amount of heat being only learned by experience. After drying, the leaves are reduced to coarse powder in mortars formed of pits in the earth well rammed. Maté so prepared is called *caa gazu* or *yerva do polos*, and is chiefly used in Brazil. In Paraguay and the province of Parana in the Argentine Republic, the leaves are deprived of the midrib before roasting; this is called *caa-miri.* A very superior quality, or *caa-cuys*, is also prepared in Paraguay from the scarcely expanded buds. More recently a different method of drying maté has been adopted, the leaves being heated in large cast iron pans set in brick work, in the same way that tea is dried in China; it is afterwards powdered by machinery.

The different methods of preparation influence to a certain extent the value of the product, the maté prepared in Paraguay being considered the best, that of Oran and Paranagua very inferior. The leaves when dried are packed tightly in serons or oblong packages made of raw hides, which are then carefully sewed up. These shrink by exposure to the sun, and in a couple of days form compact parcels each containing about 200 lb of tea; in this form it keeps well. The tea is generally prepared for use in a small silver-mounted calabash, made of the fruit of *Crescentia Cujete* (Cuca) or of *Cucurbita lagenaria* (Cabaço), usually about the size of a large orange, the tapering end of the latter serving for a handle. In the top of the calabash, or *maté*,[2] a circular hole about the size of a florin is made, and through this opening the tea is sucked by means of a bombilla. This instrument consists of a small tube 6 or 7 inches long, formed either of metal or a reed, which has at one end a bulb made either of extremely fine basket-work or of metal perforated with minute holes, so as to prevent the particles of the tea leaves from being drawn up into the mouth. Some sugar and a little hot water are first placed in the gourd, the yerva is then added, and finally the vessel is filled to the brim with boiling water, or milk previously heated by a spirit lamp. A little burnt sugar or lemon juice is sometimes added instead of milk. The beverage is then handed round to the company, each person being furnished with a bombilla. The leaves will bear steeping about three times. The infusion, if not drunk soon after it is made, rapidly turns black. Persons who are fond of maté drink it before every meal, and consume about 1 oz. of the leaves per day. In the neighbourhood of Parana it is prepared and drunk like Chinese tea. Maté is generally considered disagreeable by those unaccustomed to it, having a somewhat bitter taste; moreover, it is the custom to drink it so hot as to be unpleasant. But in the south-eastern republics it is a much-prized article of luxury, and is the first thing offered to visitors. The *gaucho* of the plains will travel on horseback for weeks asking no better fare than dried beef washed down with copious draughts of maté, and for it he will forego any other luxury, such as sugar, rice, or biscuit. Maté acts as a restorative after great fatigue in the same manner as tea. Since it does not lose its flavour so quickly as tea by exposure to the air and damp, it is more valuable to travellers.

Some writers attribute deleterious effects to its use, while others praise it to an almost incredible degree. Its physiological action does not appear to have been carefully worked out, but its extensive use in countries where tea and coffee are known seems to indicate that it may possess virtues peculiar to itself.

Its properties appear to be chiefly due to theine or caffeine. Analysed by Dr H. Byasson, 100 grains were found to yield

	Grains.
Caffeine	1·850
Glutinous substance or peculiar fatty matter and colouring matter	3·870
Complex glucoside	2·380
Resin	0·630
Inorganic salts, including iron	3·920
Malic acid not estimated.	

[1] Mr J. Miers has proved that *I. curitibensis*, *I. gigantea*, *I. ovalifolia*, *I. Humboldtiana*, and *I. nigropunctata*, besides several varieties of these species, are in general use for preparing maté.

[2] The word *caa* signified the plant in the native Indian language. The Spaniards gave it a similar name, *yerba.* *Maté* comes from the language of the Incas, and originally means a calabash. The Paraguay tea was called at first *yerva do maté*, and then, the *yerva* being dropped, the name *maté* came to signify the same thing.

According to analyses made by Alonzo Robbins it also contains about 1·5 of a peculiar tannin which does not precipitate potassio-tartrate of antimony, nor tan leather. The glutinous substance resembles in consistence common birdlime, and is considered by Byasson to be a compound ether, the alcohol of which would be near cholesterin. Since the beginning of the 17th century maté has been drunk by all classes in Paraguay, and it is now used throughout Brazil and the neighbouring countries. In 1855 the amount of maté annually consumed in South America was estimated by Von Bibra at 15,000,000 lb, and the consumption is now probably three or four times as great; in Brazil it brings in a revenue of about £410,000. In the Argentine Republic alone the consumption is not less than 27,000,000 lb per annum, or about 13 lb per head, while the proportion of tea and coffee consumed is only about 2 lb of the former and ¼ lb of the latter per head. The export of maté from Brazil to foreign countries has also increased from 2,720,475 kilos in 1840 to 5,206,485 kilos in 1850, 6,808,056 kilos in 1860, 9,507,086 kilos in 1870, and 14,063,731 kilos in 1879–80.

See Scully, *Brazil*, London, 1866; Mansfield, *Brazil, &c.*, London, 1856; *Pharmaceutical Journal* (3), vol. vii. p. 4; (3), vol. viii. p. 615, 1627; Christy, *New Commercial Plants*, No. 3, London, 1880; Mulhall, *Progress of the World*, 1880, p. 488; *Zeitschrift Oesterreichischer Apothekerverein*, 1882, pp. 273, 285, 310.

MATERA, a city of Italy in the north-east of the province of Potenza, 48 miles from Potenza, on the high road to Bari. Part of it is built on a level plateau and part in deep valleys adjoining, the tops of the campaniles of the lower portions being on a level with the streets of the upper. The principal building is the co-cathedral of the archbishopric of Acerenza and Matera, formed in 1203 by the union of the two bishoprics, dating respectively from 300 and 398. In 1871 the population of the commune was 14,312 (that of the city 14,262), in 1881 15,700.

Under the Normans Matera, the ancient Mateola, was a countship for William Bras de Fer and his successors. It was the chief town of the Basilicata from 1664 till 1811, when the French transferred the administration to Potenza.

MATHEMATICAL DRAWING AND MODELLING. The necessity for geometrical drawings and models is as old as geometry itself. The figure has formed the basis of many a geometrical truth; and demonstration by mere inspection of this has frequently to do service for more rigorous proof. So necessary is this visual representation of an idea that there is hardly a branch of mathematics which does not make use of it in the form of tables, symbols, formulæ, &c. The visual method is especially important in geometry. The figure is to the geometer what the numerical example is to the algebraist—on the one hand limiting the horizon, on the other imparting life to the conception. Herein lies the didactic value of the figure, which is the more indispensable the more elementary the stage of instruction. To be able to dispense with it is a faculty acquired only after a long and special training. The power of mental picturing is a talent which can be so strengthened by use that even a slightly gifted mind may acquire the power of carrying out a series of geometrical operations without the aid of a figure, provided these do not lead into unfamiliar regions. But each new group of ideas which the geometer would master requires a new graphic setting forth, which not even the experienced can dispense with. Drawings are sufficient in plane geometry; but solid geometry requires models, except in specially simple cases, in which delineation by means of perspective or some conventional method may suffice. Then, again, in passing from the geometry of the plane, straight line, and point in space to that of curved surfaces, tortuous curves, &c., new and distinct graphical methods are necessary. The difficulties encountered in understanding new groups of geometrical forms are best removed by a careful study of a small number of characteristic models and drawings. As a means of education, the model is lively and suggestive, forming in this way a completing factor in the course of instruction. We remember the pleasure experienced when, after a discussion which has yielded a series of hardly reconcilable properties of one and the same geometrical figure, a model is exhibited which combined these properties in itself; or the striking manner in which a deformable model either of pasteboard or thread executes its transformations before the eye of the observer and scientific student. The study of the model raises new and unexpected questions, and can even do valuable service in leading to new truths.

In the more elementary departments of plane and solid geometry and descriptive geometry, models are abundant and easily obtainable; but there are comparatively few collections of drawings and models for instruction in higher geometry. There are numerous drawings of algebraic and transcendental curves in the well-known treatises on analytical geometry of Cramer, Euler, Salmon, in Frost's *Curve Tracing*, &c.; but there is still a deficiency in systematic enumerations of the forms of curves and surfaces of a given order or class. In this connexion we may mention Plücker's *System der analytischen Geometrie* (curves of the third order), and Beer's *Enumeratio linearum IV. ordinis*. A graphical representation of all the characteristics of the singular points of an algebraic curve of the fourth order is given in Zeuthen's *Systemer af plane Kurver* (1873). As regards tridimensional figuring, the oldest known models for instruction in the higher geometry are the thread models of skew surfaces constructed about the year 1800 under the direction of G. Monge for the École Polytechnique in Paris. In 1830 Th. Olivier of Paris got the same executed in movable form. The great development in modern times of certain branches especially of the higher geometry has given a new importance to such methods of graphical representation.

Amongst the larger collections we must mention the elegant series of complex surfaces, consisting of twenty-seven items, constructed by the celebrated J. Plücker of Bonn. After Plücker's death copies, not very satisfactory, were made from zinc casts. The collection of plaster and thread models published by Muret of Paris (now Delagrave), and intended for instruction in descriptive geometry, contains many architectural forms. The wire models of tortuous curves by Professor Wiener of Carlsruhe, and the thread-models of developable surfaces by Professor Björling of Lund, merit notice amongst others. Perhaps the largest and most extensive of the collections is that of L. Brill, bookseller in Darmstadt. These represent every department of the higher and applied mathematics. The catalogue embraces some seventy numbers, with over a hundred plaster, thread, and metal models. Several series of this collection were prepared in the mathematical department of the technical college of Munich. In the preparation of these models, involving the development of a comparatively novel art, certain practical lessons were gained, especially in the working of plaster models, to which we may direct attention.

We assume that the preliminary designs are prepared with the aid of board, ruler, square, compasses, and such well-known instruments as are used by the draughtsman.

The material to be employed, whether wire or thread, interlaced pasteboard strips, or plaster, depends upon the special circumstances of each case, and upon the purpose aimed at in the construction of the model. Two bundles of parallel disks of cardboard or metal-sheeting, inclined at an adjustable angle, may be used with advantage in representing a series of different but mutually transformable surfaces. For ruled and developable surfaces the thread model is to be recommended. The surface is enclosed in a cube, or more generally in a region of space bounded by plane walls. Upon these bounding walls are marked the series of points in which they are cut by the generative lines that are to be represented by threads. Through these points the threads are drawn, and parts of the supporting walls are then cut away so as to allow a convenient glance into the interior of the region. The more densely the threads are strung, the liker is the appearance to that of a continuous surface.

In the majority of cases plaster will be found the most convenient substance, being easily worked, and giving a result convenient and clear to the eye. There is the disadvantage, however, that one of the regions of space bounded by a surface is filled up. Should the boundaries of the surface be plane or capable of being turned on the lathe, the desired form is best approximated to by working wood or plaster blocks. Plaster is not easily worked on the lathe, but a plane surface is readily got by rubbing, and if not too dry it may be cut with the knife.

A surface which cannot be conveniently approximated to by the above method may be built up of strips cut to pattern, which are then filled in with some plastic material. To accomplish this, a system of sections either parallel or having a single axis is laid through the region to be filled up; the bounding lines of these sections are calculated or obtained by geometrical construction. Strips of plate zinc are then cut to the required form and fixed securely by cross-pieces or soldered if necessary. Between the interstices of this zinc scaffolding some plastic material is filled in, such as embossing wax or damp clay; and thus the form of the surface is rendered. The substance known in trade as plastilin is especially suitable for use in this way, as it retains its plastic property a long time. The finishing touches are given to the surface by means of a sculptor's style. From the clay model a plaster cast is formed and well dried; and its imperfections are removed by means of plaster-files and other instruments familiar to those who work in plaster. Lines which are to be shown on the model are drawn through points already marked on the original clay model, and engraved with fine files. A galvanoplastic copy of such a plaster model, not too deeply deposited, shows the surface even better than the plaster itself.

MATHEMATICS. Any conception which is definitely and completely determined by means of a finite number of specifications, say by assigning a finite number of elements, is a mathematical conception. Mathematics has for its function to develop the consequences involved in the definition of a group of mathematical conceptions. Interdependence and mutual logical consistency among the members of the group are postulated, otherwise the group would either have to be treated as several distinct groups, or would lie beyond the sphere of mathematics.

As an example of a mathematical conception we may take "a triangle"; regarded without reference to its position in space, this is determined when three elements are specified, say its three sides; or we may take a "colour sensation," which, on Young's theory, is determined when the amounts of the three fundamental colour sensations that enter into it are stated. As an example of a non-mathematical conception we may take "a man," "a mineral," "iron," no one of which admits of being so determined by a finite number of specifications that all its properties can be truly said to be deducible from the definition.

A mathematical conception is, from its very nature, abstract; indeed its abstractness is usually of a higher order than the abstractness of the logician. Thus, for instance, we may neglect the other attributes of a body and consider merely its form; we thus reach the abstract idea of "form." But the form of an irregular fragment of stone does not admit of being finitely specified, and is therefore not susceptible of mathematical treatment. If, however, we have a carefully squared cubical block of granite to deal with, for most practical purposes its form is specified by stating that it is a cube, and assigning one element, viz., an edge of the abstract mathematical cube by which we replace it. This example illustrates at once the limits of mathematical reasoning and the nature of the bearing of mathematics on practice.

A variety of words have been used to denote the dependence of a mathematical conception upon its elements. It is frequently said, for instance, that the conception is a "function" of its elements. One word has recently come into use which is very convenient, inasmuch as it draws attention at once to the fundamental idea involved in mathematical conception and to the prime object of mathematical contemplation, viz., "manifoldness."

Number is involved in the notion of a manifoldness both directly, as any one can see, and also indirectly in a manner which the mind untrained to mathematical thinking does not so readily understand. Take on the one hand the case of a triangle considered without reference to its position but merely as composed of three limited straight lines, it may be completely determined in various ways by assigning three elements. A triangle may therefore be called a triple discrete manifoldness. A plane quadrilateral considered in the same way (being fully determined when four sides and a diagonal are known) is a quintuple discrete manifoldness; and a plane polygon of n sides a $(2n-3)$-ple discrete manifoldness. Consider on the other hand the assemblage of points on a given straight line, they are infinite in number yet so related that any one of them is singled out by assigning its distance from an arbitrarily chosen fixed point on the line. Such an assemblage is called a onefold continuous manifoldness, or simply a onefold manifoldness; another example of the same kind is the totality of instants in a period of time. The assemblage of points on a surface is a twofold manifoldness; the assemblage of points in tridimensional space is a threefold manifoldness; the values of a continous function of n arguments an n-fold manifoldness.

It should be observed that the distinction between discrete and continuous manifoldness is not of necessity inherent in the conception. For one purpose we may treat a conception as a discrete manifoldness, for another as a continuous manifoldness. Thus we have seen that an unlimited straight line may be treated as a onefold continuous manifoldness; but, if we regard it as a whole, and with reference to the fact that its position in space is determined by four data, it becomes a quadruple discrete manifoldness.

The primary, although not the only, operation in the treatment of a discrete manifoldness is numbering or counting; hence arises the pure mathematical science of number, comprehending (abstract) *Arithmetic* and its higher branch commonly called the *Theory of Numbers.* Without entering into a discussion of the definitions and axioms of the science of number, it will be sufficient here to remark that all numerical operations are reducible to three fundamental laws commonly called the commutative, associative, and distributive laws. The four fundamental processes, or four species, as they are sometimes called, two of which, addition and multiplication, are direct, and two, subtraction and division, inverse, are solely defined by and derive their meaning from the three laws of operation just mentioned.

A careful consideration of the methods in vogue for dealing with continuous manifoldness shows that they reduce themselves to two, which may be called the synoptic method and the analytic method. In the synoptic method we deduce the properties of a manifoldness by contemplating it as a whole, aiding our understanding, when it is necessary to do so, by a diagram, a model, or any other concrete device more or less refined according to circumstances. In the analytic method we fix our attention upon the individual elements of the manifoldness, usually defining each element by a definite number of specifications the variation of which leads us from element to element of the given manifoldness. We examine the properties of an element in the most general manner, and from them we predicate the properties of the manifoldness as a whole.

The best and most familiar examples of the synoptic treatment of manifoldness are the different varieties of pure geometry. Among these we may mention the apagogic geometry of the Greeks, which starts with a collection of definitions and axioms, enunciates and proves proposition after proposition with great attention to strict logical form and with continual reference to the grounds of inference, but pays little attention to the ordering of theorems with a view to mutual illustration, and carefully suppresses all traces of the method by which the propositions were or might have been discovered. It is true that the Greeks were in possession of a method, called by them analysis, which had for its object the discovery of geometrical truth. But this consisted merely in taking any proposition suspected to be true and tracing its consequences until one was reached which either contradicted a known proposition or else was true and capable of leading by a direct process of reasoning (synthesis) to the proposition in question. In this we have no trace of the systematic development of geometric truth, and the method was apparently regarded by the ancients themselves as imperfect, for it makes no figure in such of their systematic treatises as have reached us. In somewhat sharp contrast with the Grecian geometry, but still essentially synoptic in method, stand the different varieties of modern geometry,—which aims at greater generality in its definitions, pays less explicit attention to logical form, but arranges geometrical propositions as much as possible in the natural order of development or discovery, and above all makes extensive use of the principle of continuity. As examples of the modern geometry may be cited the descriptive geometry (*Géométrie Descriptive*, *Darstellende Geometrie*) of Monge; the projective geometry (*Géométrie Projective*, *Geometrie der Lage*) of Poncelet, Steiner, and Von Staudt; and the geometry of transformation in general, of which projective geometry is but a particular case. There is one other highly interesting form of modern geometry, which, although analytic in some of its developments, and often exhibited in close alliance with other analytical methods, is nevertheless synoptic as to its fundamental principle, viz., arithmic geometry (*Abzählende Geometrie*) or theory of characteristics, which originated in the characteristic equations of Plücker, and was developed into a powerful special method by Chasles and others. See GEOMETRY and CURVE.

Geometry, however, is not the only field for the synoptic treatment of manifoldness. This is obvious if we reflect that any magnitude whatever may be represented by a line; so that any function of not more than two elements may be represented by a geometrical construction and treated by any method applicable in geometry. Since the famous dissertation of Riemann, *On the Hypotheses that form the Basis of Geometry*, mathematicians have been familiar with the fact that the methods of geometry suitably generalized can be applied to the treatment of an n-fold manifoldness; and in point of fact the synoptic treatment of manifoldness under the name of n-dimensional geometry has been usefully employed by Cayley and others as an adjunct to the analytic method.

The fundamental characteristic of the analytical treatment of an n-fold manifoldness is the specification of an element by means of n continuously varying quantities or variables (see MEASUREMENT). For dealing with continuous as distinguished from discrete quantity we have the special analytical method of the INFINITESIMAL CALCULUS (*q.v.*), built upon the notion of a limit, with its various branches, viz., the differential calculus, the integral calculus including differential equations, the calculus of functions, and the theory of functions in general (see FUNCTION). But, whether we make use of the algorithm of the infinitesimal calculus or not, we find upon examination that all analytical operations with continuous quantity fall under the three laws of commutation, association, and distribution, so that they are fundamentally identical with the operations with discrete quantity; the difference so far as there is any consists simply in the greater generality of the operand. The same fact may be looked at instructively in another light. Whether we consider analytical processes in concrete applications or look at them abstractly, we are equally led to the notion of a unit, by the multiplication or subdivision of which all the other quantities that enter into our calculus are derived. The exigencies of continuity are met by allowing that the multiplication or subdivision of the unit can be carried on to an unlimited extent; but in any case where analytical formulæ have to be reduced to arithmetical calculation (in which of course only a finite number of figures or arithmetical symbols can be used) the subdivision (or multiplication) of the unit actually stops short at a certain point; in other words, all our methods are, in practice at least, discrete. Here therefore we have the meeting point of discrete and continuous quantity, and on this ground alone we might infer the fundamental identity of their laws of operation.

The abstract science of quantity which we have just seen to be the essential part of the analytic treatment of manifoldness receives the name of ALGEBRA (*q.v.*). It was found very early in the history of that science that the full development of which it is capable could not be attained without great extension of the idea of quantity. This necessity first arose in connexion with the inverse operations, such as subtraction, the extraction of roots, and the numerical solution of algebraical equations (see EQUATION), of which root extraction is merely a particular case. In this way arose essentially negative quantities, and the so-called impossible or imaginary quantities. The former may be said to depend on a new abstract unit -1, and the latter upon new units $\pm\sqrt{-1}$. The numbers having ± 1 for abstract unit are usually classed as real numbers, and in that case we may regard the ordinary imaginaries of algebra as depending on the new unit $+\sqrt{-1}$, or ι, defined by the equation $\iota^2 + 1 = 0$. But the extension was soon carried farther by the classical researches of Hamilton and Grassmann.[1] The theory of sets and the QUATERNIONS (*q.v.*) of the former and the *Ausdehnungslehre* of the latter opened up a boundless field for algebra, and led to a total revolution in our ideas of quantity.

In view of the great extension thus effected in the meaning of quantity, it becomes an interesting if somewhat difficult undertaking to define the word. The following may be taken as a provisional definition:—*Quantity is that which is operated with according to fixed mutually consistent laws.* Both operator and operand must derive their meaning from the laws of operation. In the case of ordinary algebra these are the three laws already indicated, in the algebra of quaternions the same save the law of commutation for multiplication and division, and so on. It may be questioned whether this definition is sufficient, and it may be objected that it is vague; but the reader will do well to reflect that any definition must include the linear algebras of Peirce, the algebras of logic, and others that may be easily imagined, although they have not yet been developed. This general definition of quantity enables us to see how operators may be treated as quantities, and thus to understand the rationale of the so-called symbolical methods. In combining operations, it is often observed that the combinations of operators fall under a few simple laws, in some cases in fact under the three laws of ordinary algebra; these operators are therefore quantities according to the general definition, and can be treated as such.

From the historical development of the analytic method there is little danger of the error arising that its application is peculiar to any special kind of manifoldness. As examples of its use in deducing the properties of tridimensional space we may cite the Cartesian geometry, the *Géométrie de Position* of Carnot, and the line geometry of Plücker (see GEOMETRY). Its use in the various branches of applied mathematics, of which geometry is merely one of the simplest, is far more common than that of the

[1] In this connexion should be mentioned the great services of De Morgan, whose bold speculations on the fundamental principles of mathematical science have perhaps met with less than their due share of appreciation.

synoptic method, although most branches of applied mathematics are mixtures using the one or the other, as happens to be convenient. In addition to those already mentioned, we may enumerate the following as among the more important departments of applied mathematics:—Kinematics; Abstract Dynamics, including Statics and Kinetics whether of a Particle, of a Rigid Solid, of an Elastic Solid, of a Fluid, or of a Chain; Statistical Mathematics, as exemplified in the Theory of Annuities, and the Kinetic Theory of Gases; the Mathematical Theory of Diffusion whether of Heat or of Matter; the Theory of Potential; and so on. See MECHANICS, HYDROMECHANICS, ANNUITIES, HEAT, ELECTRICITY, MAGNETISM, &c.

The two great methods employed in the investigation of manifoldness must of course be, at bottom, identical; and every conclusion arrived at by the one must be reachable by the other. The exact nature of the connexion between them will be well seen by studying two instances. One of these is the treatment of areas by Euclid and the treatment by the analytical method, which are carefully compared in the article GEOMETRY, vol. x. p. 379. The other is the connexion between the descriptive and the metrical properties of loci. The former include all properties such as intersection, tangency, &c., depending on position merely, and are obviously the natural product of the synoptic method. The latter include all relations involving the lengths of lines and the magnitudes of angles, they depend therefore on expression in terms of a unit, and are the natural product of the analytic method. Nevertheless the analytic method furnishes descriptive properties of loci, and by the introduction of "the absolute" descriptive theorems are made to furnish metrical relations, as has been fully shown by Cayley, Clifford, and Klein (see MEASUREMENT). (G. CH.)

MATHER, COTTON (1663–1728), was the most learned and widely known of a family which through four generations enjoyed singular consideration, and exercised commanding influence upon New England in its first century. Richard, son of Thomas Mather of Lowton (Winwick), Lancashire, England, after studying for a time at Brasenose, Oxford, and teaching and subsequently preaching at Toxteth Park, went to New England, for nonconformity's sake, in the summer of 1635, where, till his death in 1669, at seventy-three, he was pastor of the Congregational church in Dorchester (now a part of Boston),—acquiring large repute, writing three or four instructive and constructive treatises upon polity, and being much trusted as to the foundations of both church and state. His youngest son Increase took his first degree at Harvard College in 1656, at seventeen,—returning, after a visit to the old country, in which he served several pulpits, to take at twenty-five the pastorate of the second (or North) church in Boston, which place he held till his death in 1723 at eighty-five, while, in addition, he had been acting, or actual, president of the college most of the time from 1681 to 1701, the author of one hundred and sixty books or tracts, and for four of its most perilous years the choice of all its citizens to represent the Massachusetts colony before the English Government. His wife Maria was daughter of the famous John Cotton, and their first-born received both family names, and when he took his B.A. degree at less than sixteen, at Harvard, in 1678, his promise tempted President Oakes to say in his presence, referring to his two distinguished grandfathers: "Cottonus atque Matherus tam re quam nomine coalescant et reviviscant." After a short time spent as tutor, and a period of diligent toil ending in the conquest of an impediment of speech which endangered success in the family profession, he became assistant to his father, in two years being ordained co-pastor, and holding the pulpit for nearly three and forty years, till his death at sixty-five. As a private Christian, from his frank diaries, it is clear that he laboured much with himself, in a single year devoting more than sixty days to fasting and twenty nights to vigil. As a preacher he was conscientious and successful,—always diligently studying his discourses, in one year delivering more than seventy public sermons, with nearly half as many in private houses, sometimes thus "pressing a glorious Christ" through eleven successive days, and, with six competitors by his side, maintaining to the last his hold upon the largest congregation in New England, having about four hundred gifted communicants. As a pastor he was exceptionally laborious,—systematically exhorting and praying with his people at their homes, making conscience of spiritualizing every casual interview, and now and then spending days upon his knees with the names of his flock before him to prompt his intercessions for them, and for himself that he might better reach their peculiar need. As a philanthropist, while abundant in personal benefactions, he originated more than twenty societies for public charity, bore the cost of a school for Christianizing the negroes, and, at the risk of life, in the face of popular opposition medically led, advocated and vindicated the introduction of inoculation as a protection against the then terrible ravages of the small-pox. As an author he was learned—publishing in French, Spanish, and Algonkin as well as English—and voluminous, three hundred and eighty-two of his printed works having been catalogued, several of which are elaborate books, and one a folio of 800 pages; while his *Biblia Americana*, by him considered the great work of his life, remains in six huge volumes of manuscript to this day. As a scholar he was better known across the sea than any other American of his time, once contemporaneously corresponding with more than fifty learned Europeans, in his forty-seventh year being made doctor of divinity at Glasgow, and receiving election as a Fellow of the Royal Society—in those days eminent distinctions for a colonist. With all this it must be confessed that he had some grave defects. His common sense was not uniformly equal to his need. Always ambitious and self-opinioned, he was occasionally irritable and conceited. He lacked good taste, and it was his unconcealed grief that he was never elected to preside over Harvard College. His enormous knowledge did not digest well, and his use of learning tended to be crude. He was superstitious, and it was his misfortune that, as to witchcraft, he was not, as with vaccination, in advance of his generation, any more than such men as Richard Baxter and Sir Matthew Hale. Of his works, the *Magnalia* and *Ratio Disciplinæ* are indispensable to the student of New England history.

MATHEW, THEOBALD (1790–1856), popularly known as Father Mathew, the "Apostle of Temperance," was descended from an illegitimate branch of the Llandaff family, and was born at Thomastown, Tipperary, on October 10, 1790. He received his school education at Kilkenny, whence he passed for a short time to Maynooth; from 1808 to 1814 he studied at Dublin, where in the latter year he was ordained to the priesthood. Having entered the Capuchin order, he, after a brief time of service at Kilkenny, joined the mission in Cork, which was the scene of his religious and benevolent labours for many years. The movement with which his name is most intimately associated began in 1838 with the establishment of a total abstinence association, which in less than nine months, thanks to his moral influence and eloquence, enrolled no fewer than 150,000 names. It rapidly spread to Limerick and elsewhere, and some idea of its popularity may be formed from the fact that at Nenagh 20,000 persons are said to have taken the pledge in one day, 100,000 at Galway in two days, and 70,000 in Dublin in five days.

In 1844 he visited Liverpool, Manchester, and London with almost equal success. Meanwhile the expenses of his enterprise had involved him in heavy liabilities, and led on one occasion to his arrest for debt; from this embarrassment he was only partially relieved by a pension of £300 granted by the queen in 1847. In 1849 he paid a visit to the United States, returning in 1851. He died at Queenstown on December 8, 1856. See *Father Mathew, a Biography*, by J. F. Maguire, M.P. (1863).

MATHEWS, CHARLES (1776–1835), comedian, was born in London, 28th June 1776. His father was what he called "a serious bookseller," and also officiated as minister in one of Lady Huntingdon's chapels. Mathews was educated at Merchant Taylors' School. His love for the stage was formed in his boyhood, partly from admiration of Elliston, with whom he had taken part in private theatricals. According to his own statement, it ripened into an "overpowering, all-absorbing passion," unfitting him for business when he became apprentice to his father, who at length, in 1794, unwillingly permitted him to enter on a theatrical engagement in Dublin. For several years Mathews had not only to content himself with the most thankless parts at an almost nominal salary, but his figure, at this period of life thin and ungainly, and the peculiar twist in his countenance generally awakened the unconcealed ridicule of the audience. In 1798 he obtained a conditional engagement from Tate Wilkinson at York. In 1802 Mathews began to play in London at the Haymarket, and from this time his professional career was an uninterrupted triumph. His special excellence as an actor consisted in his wonderful gift of mimicry, enabling him to grasp the minutest and most individual features of the character he represented. His sense of the purely ludicrous in all its varied phases was perhaps unequalled, and by his marvellous command of facial expression and of different tones and accents of voice he could, when he so willed, completely disguise his personality without even the smallest change of dress. The versatility and originality of his powers were, in public, best seen in his "At Homes," begun in the Lyceum Theatre in 1818, "which," according to Leigh Hunt, "for the richness and variety of his humour, were as good as half a dozen plays distilled." But it was in the social circle that he displayed the finest and rarest traits of genius, while his simple and truly kind-hearted disposition won him an affection and esteem which mere genius could not have purchased. From his infancy the health of Mathews had been uncertain, and the toils of his profession gradually undermined it. He died at Plymouth, of heart disease, 28th June 1835. See *Memoirs*, by Mrs Mathews, 4 vols., 1838–39.

MATHEWS, CHARLES JAMES (1803–1878), comedian, son of the above, was born at Liverpool, 26th December 1803. After attending Merchant Taylors' School he was articled as pupil to an architect, and he continued nominally to follow this business till 1835. His first appearance on the stage was made at the Adelphi, London. In 1838 he married Madame Vestris, then lessee of the Olympic, but neither his management of this theatre, nor subsequently of Covent Garden, nor of the Lyceum, resulted in pecuniary advantage. As an actor, however, he held from the first an unrivalled place in his peculiar vein of light eccentric comedy. The inimitable easy grace of his manner, and the imperturbable solemnity with which he perpetrated his absurdities, never failed to charm and amuse; his humour was never broad, but always measured and restrained. His range of characters was exceptionally narrow, and he was wholly incapable of representing any form of strong passion. It was as the leading character in such plays as the *Game of Speculation*, *My Awful Dad*, *Cool as a Cucumber*, *Patter versus Clatter*, and *Little Toodlekins*, that he specially excelled. Mathews was one of the few English actors who have played in French successfully—his appearance at Paris in 1863 in a French version of *Cool as a Cucumber*, written by himself, being received with the utmost approbation. After reaching his sixty-sixth year, Mathews set out on a tour round the world, and on his return in 1872 he continued to prosecute his professional duties without interruption till within a few weeks of his death, on July 26, 1878. See *Life of Charles James Mathews*, edited by Charles Dickens, 2 vols., 1879.

MATILDA, countess of Tuscany (1046–1114), popularly known as the Great Countess, was born in 1046, of a race of nobles of Lombard descent. By the death of her father Boniface the Rich, duke and marquis of Tuscany, she was left, at eight years old, under the guardianship of her mother, Beatrice of Lorraine, heiress to a powerful state, including Tuscany, Liguria, part of Lombardy, Modena, and Ferrara. Her life was a protracted struggle against the schism which rent the church, under a series of antipopes, supported by a large section of the clergy and people of Italy and Germany, as well as by the whole strength of the empire. Against this formidable combination she maintained the cause of the holy see, often single-handed, for years, with varying fortune but undaunted resolution. The champion of several successive pontiffs, she is best known as the ally of Gregory VII., and her hereditary fief of Canossa was, in 1077, the scene of the celebrated penance of Henry IV. in presence of this pope. On the same occasion she made the donation, subsequently renewed in 1102, of her possessions to the holy see, in right of which the church owned the greater part of its temporal dominions. Matilda was twice married, first to Godfrey of Lorraine, surnamed the Humpbacked, son of her mother's second husband, and secondly to Guelph of Bavaria,—both marriages of policy, which counted for little in her life. She died of gout in 1114, in her sixty-ninth year, and was buried first at San Benedetto, and finally in the Vatican. Her steadfastness of purpose, strength of character, and loftiness of aim, made her one of the most striking figures even of the age which produced Robert Guiscard, William the Conqueror, Pope Hildebrand, and Godfrey of Bouillon, her nephew by marriage. The contemporary record of her life in rude Latin verse, by her chaplain Donnizone, is preserved in the Vatican Library.

An Italian biography was published in Lucca by Francesco Fiorentini in 1642 (new edition by Mansi, 1756), and one in French by Amédée Renée, *La Grande Italienne*, in 1859.

MATLOCK, a town of Derbyshire, England, is situated on the river Derwent and on the Midland Railway, 149 miles north-west of London and 17 north-west of Derby. It possesses cotton, corn, and paper mills, and in the vicinity there are lead-mines. About 1½ miles south-east, also on the Derwent, is Matlock Bath, possessing hot medicinal springs. There are in all three springs, the first of which was discovered in 1692. Their mean temperature is 68° Fahr., and applied both externally and internally the water is efficacious in glandular affections, rheumatism, biliary obstructions, and relaxation of the muscular fibres. The fine scenery of the vale of Matlock, and its proximity to the thickly peopled districts of Lancashire and Yorkshire, cause the village to be much frequented in summer not only by invalids but by holiday visitors. There are several large stalactite caverns. Matlock Bank, a mile to the north-east, in a finely sheltered situation, contains several well-known hydropathic establishments. The population of the urban sanitary district of Matlock (4513 acres) in 1871 was 3834, and in 1881 it was 4396; that of Matlock Bath and Scarthin Nick in the same years was 1386 and 1698. These two districts are conterminous with the civil parish of Matlock.

MATSYS, QUINTIN. See MASSYS.

MATTER, PROPERTIES OF. If we knew thoroughly the nature of any piece of matter, the deduction of its properties would be a question of mere reasoning, just as (for instance) the definition of a circle really involves all the properties which mathematical methods have deduced from it. But, as we do not even know what matter is, in the abstract, the converse operation is (at least for the present) the natural and necessary one. We must endeavour from the experimentally ascertained properties of matter to discover what it is. The reader will find the limits of our present knowledge in the article ATOM. The properties of matter may be arranged in several classes, thus:—

1. Properties of matter in itself; such as Inertia, Hardness, Brittleness, ELASTICITY (*q.v.*), Density, Compressibility, Viscosity, &c. These depend upon its ultimate structure and upon the law and intensity of the so-called molecular forces. See ATOM, CONSTITUTION OF BODIES, ATTRACTION.

2. Relative properties of different kinds of matter, chemical, catalytic, &c. See CAPILLARY ACTION, CHEMISTRY, DIFFUSION, &c.

3. Properties relative to different forms of energy:—Conductivity (Thermal and Electric), Specific Gravity, Specific and Latent Heat, Transparency, Colour, Specific Inductive Capacity, Radiating and Absorbing Power, Magnetic Retentiveness, &c., Thermo-electric Position, Refractive Index, Reflective Power, Double Refraction, Rotatory Polarization, &c. These will be found mainly under the heads ELECTRICITY, HEAT, LIGHT, MAGNETISM, &c.

MATTEUCCI, CARLO (1811–1868), an Italian physicist, was born at Forlì, June 20, 1811. In 1832, after completing his studies at L'École Polytechnique, Paris, he became professor of physics at Bologna, where he had passed his earlier student days. In 1837 he removed to Ravenna, and in 1840 settled as professor of physics at Pisa. From 1847 he took an active part in politics, and in 1860 was chosen an Italian senator. At the same time he became general telegraph director, and later the superintendent of the meteorological bureaus. He died at Leghorn, June 25, 1868.

He is the author of four scientific treatises:—*Lezioni di fisica* (2 vols., Pisa, 1841; second edition 1851), *Lezioni sui fenomeni fisico-chimici dei corpi viventi* (Pisa, 1844; second edition 1846), *Manuale di telegrafia elettrica* (Pisa, 1850; and several later editions), and *Cours spécial sur l'induction, le magnétisme de rotation*, &c. (Paris, 1854). His numerous papers were published in the *Annales de Chimie et de Physique* (1829–58); and most of them also appeared at the time in the Italian scientific journals. They relate almost entirely to electrical phenomena, such as the magnetic rotation of light, the action of gas batteries, the effects of torsion on magnetism, the polarization of electrodes, &c., sufficiently complete accounts of which are given in Wiedemann's *Galvanismus*. Nine memoirs, entitled "Electro-Physiological Researches," were published in the *Philosophical Transactions*, 1845–60. See Bianchi's *Carlo Matteucci e l'Italia del suo tempo* (Rome, 1874).

MATTHEW (Μαθθαῖος or Ματθαῖος, *i.e.*, מתי, a shortened form of Mattaniah or Mattithiah, equivalent to Theodorus; comp. vol. xi. p. 370), one of the twelve apostles of Jesus Christ, and, according to tradition, the author of the First Gospel. In its full Hebrew form the name occurs several times in the Old Testament, being borne by more than one person of priestly or Levitical family. Matthew, in the Gospel which bears his name, is described as having been a tax gatherer (τελώνης, Matt. x. 3), and the circumstances of his call to become a follower of Jesus, which he received as he sat at the "receipt of custom" or "tax office" in one of the towns by the Sea of Galilee, are briefly related in chap. ix. 9. It has sometimes been doubted, but without any good reason, whether the precisely parallel narrative relating to "Levi the son of Alphæus" (Mark. ii. 14; Luke v. 27, 28) has reference to the same person (compare the double names Simon and Peter, Joses and Barnabas, and others). In the lists of the names of the apostles given in the synoptical Gospels and in the Acts, Matthew ranks third or fourth in the second group of four. Little is recorded of him except the feast which he gave in his house at the beginning of his discipleship; the way in which this is related seems to indicate that he was (comparatively at least) a wealthy man. He was also present in "the upper room" at Jerusalem after the ascension, when Matthias was elected to be the successor of Judas. Tradition has nothing trustworthy to tell about his subsequent career, but there is nothing inherently improbable in the allegation of Eusebius (*H. E.*, iii. 24) that he spent several years in Jerusalem preaching to the Hebrews (and writing the Gospel which bears his name), or that he afterwards extended his missionary activities in other directions. Socrates (*H. E.*, i. 19) speaks of him as having carried the gospel to Ethiopia; the earlier legends, however, embodied in the apocryphal *Acta Andreæ et Matthæi* and *Acta et Martyrium Matthæi*, unanimously point to the regions bordering on the Black Sea ("Pontus" and the land of the Anthropophagi) as having been the scene of his labours (see the article of Lipsius on the "Apocryphal Acts of the Apostles" in Smith's *Dict. of Christ. Biog.*; also his *Apokr. Apostelgesch.*, 1883). According to the Gnostic Heracleon, whose statement is quoted and apparently homologated by Clement of Alexandria (*Strom.* iv. 9), Matthew died a natural death. He is commemorated as a martyr by the Greek Church on November 16, and by the Roman on September 21, the scene of his martyrdom being placed by the Breviary in "Ethiopia"; the same authority affirms that his body was afterwards translated to Salerno, where it now lies in the church built by Robert Guiscard. In Christian art (following Jerome) he is generally regarded as symbolized by the "man" in Ezek. i. 10, Rev. iv. 7.

MATTHEW, GOSPEL OF. See GOSPELS, vol. x. p. 789 *sqq.*

MATTHEW OF PARIS, one of our most important writers in connexion with English mediæval history, was born about the year 1200, or possibly somewhat earlier. His surname was probably derived either from his having been born in Paris or having studied in the university there; but his English origin is proved by the tone in which he uniformly speaks of foreigners, especially the French, while his knowledge of the French language is attested by the fact of his having written in that language, and also by the introduction of many French words in his Latin writings.

We have it on his own authority, as recorded in an autograph marginal note (MS. Cott., Nero, D. 1, fol. 165*b*), that he assumed the monastic habit at the abbey of St Alban's on the 21st of January 1217. In 1236 he accompanied the newly-elected prior of his abbey, John of Hertford, to London, to attend the ceremony of the nuptials of Henry III. and Eleanor of Provence; and in October 1247 he was at Westminster, in order to be present at the celebration of the feast of St Edward the Confessor, when he was desired by the king himself to write an account of the proceedings. The most important event in his tranquil and uneventful life (which was passed chiefly within the walls of his monastery) occurred in the year 1248, when he was sent on a mission to the Benedictine monastery of Holm (Throndhjem), which had become involved in difficulties owing to the maladministration of one of its abbots. He returned to England after more than a year's absence, and we can trace him as attending the royal court at Winchester in July 1251, and as present at York on the occasion of the marriage of Henry's daughter with Alexander II. of Scotland, some six months later. In March 1257 Henry himself visited St Alban's, and remained at the monastery for a whole week. During this time he not only admitted Matthew to his table and to conversations in his private chamber, but also communicated to him facts and details of an historical character derived from his own personal knowledge and experience. Among other information, Matthew tells us that Henry repeated to him from memory the titles of the English baronies to the number of two hundred and fifty. The last incident recorded by the historian himself with respect to his own career is the fact that he exerted his influence with Henry on behalf of the university of Oxford, when that body found its privileges endangered by the encroachments of the bishop of Lincoln. In his latter years, Matthew's growing infirmities compelled him to have recourse to the aid of a fellow-monk in order to complete his works; this assistance is to be traced in the *Historia Anglorum* from 1252 to the end of the work (1253); in the *Abbreviatio Chronicorum* for the years 1253, 1254, and 1255; and in the *Chronica Majora* for the years 1258 and 1259. Matthew died after the month of May 1259, and his portrait, as he lay on his couch when dead, was drawn by his fellow-monk.

Works.—Matthew Paris's chief work, the *Historia Major*,—often styled the *Chronica Majora*,—is a narrative professing to record the outlines of human history from the creation, and terminating with the year 1259. It was long supposed that Roger of Wendover was the author of a much larger proportion of the work than was really the case; but the question may be regarded as finally set at rest by the decisive investigations and conclusions of Dr Luard, as stated at length in his prefaces to the volumes of his edition of the work in the Rolls Series. He concludes that the *Historia Major* down to the year 1189 was the work of John de Cella, abbot of St Alban's from the year 1195 to 1214; that it was then continued by Roger of Wendover on the same plan and from the same sources to the year 1235, the whole work down to this date passing for a long time as the production of the latter writer exclusively, and being known as the *Flores Historiarum*; that it was then transcribed by Matthew Paris, who, however, made numerous corrections and additions, but, in the opinion of Professor Stubbs, "interpreted" rather than "interpolated"; that it was then continued by the same writer, and is, from 1235 to the year 1259, exclusively his work. In style, in vividness of narration, and in descriptive power Matthew far excels his two predecessors. He is also entitled to the praise of having been a warm advocate of English rights and liberties, and a sturdy opponent alike of regal and papal tyranny; in fact, the national sentiment may be said first to receive adequate expression in his pages. The work, moreover, is not only the best source of information with respect to events in England during the reign of Henry III. down to the commencement of the Barons' Wars, but is also an authority with respect to Continental affairs, especially those of France and the empire.

The *Historia Anglorum* of Matthew is mainly an abridgment of his larger work,—the chief feature of difference being the omission of almost everything relating to foreign events. Sometimes, however, details and more particularly personal anecdotes are introduced, with many minute facts and circumstances which would be sought for in vain elsewhere, and largely illustrate contemporary usages and the general condition of society. Besides the above, Matthew wrote an *Abbreviatio Chronicorum*, extending from the year 1100 to 1255. Of this only one manuscript exists,—that in the author's own handwriting, preserved in the Cottonian collection in the British Museum, and printed in the third volume of the *Historia Anglorum*, edited by Sir Francis Madden. Matthew also compiled a *Liber Additamentorum* or *Supplementorum*, containing documents illustrative of the Greater Chronicle. This is contained in the folio edition of Matthew's writings edited by Wats, and published in 1640.

The *Vitæ viginti trium Abbatum S. Albani*, or *Lives of the Abbots of St Alban's*, does not bear Matthew's name, but is unquestionably the production of his pen. The biographies which belong to the period preceding the Norman Conquest contain valuable and interesting notices, but also include much of what is evidently fabulous. The *Vitæ duorum Offarum*, or *Lives of the two Offas*,—the one a mythical character, the other the historic monarch of Mercia,—is a composition of little value, and some doubt attaches to the authorship. Both the foregoing, however, are included in the edition by Wats.

Editions.—The best edition of the *Historia Major* is that by Dr Luard, published in five volumes in the Rolls Series, 1872–80. Of the *Historia Minor* an edition in three volumes in the same series was edited by Sir Frederic Madden, 1866–69. (J. B. M.)

MATTHIAS (1557–1619), holy Roman emperor, the fourth son of the emperor Maximilian II., was born on the 24th of February 1557. He was educated in Germany by the diplomatist Busbecq, while his brother, afterwards the emperor Rudolph II., was trained at the court of Philip II. of Spain. In 1577 Matthias went secretly to the Netherlands, the sovereignty of which he unlawfully assumed; but in 1580 he was compelled to withdraw into private life. He was vain, restless, and ambitious, and intrigued incessantly against the emperor Rudolph, a man of weak character, with a constitutional tendency to insanity. Rudolph passed wholly under the dominion of the Jesuits, and this rendered it easy for Matthias to stir up his Protestant subjects against him. In 1595 Matthias was made regent in Austria, and in 1606 the archdukes recognized him as head of the house of Hapsburg. Rudolph had to relax his hold over one country after another, and in 1611 Matthias was ruler of Hungary, Moravia, Silesia, Lusatia, and even Bohemia, whose loyalty the emperor had tried to secure by many concessions, especially by the letter of majesty granting religious freedom to Protestant sects. In 1612, after the death of Rudolph, Matthias was elected emperor; and his reign was not less disturbed than that of his predecessor. The intervention of Turkey in Transylvania led to war, and in 1615 Matthias, being unsupported by the empire and by his own estates, found that he had no alternative but to conclude peace for twenty years on humiliating terms. Protestants and Catholics, bitterly hating each other, formed respectively the Union and the League; and the rising power of the archduke Ferdinand, afterwards emperor, a bigoted prince who became king of Bohemia in 1617 and king of Hungary in 1618, indicated that even more serious troubles were approaching than those with which Rudolph had contended. In the last two years of the reign of Matthias, the Bohemians having rebelled, the first blows in the Thirty Years' War were struck. He died on the 20th of March 1619.

MATTHIAS CORVINUS (1443–1490), king of Hungary, was born at Klausenburg in Transylvania on March 27, 1443, and died at Vienna on April 6, 1490. He was the younger son of John Hunyady (Corvinus) who died in 1456 after having been "governor of Hungary" from 1446 to 1453. On the death of John, the elder of his two sons (Ladislaus) was executed by command of Ladislaus Posthumus, while Matthias was imprisoned at Prague; but shortly after the king's own death without issue in 1457, Matthias Hunyady (Corvinus) was elected by the Hungarian magnates to the vacant throne (January 24, 1458). The leading events of his reign are summarized in the article HUNGARY (vol. xii. p. 368, 369).

MATTING. Under this name are embraced many coarse woven or plaited fibrous materials used for covering floors or furniture, for hanging as screens, for wrapping up heavy merchandise, and for other miscellaneous purposes. In the United Kingdom, under the name of "coir" matting a large amount of a coarse kind of carpet is made from cocoa-nut fibre; and the same material, as well as strips of cane, Manila hemp, various grasses and rushes, is largely employed in various forms for making door mats. Perforated and otherwise prepared india-rubber is also largely utilized for door and floor mats. Matting of various kinds is very extensively employed throughout India for floor coverings, the bottoms of bedsteads, fans and fly-flaps, &c.; and a considerable export trade in such manufactures is carried on. The materials used are numerous; but the principal substances are straw, the bulrushes *Typha elephantina* and *T. angustifolia*, leaves of the date palm (*Phœnix sylvestris*), of the dwarf palm (*Chamærops Ritchiana*), of the Palmyra palm (*Borassus flabelliformis*), of the cocoa-nut palm (*Cocos nucifera*), and of the screw pine (*Pandanus odoratissimus*), the munja or munj grass (*Saccharum Munja*) and allied grasses, and the mat grasses *Cyperus textilis* and *C. Pangorei*, from the last of which the well-known Palghat mats of the Madras Presidency are made. Many of these Indian grass mats are admirable examples of elegant design, and the colours in which they are woven are rich, harmonious, and effective in the highest degree. Vast quantities of coarse matting used for packing furniture, heavy and coarse goods, and plants, &c., are made in Russia from the bast or inner bark of the lime tree. This industry centres in the great forest governments of Viatka, Nijni-Novgorod, Kostroma, Kazan, Perm, and Simbirsk.

MATTOON, a city of the United States, in Coles county, Illinois, 172 miles south-south-west of Chicago, on the Central Illinois Railroad, which at that point intersects the Indianapolis and St Louis and the Peoria, Decatur, and Evansville Railroads. It had 5742 inhabitants in 1880, has railway carriage works and repair shops, and is rising rapidly in commercial importance.

MATURIN, Charles Robert (1782–1824), novelist and dramatist, perplexed the serious and served as a butt for the more light-minded critics of the first quarter of the 19th century. The bombastic extravagance of his language, the incoherence of his plots, the wild improbability of many of his incidents, the inconsistency of his characters, were obvious and undeniable; but there were so many passages of extraordinary eloquence in his novels, especially in his descriptions of turbulent passion, that, though some pronounced him evidently mad, all admitted that it was a madness allied to genius. At first he published only sermons in his own name, being curate of St Peter's, Dublin. His first novels, *The Fatal Revenge* (1804), *The Wild Irish Boy* (1808), *The Milesian Chief* (1811), were issued under the pseudonym of Dennis Jasper Murphy. All these were mercilessly ridiculed by the press and neglected by the public, but the irregular power displayed in them attracted the notice of some social and literary magnates; and through the influence of Byron and Scott Maturin's tragedy of *Bertram* was produced at Drury Lane in 1816, with a prologue by Hobhouse, an epilogue by the Hon. George Lamb, and with Kean and Miss Kelly in the leading parts. The magnificent scenic situations, and the character of Bertram (like one of Byron's sombre heroes), make this an effective stage play. It was the first and only success of the author; he returned to "the baffled efforts and the blighted hopes" of which Hobhouse speaks in his prologue. Two more tragedies, *Manuel* (1817) and *Fredolpho* (1819), were failures. A poem, *The Universe* (1821), fell flat. Three novels, *Women* (1818), *Melmoth* (1820), and *The Albigenses* (1824), produced a considerable impression. In the preface to *Women* he admitted that his previous novels had been justly condemned, being an impossible attempt to revive the exploded style of Mrs Radcliffe, and promised that he would enter on a new vein. But he could not alter his character. The new vein was as wild, fantastic, incoherent, interspersed with passages of really splendid eloquence, as the old. The *Albigenses* was to be the first of a series of historical romances, illustrating periods of European history, and it was noticed in the *Westminster Review* as giving, with all its faults, promise of better things; but the author died in the year of its publication.

MAUBEUGE, a fortified place of northern France, situated on both banks of the Sambre, 142 miles by rail north-east from Paris, and about 2 miles from the Belgian frontier. Its fortifications were planned by Vauban; the enceinte is pierced by two gateways, that of France and that of Mons. Maubeuge, besides containing an arsenal and several old convents, is an industrial town, manufacturing swords, files, axles, tools, hardware, machinery, porcelain tiles, and paper; in the neighbourhood there are numerous forges. The population in 1876 was 14,400.

Maubeuge owes its origin to a double monastery for men and women founded in the 7th century by St Aldegonde. It was burnt by the Normans, by Louis XI., by Francis I., and by Henry II., and was finally assigned to France by the treaty of Nimeguen. It was fortified by Vauban at the command of Louis XIV., who first saw military service there, under Turenne. Besieged in 1793 by the prince of Coburg, it was relieved by the victory of Wattignies. It was unsuccessfully besieged by the duke of Saxe-Weimar in 1814, but was compelled to capitulate, after a vigorous resistance, in the following year.

MAULMAIN, or Moulmein, a town in Amherst district, British Burmah, situated on the left bank of the Salwín river, in 16° 30′ N. lat. and 97° 38′ E. long. At the time of the cession of this part of the province to the British in 1826, Maulmain was a mere waste. It has now developed into a thriving commercial town, ranking next to Rangoon in importance, with a rapidly increasing population and trade. The population, which in 1857 was 23,683, had increased in 1872 to 46,472, and in 1881 to 53,107 (32,895 males and 20,212 females). The principal buildings are Salwín House, originally a private residence, but now the property of the municipality, the hospital, the jail, Protestant and Roman Catholic churches, the custom-house, and other public offices, and the barracks for the garrison of Madras native infantry. For many years timber formed the only export, but with the gradual settlement of the country and increase in agriculture rice and cotton began to be also exported; besides these, the other staple exports are hides, horns, lead, copper, yellow orpiment, and stick-lac. The principal imports are cotton twist and cloth, woollen piece-goods, wines and spirits, sugar, and betel-nuts. In 1880–81 573 vessels (266,010 tons) entered the port, and 536 (265,147 tons) cleared. The value of merchandise imported was £666,810, of treasure £312,190, of merchandise exported £1,389,763, and of treasure £92,817. Shipbuilding forms an important industry of the town.

MAUNDY THURSDAY, the day preceding Good Friday. The word "maundy" (Middle-English, *maundee* or *maunde*, a command) is identical with the "mandatum" of the rubric and anthem of the Missal for the fifth day in Holy Week, sometimes called "Dies Mandati" (see this shown at length by Skeat in *Etym. Dict.*, and in note to *Piers Plowman*, xvi. 140). The "mandatum" or "maund" referred to is the "new commandment" of John xiii. 34, but more particularly the precept given to the disciples in the same chapter "to wash one another's feet." The practice by prelates and others of literally and formally carrying out this injunction in a public manner on a given day has long been established both in the East and in the West. Perhaps an indication of it may be discerned as early as the 4th century in a custom, current in Spain, northern Italy, and elsewhere, of washing the feet of the catechumens towards the end of Lent before their baptism; it was not, however, universal, and in the 48th canon of the synod of Elvira (306 A.D.) it is expressly prohibited (comp. *Corp. Jur. Can.*, c. 104, caus. i. qu. 1). Be this as it may, the "pedilavium," or ceremony of washing the feet of twelve beggars on this day, has now for centuries been observed by the prelates of the Church of Rome, including the pope himself, according to a ritual minutely prescribed in the Missal; it is also practised by the Austrian emperor, the king of Bavaria, and other European sovereigns in the Latin obedience, as well as by the emperor of Russia and others at the head of the Greek Church. In England it was continued by the sovereign even after the Reformation; the last recorded instance of its full performance is in the case of James II., but a distribution of royal alms, consisting of money and clothing, is still continued. It is on Maundy Thursday also that in the Church of Rome the sacred oil is blessed, and the chrism prepared, according to an elaborate ritual which is given in the *Pontificale*.

MAUPERTUIS, Peter Louis Moreau de (1698–1759), a mathematician and astronomer of considerable reputation in his day, was born at St Malo, July 17, 1698. When twenty years of age he entered the army, becoming lieutenant in a regiment of cavalry, and employing his leisure on mathematical studies. After five years he quitted the army and was admitted in 1723 a member of the academy of sciences. In 1728 he visited London, and was elected a fellow of the Royal Society. In 1736 he acted as chief of the expedition sent by Louis XV. into Lapland to measure the length of a degree of the meridian within the polar circle, in order to settle the then much disputed question of the oblate figure of the earth, and, on his return home, he became a member of almost all the scientific societies of Europe. In 1740 Maupertuis went to Berlin on the invitation of the king of Prussia, and took part in the battle of Mollwitz, where he was taken prisoner by the Austrians. On his release he returned to Berlin, and thence to Paris, where he was elected director of the academy of sciences in 1742, and in the following year was admitted into the Academy. Returning to Berlin in 1744, Maupertuis married a lady of rank and great beauty, and in 1746 was chosen president of the royal academy of sciences. Finding his health declining, he repaired in 1757 to the south of France, but went in 1758 to Basel, where he died July 27, 1759. Maupertuis was unquestionably a man of considerable ability as a mathematician, but his restless, gloomy disposition involved him in constant quarrels, of which his controversies with König and Voltaire during the latter part of his life furnish examples.

The following are his most important works:—*Essay on Cosmology*; *Discourse on the Different Figures of the Stars*; *Essay on Moral Philosophy*; *Philosophical Reflexions*, &c.; *Animal Physics*; *System of Nature*; *Elements of Geography*; *Account of the Expedition to the Polar Circle*, &c.; *Laws of Motion*; *Laws of Rest*; *Parallax of the Moon*; *The Comet of* 1742; *On the Progress of the Sciences*. He also contributed a large number of interesting papers to the *Memoirs* of the academies of Paris and Berlin.

MAU RÁNÍPUR, a town in Jhánsí district, in the North-Western Provinces of India, in 25° 15′ N. lat., 79° 11′ E. long. The population in 1872 was 16,428. Although now a large trading centre, the town is of quite modern commercial importance, having risen from the position of a small agricultural village through the influx of merchants seeking relief from extortionate demands made by the rájá of a neighbouring native state. It contains a large community of wealthy merchants and bankers. A special variety of cloth, known as *kharua*, is manufactured and exported to all parts of India. The principal imports are sugar, English piece-goods, silk, metals, and coffee. Trees line many of the streets, and handsome temples ornament the town.

MAURER, Georg Ludwig von (1790–1872), a distinguished German jurist and statesman, was born at Erpolsheim in the Bavarian Palatinate, November 2, 1790. He was the son of a Protestant pastor. He received his education at the university of Heidelberg, and afterwards followed for some time the profession of an advocate. In 1812 he went to reside in Paris, where, with the aid of the great libraries of that city, he entered on a systematic study of the ancient legal institutions of Germany. On his return to Bavaria he was appointed substitute for the attorney-general in the district of Spires and Landau. In 1824 he published at Heidelberg his first work, *Geschichte des alt-germanischen und namentlich alt-bairischen öffentlich-mündlichen Gerichtsverfahren*, which obtained the first prize of the academy of Munich. In 1826 he was made one of the professors of law in the university of Munich. In 1832, Otho, son of King Louis of Bavaria, having been chosen to fill the throne of Greece, a council of regency was nominated to conduct the government of that country during his minority. Of this council Von Maurer was appointed a member, the others being the Count von Armansperg, who was president, Major-General K. W. von Heideck, and K. von Abel. They applied themselves energetically, and at first apparently in a spirit of concord, to the task of creating for the new kingdom institutions adapted to the requirements of a modern civilized community. But grave differences soon made themselves felt, Maurer being at variance with the president on important administrative questions. These being referred to King Louis, he decided in favour of the president, and Maurer and Abel were suddenly recalled in 1834. The loss of Maurer was a serious one for Greece; he was the ablest, most energetic, and most liberal-minded member of the regency, and had already done important work in the juridical and educational organization of the kingdom. It was through his enlightened efforts that Greece had obtained a revised penal code, regular tribunals, and an improved system of civil procedure. Soon after his recall, he published his work entitled *Das griechische Volk in öffentlicher, kirchlicher, und privatrechtlicher Beziehung vor und nach dem Freiheitskampfe bis zum* 31 *Juli* 1834 (3 vols., Heidelberg, 1835–36). This book is a valuable source of information on the history of Greece during the preceding years, its condition before the call of Otho to the throne, and the labours of the council of regency down to the time of the author's recall. Notwithstanding his removal from office, he does not appear to have forfeited the esteem or goodwill of King Louis. After the fall of the ultramontane ministry of Abel in 1847, he became minister of foreign affairs and of justice, but on attempting to carry out reforms he was overthrown; retiring then from political life, he devoted himself altogether to historical and juristic studies, the fruits of which he gave to the world in successive publications. He died at Munich, May 9, 1872.

The following is believed to be a complete list of such of his writings as have not been already mentioned:—*Grundriss des deutschen Privatrechts*, 1828; *Ueber die bairischen Städte und ihre Verfassung unter der römischen und fränkischen Herrschaft*, 1829; *Ueber die deutsche Reichsterritorial- und Rechtsgeschichte*, 1830; *Das Stadt- und das Landrechtsbuch Ruprechts von Freising nach 5 münchener Handschriften, ein Beitrag zur Geschichte des Schwabenspiegels*, 1839; *Ueber die Freipflege* (plegium liberale), *und die Entstehung der grossen und kleinen Jury in England*, 1848; *Einleitung zur Geschichte der Mark-, Hof-, Dorf-, und Stadt-Verfassung und der öffentlichen Gewalt*, 1854; *Geschichte der Marken-Verfassung in Deutschland*, 1856; *Rede bei der 100-jährigen Stiftungsfeier der K. Akademie der Wissenschaften am* 28 *März*, 1859; *Geschichte der Dorf-Verfassung in Deutschland*, 2 vols., 1865–66; *Geschichte der Fronhöfe, der Bauernhöfe, und der Hofverfassung in Deutschland*, 4 vols., 1862–63; *Geschichte der Städteverfassung in Deutschland*, 4 vols., 1869–71. He also superintended the preparation of a part of the continuation of Jacob Grimm's *Weisthümer*, published under the auspices of the academy of Munich, 1866. His researches on the ancient village communities of Germany are of special interest and importance.

MAURETANIA, or Mauritania (the former is the more correct form of the name, according to coins and inscriptions), was the name given in ancient geography to the district which constituted the north-western angle of the African continent. It comprised a considerable part of the modern empire of Morocco, together with the western portion of Algeria. But its limits varied much at different times. When it first appears in history the river Mulucha constituted its eastern limit, which separated it from the Numidian tribe of the Massyli, who held all the country from that river to the Ampsaga; but at a later period the kingdom of Mauretania was extended to the latter river so as to include the whole territory from the Ampsaga to the Atlantic Ocean. Towards the south it was bounded by the great range of Mount Atlas, and it appears to have been regarded by geographers as extending along the coast of the Atlantic as far as the point where that chain descends to the sea, in about 30° N. lat., though the Roman province of the name extended but a little beyond Sala (Sallee), and it is probable that there were no towns or permanent settlements farther south. The magnificent plain, or rather plateau, in which the city of Morocco is situated seems to have been unknown to ancient geographers, and was certainly never included in the Roman empire. On the other hand the Gætulians, who inhabited the narrow strip of fertile date-producing territory on the southern slopes of the Atlas, though not included under the name of Mauretania, seem to have always owned a precarious subjection to the kings of that country, and in after days to its Roman governors.

The physical geography of the country will be described under the heading MOROCCO, though it must be observed that the term Mauretania, as used by the Romans, comprised also the greater portion of the French colony of Algeria, including the provinces of Oran and Algiers, and even a part of that of Constantine. The range of Mount Atlas forms throughout the backbone of the country, from which the streams descend to the Mediterranean and the ocean. The most important of those on the north coast is the Mulucha or Molochath, which in the earliest times constituted the eastern limit of the country; it is still called Muluya. Farther east are the Chinala, the Usar, and the Ampsaga. Of those that flow westward towards the Atlantic, the most considerable were the Lixus, Subur, and Sala. But from the proximity of the mountain ranges to the sea none of these streams were of any importance, or navigable beyond a short distance from the sea.

A large part of the country is of great natural fertility, and was in ancient times extensively cultivated, and produced large quantities of corn, while the slopes of Mount Atlas were clothed with vast forests, which, besides other kinds of timber, supplied the celebrated ornamental wood called *Citrus*, for tables of which the Romans gave such fabulous prices.

Mauretania, or Maurusia, as it was called by Greek writers, unquestionably signified the land of the Mauri, a term still retained in the modern name of Moors, and probably meaning originally nothing but "black men." The origin and ethnical affinities of the race are unknown; but it is probable that the inhabitants of all this northern tract of Africa along the coast of the Mediterranean were kindred races belonging to the family which is represented at the present day by the Berbers of the mountain districts and the Tuaricks of the tract south of the Atlas. They first appear in history at the time of the Jugurthine War (110–106 B.C.), when Mauretania west of the Mulucha was under the government of a king called Bocchus, and appears to have constituted a regular and organized state. It retained its independence till the time of Augustus, who in 25 B.C. bestowed the sovereignty of the previously existing kingdom upon Juba II., king of Numidia, at the same time uniting with it the western portion of Numidia, from the Mulucha to the Ampsaga, which now received the name of Mauretania Cæsariensis, while the province that had previously constituted the kingdom, or Mauretania Proper, came to be known as Mauretania Tingitana. This distinction continued to subsist after the incorporation of the two provinces in the Roman empire under Claudius in 42 A.D., and remained unchanged till the time of Constantine.

In the time of Pliny and Ptolemy, Mauretania contained a number of flourishing cities and towns, several of which enjoyed the privileges of Roman colonies, having been founded no doubt in great part with a view of keeping in check the wild barbarians who still occupied the greater part of the country. The most important of these places were—Tingis, on the site of the modern Tangier, the capital of the province to which it gave its name; Lixus and Sala, on the coast of the Atlantic, at the mouths of the rivers of the same name; and three towns in the interior of the same province, Zilis, Babba, and Banasa, all of them bearing the title of Roman colonies. On the coast of the Mediterranean stood Rusaddir (now Melilla), within the limits of Tingitana; and beyond the Mulucha Cartenna (now Tenes); Iol, surnamed Cæsarea, which was made his capital by Juba II., and continued to be that of Mauretania Cæsariensis under the Romans (its site is now called Cherchell); Icosium (the modern Algiers); Saldæ (Bujeyah); Igilgili (Jijeli) near the eastern limit of the province; and Sitifis (Setif) at no great distance in the interior, a town of considerable importance, which after the time of Constantine gave the name of Mauretania Sitifensis to this eastern portion of the province. The prosperity of this part of Africa under the Roman empire, previous to the irruption of the Vandals in 429 A.D., is shown by the fact that no less than one hundred and seventy towns which were episcopal sees are enumerated in the Notitia in the two provinces of Mauretania.

MAURICE (MAURICIUS), ST, and his companions are commemorated as martyrs by the Roman Church on September 22. The earliest extant form of the legend relating to them is that of Eucherius, bishop of Lyons about the middle of the 5th century, who tells us that Maurice was in command of the Theban legion (so called because raised in the Thebais) when it was sent into the West and attached to the army of Maximian. Themselves Christians to a man, its members refused to persecute their coreligionists, and for this, after having twice been decimated, the legion was utterly destroyed by command of the emperor at Octodurum (Martigny) near Geneva. A later form of the legend connects it with the expedition of Maximian against the Bagaudæ, who are taken to have been Christians; the martyrdom of the legion arises out of its refusal to take part in a great sacrifice which had been ordered at Octodurum; and another name—that of Exsuperius—is associated with Maurice's. Later still, Gregory of Tours knows of a company of the same legion which suffered at Cologne (their leader subsequently became known as Gereon). The date usually assigned to the martyrdom of the Theban legion is 286 A.D.; but it is matter of history that at that period the Christians were everywhere unmolested in the exercise of their religion throughout the Roman empire. On the other hand, at no later date have we any evidence of the presence of Maximian in the Valais; and, apart from the great *a priori* improbability of the extirpation of a whole legion under any circumstances on account of its Christian profession, it is practically impossible to get over the fact that such writers as Eusebius, Lactantius, Orosius, and Sulpicius Severus know nothing of such a noteworthy and startling event having taken place. But in the long and voluminous controversy as to the historical character of this legend it has of course never been attempted to deny that isolated cases of officers being put to death on account of their religion occurred during the reign of Maximian. The cultus of St Maurice and other members of the Theban legion occurs chiefly in Switzerland, the region of the Rhine, and northern Italy; the foundation of the abbey of St Maurice (Agaunum) in the Valais is usually ascribed to Sigismund of Burgundy (515).

MAURICE (MAURICIUS FLAVIUS TIBERIUS), emperor of the East from 582 to 602, was of Roman descent but a native of Arabissus in Cappadocia, where he was born about 539. He spent his youth at the court of Justin II., and, having joined the army, fought with distinction in the Persian war (578–581). At the age of forty-three he was declared Cæsar by the dying emperor Tiberius II., who bestowed upon him the hand of his daughter Constantina. In the meagre annals of the reign of Maurice the most conspicuous events are the termination of the long struggle in the East with the restoration to the Persian throne of Chosroes II. by the Roman general Narses (not the conqueror of Italy) in 591, and the successes of Priscus in the protracted war against the Avars. Some inopportune attempts at army reform, and an ill-judged refusal to provide a ransom which might have prevented the massacre of twelve thousand prisoners in the hands of the enemy, led to a rebellion among the legions on the Danube, who declared Maurice unworthy to reign, and, commanded by Phocas, then a simple centurion, but destined to become emperor, marched upon Constantinople. The capital having declared against him, Maurice abdicated and withdrew to Chalcedon, but was pursued and put to death there after having witnessed the murder of five of his sons (November 27, 602). He was the author of a work on military art (στρατηγικά) in twelve books, of which there is an edition by Scheffer, published at Upsala in 1664. There is a *Vita Mauricii* by Theophylact Simocatta.

MAURICE OF NASSAU, prince of Orange, the younger son of William the Silent, was born at Dillenburg in 1567, and was made governor of the United Provinces after the assassination of his father in 1584. He succeeded his brother as prince of Orange in 1618, and died at the Hague on April 23, 1625. For the leading features of his character and events of his life see HOLLAND, vol. xii. pp. 77, 78.

MAURICE (1521-1553), duke and elector of Saxony, the son of Duke Henry the Pious, was born on the 21st of March 1521. He received a learned education, and at an early age gave evidence of an energetic and ambitious temper. In 1541 he married Agnes, daughter of the landgrave Philip of Hesse, and succeeded his father as duke of Saxony, of the Albertine line. Although a Protestant, he held cautiously aloof from the League of Smalkald; and in 1542 and 1543 he received imperial favour by supporting Charles V. against the Turks and the French. In 1546, when Charles V. attacked the League of Smalkald, Maurice sided with the emperor, the result being that he was made elector of Saxony in place of his cousin John Frederick (of the Ernestine line), who was taken prisoner and deposed. At this time Maurice was detested by the German Protestants, who considered him a traitor to his religion; but the tide soon turned. Fearing that the emperor's ultimate aim was to strike at the authority of the princes, he began silently to make preparations for war; and Charles V. was imprudent enough to provide him with a pretext for opposition by detaining the landgrave Philip of Hesse, whose freedom Maurice had guaranteed. In 1551 Maurice concluded a secret treaty with Henry II. of France against the emperor, and an alliance was also formed with several German princes. Charles V. refused to believe in the reality of the danger; but in March 1552 he was startled by the intelligence that Henry II. had entered Germany as an invader, and that Maurice was hastening southward at the head of a powerful army. John Frederick and Philip were at once released, and the emperor, after an ignominious flight, was compelled to sign the treaty of Passau. After the re-establishment of peace Maurice fought for some time against the Turks in Hungary; he then returned to Saxony, and associated himself with the alliance against Margrave Albert of Brandenburg, by whom the treaty of Passau had not been recognized. At Sievershausen, on the 9th of July 1553, the margrave was defeated; but during the battle Maurice was wounded, and two days afterwards he died in his tent. He was not only a great diplomatist and general, but one of the most enlightened rulers of his age, and his early death was sincerely deplored by his subjects. In his last years he was content "with small diet and little sleep." "Therefore," says Roger Ascham, who had seen him, "he had a waking and working head, and became so witty and secret, so hardy and ware, so skilful of ways, both to do harm to others and to keep hurt from himself, as he never took enterprise in hand wherein he put not his adversary always to the worse."

See Roger Ascham, *A Report and Discourse of the Affairs and State of Germany*; Langenn, *Moritz, Herzog und Kurfürst von Sachsen*, 1841; G. Voigt, *Moritz von Sachsen* 1541-47, 1876.

MAURICE, JOHN FREDERIC DENISON (1805-1872), better known without his first name, an English clergyman and theologian, was born in the year 1805. He was the son of a Unitarian minister, and educated in his father's faith, entering Trinity College, Cambridge, as a Nonconformist, for the sake of the university course, at a time when it was impossible for any but members of the Established Church to obtain a degree. Together with John Sterling, Maurice migrated to the smaller college of Trinity Hall, whence he obtained a first class in civil law in 1827; he then came to London, and gave himself to literary work, editing for a short time the *Athenæum* newspaper. During this period of his life he came under the influence of S. T. Coleridge,—an influence which drew Maurice into conformity, and issued through him in what was known as the Broad-Church school of thought.

When Maurice joined the Church of England, he might no doubt have returned to Cambridge for his degree, or, when he chose Oxford, his terms at Cambridge would have been allowed him, but with characteristic thoroughness he elected to go through the whole Oxford course. He entered Exeter College, and obtained a second class in classics in 1831.

The intellectual stir of Oxford life, and the vehement controversies in the clash of which sparks of truth seemed struck out, were probably among the causes which attracted Maurice to Oxford, and he afterwards took his full share in them, always in a liberal, tolerant, yet strongly Protestant spirit. He was ordained in 1834, and after a short interval spent in parish work in the country was appointed chaplain of Guy's Hospital, and became thenceforward a sensible factor in the intellectual and social life of London. Carlyle has told us how "going to Guy's" Sunday after Sunday was a part of Sterling's routine, and an appreciable number of persons far above the average were attracted to the hospital chapel. In 1840 Maurice was appointed professor of history and literature in King's College, to which in 1846 was added the chair of divinity. These chairs he held till 1853. In that year he published *Theological Essays*, wherein were stated opinions which savoured, to the principal, Dr Jelf, and to the council, of unsound theology in regard to eternal punishment. Maurice maintained with great warmth of conviction that his views were in close accordance with Scripture and the Anglican standards, but the council ruled otherwise, and he was deprived of his professorships. He held at the same time the chaplaincy of Lincoln's Inn (1846-60), but no attempt was made to deprive him of this. Neither was he assailed in the incumbency of St Peter's, Vere Street, which he held for nine years (1860-69), and where, though his congregation was never large, partly perhaps because no parish or district was apportioned to his church, he drew round him a circle of thoughtful persons, attached in no common degree to himself and to his teaching.

During his residence in London Maurice was specially identified with two important movements for education, the Working Men's College, and Queen's College for the education of women, while he threw himself with great energy into all that affected the social life of the people. Certain abortive efforts at a true co-operation among working men, and the movement known as Christian Socialism, were the immediate outcome of his teaching, and directly fostered by himself. In 1866 Maurice was appointed professor of moral philosophy in the university of Cambridge. He died on the 1st of April 1872.

Maurice was before all things a preacher. The actual message he had to proclaim was apparently simple; his two great convictions, which he strove to impress on all other men, were the fatherhood of God, and that all religious systems which had any stability lasted because of a portion of truth which had to be disentangled from the error differentiating them from the doctrines of the Church of England as understood by himself. His love to God as his Father was a passionate adoration which filled his whole heart. No one who ever heard Maurice read the Lord's Prayer can possibly forget it; the intensity of his convictions in the pulpit made his message seem as luminous and clear as it was brief and concentrated, though his teaching apart from the living voice had by no means the same character.

It was the peculiarity of his congregation that those who wanted his advice sought him; having no parish, he had no definite sphere of work beyond the church. Thus his preaching took the forms now of exposition and now of the resolution of metaphysical difficulties, rather than of direct dealing with the facts, the sins, and the temptations of human life common to all. Feeling this defect, he took for a time a district for parochial visitation, but was perplexed and distressed at the experience to which he was unequal. With all his affectionateness and desire to give sympathy he was unable even to conceive intellectual difficulties which were not his own. To those who did not demand of him all they needed, but took thankfully what he had to give, he was altogether a stimulating and helpful teacher. He opened new views, and encouraged men to think for themselves, and see what their words meant. He was even morbidly fearful of founding a party, and was deeply distressed at the name Broad-Church. Those who surrounded him, and were kept together by his personal charm and influence, were learning to think for themselves, and have dispersed in many directions. There are probably not half a dozen persons who, even nominally, reflect the precise shades of Mauricean teaching.

As a writer it is extremely doubtful if his work will have a great and permanent place in the future. His one novel, *Eustace Conway*, is even now unread; his theological works, though abounding in passages of great beauty, full now and then of a fiery eloquence, are as a whole somewhat obscure. He published too much, and a large number of his works are sermons recast. We miss the human voice, and we find a class of writing which only the highest excellence can make tolerable out of the pulpit.

Maurice's greatest effect on his time is in his educational work. The Working Men's College, which owes more to him than to any one else, for which he rendered great sacrifices, and which was and is more full of his spirit than are most institutions of that of their founders, was a totally new departure in education. It was intended to give, and it has largely succeeded in giving, not what is called a popular education, but "higher education" to working men, and in combining teachers and taught in a college with its social life, and a bond of common interests. Queen's College, in like manner for the higher education of girls, is scarcely less identified with his life, though its influence is not so great, nor can its work be so widely known.

Both at King's College and at Cambridge Maurice gathered round him a band of earnest students, to whom he directly taught much that was valuable drawn from wide stores of his own reading, wide rather than deep, for he never was, strictly speaking, a learned man. Still more did he encourage the habit of inquiry and research, more valuable than his direct teaching. In his power, which has been truly called Socratic, of convincing his pupils of their ignorance he did more than perhaps any other man of our time to awaken in those who came under his sway the desire for knowledge and the process of independent thought.

If, as a social reformer, Maurice's name be forgotten in the future, it will be because in much he was before his time, and gave his eager support to schemes for which the world was not ready. From a very early period of his life in London the condition of the poor pressed upon him with consuming force; the enormous magnitude of the social questions involved was a burthen which he could hardly bear. He threw himself with characteristic energy into schemes for a true co-operative system, in which some ardent young men were then engaged, and in spite of his dislike for systems and party names did not shrink from being known as a Christian Socialist, and taking a keen interest in the paper which bore that name, and was the organ of the movement. That and the *Politics for the People*, much the same paper under a different name, received his sanction and aid; many strifes between masters and workmen were appeased, if not directly by himself, by those who were aided by his counsel, and were in constant intercourse with him. For many years he was the clergyman whom working men of all opinions seemed to trust even if their faith in other religious men and all religious systems had faded, and his power of attracting the zealot and the outcast resembled that of the Master whom he followed.

Maurice was twice married, first to a sister of John Sterling, secondly to a sister of his friend Archdeacon Hare. By his family ties and his closest friendships he came in contact with few but intellectual people. Thus while he wrote and spoke and worked for the average man he set that average somewhat high. Those who were privileged to know him did not know a more beautiful soul.

The following are Maurice's more important works. Some of them were re-written and in a measure recast, and the date given is not necessarily that of the first appearance of the book, but of its more complete and abiding form. *Eustace Conway, or the Brother and Sister*, a novel, 1834; *The Kingdom of Christ*, 1842; *Christmas Day and other Sermons*, 1843; *The Unity of the New Testament*, 1844; *The Epistle to the Hebrews*, 1846; *The Religions of the World*, 1847; *Moral and Metaphysical Philosophy* (at first an article in the *Encyclopædia Metropolitana*), 1848; *The Church a Family*, 1850; *The Old Testament*, 1851; *Theological Essays*, 1853; *The Prophets and Kings of the Old Testament*, 1853; *Lectures on Ecclesiastical History*, 1854; *The Doctrine of Sacrifice*, 1854; *The Patriarchs and Lawgivers of the Old Testament*, 1855; *The Epistles of St John*, 1857; *The Commandments as Instruments of National Reformation*, 1866; *On the Gospel of St Luke*, 1868; *The Conscience: Lectures on Casuistry*, 1868; *The Lord's Prayer, a Manual*, 1870. The greater part of these works were, as has been already noticed, first delivered as sermons or lectures. Besides this more formal work, Maurice contributed many prefaces and introductions to the works of friends, as to Archdeacon Hare's *Charges*, Kingsley's *Saint's Tragedy*, &c. His occasional sermons, speeches, periodical writings, and letters to various newspapers need not be here noticed, though they were at the time evidence of his interest in all the life of his time, and his eager and abounding energy.

MAURITIUS, formerly called the ISLE OF FRANCE, an island in the south-western portion of the Indian Ocean, between 57° 18′ and 57° 48′ E. long., and 19° 58′ and 20° 31′ S. lat., 550 miles east of Madagascar, and 115 miles north-east of the island of Réunion, 940 miles south-east of the Seychelles, 2300 miles from the Cape of Good Hope, and 9500 miles from England *via* Aden and Suez. The island is irregularly elliptical—somewhat triangular—in shape, and is 36 miles long from north-north-east to south-south-west, and about 23 miles broad. It is 130 miles in circumference, and its total area is about 713 square miles. The island is surrounded by coral reefs, so that the ports are difficult of access.

Map of Mauritius.

From its mountainous character Mauritius is a most picturesque island, and its scenery is very varied and beautiful. The most level portions of the coast districts are the north and north-east, all the rest being broken by hills, which vary from 500 to 2700 feet in height. There are three principal masses of mountain: the north-western or Pouce range, in the district of Port Louis; the south-western, in the districts of Rivière Noire and Savanne; and the south-eastern range, in the Grand Port district. In the first of these, which consists of one principal ridge with several lateral spurs, overlooking Port Louis, are the singular peaks of the Pouce (2650 feet), so called from its supposed resemblance to the human thumb; and the still loftier Pieter Botte (2676 feet), a tall obelisk of bare rock, crowned with a globular mass of stone. The highest summit in the island is in the south-western mass of hills, the Montagne de la Rivière Noire, which is 2711 feet above the sea. The principal ranges in this mountain mass are three in number, arranged in a triangular form, and are called respectively the mountains of La Pierre Rouge, La Rivière Noire, and Savanne. The south-eastern group of hills consists of one chief range, the Montagne du Bambou, with several spurs running down to the sea. In the interior are extensive fertile plains, some 1200 feet in height, and forming the districts of Moka, Vacois, and Plaines Wilhelms; and from nearly the centre of the island rises an abrupt peak, the Piton du Milieu de l'Île, to a height of 1932 feet above the sea-level. Other prominent summits are the Trois Mamelles, the Montagne du Corps de Garde, the Signal Mountain, near Port Louis, and the Morne Brabant, at the south-west corner of the island.

The rivers are of course small, and none of them are navigable beyond a few hundred yards from the sea. In the dry season most of them are little more than brooks, although they soon become raging torrents when swollen by the heavy rains of the wet period of the year. The principal stream is the Grande Rivière, with a course of about 10 miles. A remarkable and very deep lake, called Grand Bassin, is found in the south of the island, and is probably the extinct crater of an ancient volcano; other similar lakes are the Mare aux Vacois and the Mare aux Jones, and there are some other deep hollows which have a like origin.

The geological structure of Mauritius is undoubtedly a result of volcanic action, all the rocks being of basalt and greyish-tinted lavas, excepting some beds of upraised coral. Columnar basalt is seen in several places. There are many caverns and steep ravines, and from the character of the rocks the ascents are rugged and precipitous. The island has few mineral productions, although iron, lead, and copper in very small quantities have in former times been obtained.

The climate is pleasant during the cool season of the year, but oppressively hot in summer (December to April), except in the interior plains, where the thermometer ranges from 70° to 80°, while in Port Louis and the coast generally it ranges from 90° to 96°. The mean temperature for the year at Port Louis is 78°·6. During the last thirty years the island has been subject to severe epidemics, which have been extremely fatal. In 1854 a visitation of Asiatic cholera swept off 17,000 people; and in 1867 a still more destructive inroad of malarial fever, of an unusually fatal type, almost paralysed the whole community for many weeks, carrying off 30,000 people, and greatly affecting the finances of the colony. The seasons are divisible into two, the cool and comparatively dry season, from April to November, and the hotter season, during the rest of the year. From the month of January to the middle of April, Mauritius, in common with the neighbouring islands and the surrounding ocean from 8° to 30° of S. lat., is subject to severe and destructive cyclones, accompanied by torrents of rain, which often cause great destruction to houses and plantations. These hurricanes generally last about eight hours, but they appear to be now less frequent and violent than in former times, owing, it is thought, to the destruction of the ancient forests and the consequent drier condition of the atmosphere.

The soil of the island is of considerable fertility; it is a ferruginous red clay, but so largely mingled with stones of all sizes that no plough can be used, and the hoe has to be employed to prepare the ground for cultivation. The woods with which the island was largely clothed when first discovered have been to a great extent cut down, and the greater portion of the plains is now a vast sugar plantation. The bright green of the sugar fields is a striking feature in a view of Mauritius from the sea, and gives a peculiar beauty and freshness to the prospect. The soil is suitable for the cultivation of almost all kinds of tropical produce, and it is to be regretted that the prosperity of the colony depends entirely on one article of production, for the consequences are serious when there happens to be a failure, more or less, of the sugar crop. Guano is extensively imported as a manure, and by its use the natural fertility of the soil has been increased to a wonderful extent.

For purposes of law and government Mauritius is divided into nine districts, named respectively Port Louis, Pamplemousses, Rivière du Rempart, Flacq, Grand Port, Savanne, Moka, Plaines Wilhelms, and Rivière Noire. The capital and seat of government, the city of Port Louis, is situated on the north-western side of the island, at the head of an excellent harbour, a deep inlet about a mile long. This is protected by two forts,—Fort William and Fort George,—as well as by the citadel in the city, and its value is further increased by three graving docks connected with the inner harbour. Lighthouses have been erected on Flat Island and at Cannonier's Point. Port Louis has a population of about 70,000, but from the lofty mountains by which it is enclosed its situation is hot, and from the small amount of tide in the harbour effectual drainage is difficult, so that it is not a very healthy town. The public buildings are of no great architectural beauty, the government house being a three-storied structure with broad verandas, of no particular style of architecture, while the Protestant cathedral was formerly a powder magazine, to which a tower and spire has been added. The Roman Catholic cathedral is more pretentious in style, but is tawdry in its interior. In the city are large barracks and military stores. A maximum contribution of £45,000 is paid to the imperial government by the colony towards the expenses of the troops stationed in the island, but this sum is reduced when the garrison is below a certain standard. In 1880 the amount paid was £29,972. The governor and chief officers of government reside out of Port Louis in the cooler uplands of the interior, as do also a large number of the principal inhabitants, especially since the completion of the railways has made access easy to many portions of the island. The most favourite place of residence is at Curepipe, a place situated about 1800 feet above the sea; here the climate resembles that of the south of France, and it has been so much resorted to of late years that it is rapidly becoming a large town. The construction of the Mauritian railways has given a great impetus to the trade of the colony; the system embraces two lines, of a total length of 87 miles. The main roads of the island are kept in good order, but much yet remains to be done before the road system can be said to be complete throughout all the districts.

The prosperity of Mauritius, as already mentioned, depends almost entirely upon its sugar-crop, and the export trade of the island has greatly increased during the last twenty years, as will be seen by the following statistics:—

	1864.	1868.	1873.	1877.	1880.
Imports ...	£2,582,980	£2,200,098	£2,454,101	£2,359,449	£2,169,672
Exports ...	2,249,740	2,339,342	3,375,401	4,201,286	3,634,788

Of the imports the principal items are rice (about a fifth of the whole), wheat, and other grains, plain and coloured cottons, and haberdashery. Madagascar supplies cattle to the colony, and also rice, although the greater portion of the latter import comes from India. Horses are imported from the Cape, ponies from Burmah and Pegu, mules from Spain, and sheep from Bombay and the Cape. Of the exports, sugar forms of course the great item, amounting, on an average, to nearly nineteen-twentieths of the whole; the increase in its production is shown by the following figures, giving values of the sugar exported:—

1864.	1871.	1877.	1878.
£2,126,511	£2,841,829	£3,783,291	£3,408,020

In 1877 the quantity of sugar exported was 189,164 tons; while in 1854 the quantity was 102,000 tons. The next item is rum, which was exported to the value of £45,386 in 1878; and the production of cocoa-nut oil has increased from 7569 gallons in 1864 to 253,263 gallons in 1878, the latter quantity being worth £37,263. The value of the coffee exported in 1879 was £25,064. The currency consists of rupees and cents; and on the 1st of May 1878, the metric system of weights and measures came into use in the island.

Mauritius being an oceanic island of small size, its present fauna is very limited in extent, and does not contain much that is interesting. When first seen by Europeans it contained no mammals except a large fruit-eating bat (*Pteropus vulgaris*), which is plentiful in the woods; but several animals of this class have been introduced, and are now numerous in the uncultivated region. Among these are two monkeys of the genera *Macacus* and *Cercopithecus*, a stag (*Cervus hippelaphus*), a small hare, a shrew-mouse, and the ubiquitous rat. A lemur and one of the curious hedgehog-like *Insectivora* of Madagascar (*Centetes ecaudatus*) have probably both been brought from the larger island. The avifauna resembles that of Madagascar; there are species of a peculiar genus of caterpillar shrikes (*Campephagidæ*), as well as of the genera *Pratincola*, *Hypsipetes*, *Phedina*, *Tchitrea*, *Zosterops*, *Foudia*, *Collocalia*, and *Coracopsis*, and peculiar forms of doves and parroquets. The living reptiles are small and few in number, but in the surrounding seas are great numbers of fish; the coral reefs abound with a great variety of molluscs; and there are numerous land-shells. The extinct fauna of Mauritius has considerable interest. In common with the other Mascarene islands, it was the home of the Dodo (*Didus ineptus*), one of a group of birds incapable of flight; there were also *Aphanapteryx*, a species of rail, and a short-winged heron (*Ardea megacephala*), which probably seldom flew. The defenceless condition of these birds has led to their extinction since the island was colonized. Several species of large fossil tortoises have been discovered; but, strange to say, they are quite different from the living ones of Aldabra, in the same zoological region.

Owing to the extensive destruction of the primeval forests of the island for the formation of sugar plantations, the indigenous flora of Mauritius is only seen in parts of the interior plains, in the river valleys, and on the hills; and it is so much mingled with trees and plants introduced from other parts of the world that it is not very easy to distinguish between what is native and what has come from abroad. The principal timber tree is the ebony (*Diospyros ebeneum*), which grows to a considerable size. Besides this there are bois de cannelle, olive-tree, benzoin (*Croton Benzoe*), colophane (*Colophonia*), and iron-wood, all of which are useful in carpentry; the cocoa-nut palm, an importation, but a tree which has been so extensively planted during the last hundred years that it is extremely plentiful; the palmiste (*Palma dactylifera latifolia*), the latanier (*Corypha umbraculifera*), and the date-palm. The vacoa or vacois, a species of *Pandanus*, is largely grown, the long tough leaves being manufactured into bags for the export of sugar, and the roots being also made of use; and in the few remnants of the original forests the tree which is such a prominent one in the coast flora of Madagascar, the traveller's tree (*Urania speciosa*), grows abundantly. A species of bamboo is very plentiful in the river valleys and in marshy situations. A large variety of fruit is produced, including the tamarind, mango, banana, pine-apple, guava, shaddock, fig, avocado-pear, litchi, custard-apple, and the mabolo (*Diospyros discolor*), a fruit of exquisite flavour, but very disagreeable odour. Many of the roots and vegetables of Europe have been introduced, as well as some of those peculiar to the tropics, including maize, millet, yams, manioc, dhol, gram, &c. Small quantities of tea, rice, and sago have been grown, as well as many of the spices (cloves, nutmeg, ginger, pepper, and allspice), and also cotton, indigo, betel, camphor, turmeric, and vanilla.

Mauritius appears to have been unknown to European nations, if not to all other peoples, until the year 1507, when it was discovered by the Portuguese. It had then no inhabitants, and there seem to be no traces of its previous occupation by any people, either savage or civilized. The island was retained for most of the 16th century by its discoverers, but they made no colonies in it. In 1598 the Dutch took possession, and named the island "Mauritius," in honour of their prince Maurice. It had been previously called by the Portuguese "Ilha do Cerné," from the belief that it was the island so named by Pliny. But, although the Dutch built a fort at Grand Port, they made no permanent settlement in Mauritius, finally abandoning the island in 1710. Five years afterwards the French, in their turn, took possession of what had seemed so worthless to two European powers, but it was half a century before the Government of France appreciated the value of their colony, since from 1715 to 1767 it was held by agents of the French East India Company, by whom its name was again changed to "Ile de France." The Company was fortunate in having several able men as governors of its colony, especially the celebrated Mahé de Labourdonnais (1735–46), "a man of eminent talents and virtue," who introduced the culture of the sugar-cane, and thus laid a firm foundation for the future prosperity of the island. Under his direction roads were made, forts built, and considerable portions of the forest were cleared, and the present capital, Port Louis, was founded. Labourdonnais also promoted the planting of cotton and indigo, and is justly remembered as the most enlightened and best of all the French governors. The colony continued to rise in value during the time it was held by the French crown, and to one of the later governors, De Poivre, was due the introduction of the clove, nutmeg, and other spices. Another governor was D'Entrecasteaux, whose name is kept in remembrance by a group of islands east of New Guinea.

During the long war between France and England, at the commencement of this century, Mauritius was a continual source of much mischief to English Indiamen and other merchant vessels; and at length the British Government determined upon an expedition for its capture. This was effected in 1810; and upon the restoration of peace in 1814 the possession of the island was confirmed to England by one of the provisions of the treaty of Paris. By the eighth article of capitulation it was agreed that the inhabitants should retain their own laws, customs, and religion; and so it happens that, although a British colony, the island is still largely French in language, habits, and predilections; but its name has again been changed to that given by the Dutch. Perhaps the most distinguished of the English governors of the island was Sir Robert Farquhar (1810–23), who did so much to abolish the Malagasy slave trade and to establish friendly relations with the rising power of the Hova sovereign of Madagascar.

Mauritius is one of the crown colonies of Great Britain, and at the head of its administration is a governor, who is assisted by an executive council of seven members, holding the most important Government posts. There is also a legislative council, which consists of the same members as the foregoing, with three others, together with eight of the chief landed proprietors of the island, who are nominated by the crown. The average annual revenue of the colony for the ten years from 1871 to 1880 was £723,876, the average annual expenditure during the same period being £710,261. Up to 1854 there was a surplus in hand, but since that time expenditure has exceeded income, and the public debt is now about £700,000.

The island has largely retained the old French laws, the Codes Civile, de Procédure, du Commerce, and d'Instruction Criminelle being still in force, except so far as altered by the later laws for the administration of justice of April 13, 1831. By these the court of appeal was reconstituted, and a supreme court of civil and criminal justice was established, under a chief judge and three puisne judges. The police force in 1880 included 689 men.

During the last few years great improvements have been effected in the educational system of the colony. The department of public instruction has two branches, the Royal College, for higher education, and the school department, for primary instruction. In 1880 the number of Government schools was 38, with 5077 scholars, and of schools aided by grants 54, with 4316 scholars, the total teaching staff numbering 178. The annual education vote is about £13,000; and of the scholars 73 per cent. are Roman Catholic, 14 per cent. Hindu, 8 per cent. Protestant, and 5 per cent. Mohammedan. It will be seen from the above figures that the Roman Catholic religion is that professed by the large majority of the white population of Mauritius. The clergy supported by the state include the Protestant bishop of Mauritius, with an archdeacon and seven clergymen of the Church of England, and three clergymen of the Church of Scotland; and the Roman Catholic bishop of Port Louis, with a vicar-general and thirty-four priests.

The population of the island is a very varied one, and consists of two great divisions:—those of European blood, chiefly French and English, as well as numerous half-caste people; and a large coloured population, chiefly Hindu coolies, but with representatives from various African and Asiatic regions, Negroes, Malagasy, Parsees, Singhalese, Chinamen, Malays, &c. The Hindu immigrants now form more than two-thirds of the inhabitants of Mauritius, as will be seen from the following figures for the year 1881:—

General.........111,783		Indian.........249,064		Total.........360,847	
Male.	Female.	Male.	Female.	Male.	Female.
58,137	53,646	151,423	97,641	209,560	151,287

The increase of population during the last thirty years is shown by the following figures:—

1851.	1861.	1871.	1881.
183,506	313,469	317,069	360,847

The system of coolie immigration has been of great value to the colony; and the arrangements for shipping these Hindu people are under Government control. But many of the laws have been so unjust to the coloured people, and so much to the advantage of the planters, that gross evils and abuses have arisen. And, unjust as the laws are, their administration has often been still more unfair. The evil grew at length so glaring that in 1871 a royal commission was appointed, which sat for a long time investigating the subject. Various reforms were recommended, and since then some improvements have been effected. But many of the creole planters are not remarkable for their respect for the rights of coloured people, and the system is liable to gross abuse unless under vigilant control by higher authority. Much yet remains to be done for the moral and religious instruction of the labourers; and the presence of a large heathen population, and the prevalence of crime, has been at times a very serious consideration for the colony. The number of coolies arriving in and leaving the island varies very largely, from a few hundreds annually to several thousands.

The dependencies of Mauritius are the Seychelles group, the islands of Rodriguez and Diego Garcia, the Chagos group, and seventy other smaller islands scattered over a large extent of the Indian Ocean, and having a total population of about 16,000 souls. Rodriguez is situated 300 miles east of Mauritius and is cultivated chiefly by colonists from that island.

Literature.—The following works supply fuller details than can be given in this article:—Ch. Grant, *History of Mauritius, or the Isle of France and Neighbouring Islands*, 1801; J. Milbert, *Voyage pittoresque à l'Ile-de-France*, &c., 4 vols., 1812; Aug. Billiard, *Voyage aux Colonies orientales*, 1822; D'Unienville, *Statistique de l'île Maurice*, &c., 1838; J. Backhouse, *Narrative of a Visit to the Mauritius and South Africa*, 1844; P. Beaton, *Creoles and Coolies, or Five Years in Mauritius*, 1859; Paul Chasteau, *Histoire et Description de l'île Maurice*, 1860; F. P. Flemyng, *Mauritius, or the Isle of France*, 1862; James Morris, "Mauritius, Its Commercial and Social Bearings," *Soc. Arts Jour.*, 1862; A. Erny, "Séjour à l'île Maurice," in vol. vii. of *Tour du Monde*, 1863; Ch. J. Boyle, *Far Away, or Sketches of Scenery and Society in Mauritius*, 1867; L. Simonin, *Les Pays lointains, Notes de Voyage (Maurice, &c.)*, 1867; N. Pike, *Sub-Tropical Rambles in the Land of the Aphanapteryx*, 1873; A. R. Wallace, "The Mascarene Islands," in chap. xi. vol. i. of *The Geographical Distribution of Animals*, 1876; K. Möbius, F. Richter, and E. von Martens, *Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen*, Berlin, 1880; G. Clark, *A Brief Notice of the Fauna of Mauritius*, 1881. (J. S., jr.)

MAURUS, St, according to the Roman Breviary (January 15), was a Roman of noble birth, and while still a child was placed by his father Eutychius under the discipline of St Benedict, where he soon became a model of all the virtues and endowed with the gift of miracles. Sent by his master into Gaul, he founded a monastery over which he presided for forty years. When he died in 565 he was over seventy. The monastery referred to is that of Glanfeuil or St Maur-sur-Loire. In point of fact it may be said that everything relating to the introduction of the Benedictine order into France, unless the name of him who introduced it be made an exception, is purely legendary. The famous "Congregation of St Maur" dates from the 17th century, having received papal sanction in 1621 and 1627; it arose out of an earlier "congregation" of reformed Benedictines, which took its name from St Vannes near Verdun, and was sanctioned by Clement VIII.

MAURY, Jean Siffrein (1746-1817), cardinal and archbishop of Paris, the great opponent of Mirabeau in the constituent assembly, and esteemed his rival in eloquence, was the son of a poor cobbler, and was born at Valréas in the Venaissin, the district in France which belonged to the pope. His quickness was soon observed by the priests of Avignon, where he was educated and took orders, and he determined to get what he could by it. He tried his fortune by writing *éloges* of famous persons, then a favourite practice; and in 1771 his *éloge* on Fénelon was pronounced next best to Laharpe's by the Academy. The real foundation of his fortunes was the success of a sermon he preached on St Louis before the Academy in 1772, which caused him to be recommended to the king for an abbacy on the spot. In 1772 he published his *Essai sur l'éloquence de la chaire*, which, as well as his *Principes d'éloquence*, contains much good criticism, and remains a French classic. He became a favourite preacher in Paris, and was Lent preacher at court in 1781, when King Louis XVI. said of his sermon, "If the abbé had only said a few words on religion he would have discussed every possible subject." In 1781 he obtained the rich abbey of Lions, worth 20,000 livres a year, and in 1785 he was elected to the Academy. His morals were as loose as those of his great rival Mirabeau, but he was famed in Paris for his wit and gaiety as well as for his eloquence and his immorality. In 1789 he was elected a member of the states-general by the clergy of Péronne, and from the first proved to be the most able and persevering defender of the *ancien régime*. It is said that he attempted to emigrate both in July and in October 1789; but, whether he did or not, he after that time held firmly to his place, when almost universally deserted by his friends. His life was often in danger among the people, but his ready wit always saved it, and it was said that one *bon mot* would preserve him for a month. At last, in 1792, he found it necessary to fly from Paris; the Revolution had gone too far. When he did emigrate he found himself regarded as a kind of martyr to the church and the king, and was at once named cardinal, archbishop *in partibus*, and extra nuncio to the diet at Frankfort. He was finally made bishop of Montefiascone, and settled down in that little Italian town,—but not for long, for in 1796 the French drove him from his retreat, and he became ambassador, but with hardly any pay, of the exiled king Louis XVIII. to the pope. Such a life soon wearied a man who had been accustomed to wealth and reputation, and in 1804 he began to prepare his return to France by a well-turned letter to Napoleon, congratulating him on restoring religion to France once more. In 1806 he did return; in 1807 he was again received into the Academy; and in 1810, on the refusal of Cardinal Fesch, was made archbishop of Paris. On the restoration of the Bourbons he was summarily turned out of the Academy, and sent to Rome to answer for his disobedience to the pope. There he was imprisoned in the castle of St Angelo for six months, and died in 1817, a year or two after his release, of disease contracted in prison, and of chagrin.

There are two sides to Maury's character to be discussed. As a critic he was a very able writer, and Sainte-Beuve gives him the credit of discovering Bridaine, and giving Bossuet his rightful place as a preacher above Massillon; as a politician, his wit and eloquence make him a worthy rival of Mirabeau, and an interesting character in the early years of the Revolution. If in later years he forsook his old tenets, and joined Napoleon, his punishment was terribly severe, and it would have been a graceful act if Louis XVIII. had remembered the courageous supporter of Louis XVI., and the pope the one intrepid defender of the church in the states-general.

The *Œuvres choisis du Cardinal Maury* (5 vols., 1842) contain what is worth preserving. For his life and character see *Vie du Cardinal Maury par son neveu*, 1827; Poujoulat, *Cardinal Maury, sa vie et ses œuvres*, 1855; Sainte-Beuve, *Causeries du Lundi*, vol. iv.

MAURY, Matthew Fontaine (1806-1873), American naval officer and hydrographer, was born in Spottsylvania county, Virginia, January 14, 1806. In 1825 he entered the American navy as midshipman, circumnavigating the globe in the "Vincennes," during a cruise of four years. In 1836 he was made lieutenant, and gazetted astronomer to an exploring expedition. In 1839 he met with an accident which resulted in permanent lameness, and unfitted him for active service. Maury was placed in charge of the Depôt of Charts and Instruments, out of which have grown the United States Naval Observatory and the Hydrographic Office. He laboured assiduously and with complete success to place the depôt in a state of efficiency. While in the "Vincennes," and in subsequent cruises, Maury made many observations as to the winds and currents, and when in charge of the Hydrographic Office he set himself to collect further data by distributing to captains of vessels specially prepared log-books. So successful was he in this enterprise that in the course of nine years he had collected a sufficient number of logs to make two hundred manuscript volumes, each with about two thousand five hundred days' observations. One result was to show the necessity for combined action on the part of maritime nations in regard to ocean meteorology. This led to an international conference at Brussels in 1853, which produced the greatest benefit to navigation as well as indirectly to meteorology. One result was the establishment of the meteorological department of the English Board of Trade, now known as the Meteorological Office, which adopted Maury's model log-books. In 1853 he published his *Letters on the Amazon and Atlantic Slopes of South America*, and in 1855 he was promoted to the rank of commander. On the outbreak of the American civil war in 1861, Maury threw in his lot with the South, and, having lost nearly his all, retired to England, where he was presented with a handsome testimonial raised by public subscription. Afterwards he became imperial commissioner of emigration to Maximilian of Mexico, on whose death he took up his residence in Virginia, where he died on February 1, 1873.

In 1848 Maury published a *Treatise on Navigation*, which was long used as a text-book in the United States navy. The work, however, by which he is best known is his *Physical Geography of the Sea*, the first edition of which was published in London in 1855, and in New York in 1856; it was translated into several European languages. The theories which it contains are now generally admitted to be quite erroneous. Maury's reputation rests on the eminent services he rendered to navigation and meteorology, he having been the first to show how the latter could be raised to the certainty of a science. He was essentially a practical man; his great aim was to render navigation more secure and economical, and in this he was eminently successful. Other works published by Maury are the papers contributed by him to the *Astronomical Observations* of the United States Observatory, *Letters concerning Lines for Steamers crossing the Atlantic* (1854), *Physical Geography* (1864), and *Manual of Geography* (1871). In 1859 he began the publication of a series of nautical monographs.

MAUSOLUS, or according to his coins *Maussolus* (Μαύσσωλος), a king of Caria, whose reign probably began in 377 and terminated with his death in 353 B.C. The part he took in the revolt against Artaxerxes Memnon, his conquest of Lydia, Ionia, and several of the Greek islands along the coast, his co-operation with the Rhodians and their allies in the war against Athens, and the removal of his capital from Mylasa, the ancient seat of the Carian kings, to the city of Halicarnassus are the leading facts of his history. He is best known, however, from the tomb erected for him by his widow Artemisia with such cultured magnificence that the name of mausoleum has become the generic title of all similar monuments. One of the most curious of the inscriptions discovered at Mylasa details the punishment of certain conspirators who had attempted the life of Mausolus when he was attending a festival in a temple at Labranda. See HALICARNASSUS.

MAXENTIUS, MARCUS AURELIUS VALERIUS, Roman emperor from 306 to 312, was the son of Maximianus Herculius, and the son-in-law of Galerius, but on account of his vices and incapacity was left out of account in the division of the empire which took place in 305. A variety of causes, however, had produced strong dissatisfaction at Rome with many of the arrangements established by Diocletian, and the public discontent on October 28, 306, found expression in the massacre of those magistrates who maintained their loyalty to Severus and in the election of Maxentius to the imperial dignity,—an election in which the rest of Italy, as well as Africa, concurred. With the help of his father, Maxentius was enabled to put Severus to death and to repel the invasion of Galerius; his next steps were first to banish Maximian, and then, after achieving a military success in Africa against one Alexander, to declare war against Constantine for the conduct towards the old emperor of which he in turn had been guilty at Marseilles. The contest resulted in the defeat of Maxentius at Saxa Rubra, and his death by drowning in the Tiber at the Milvian Bridge on October 28, 312. (See CONSTANTINE.) The general testimony to the worthlessness and brutality of his character is unambiguous and unanimous; less apparent are the grounds for the particular statement of Gibbon that he was "just, humane, and even partial towards the afflicted Christians."

MAXIMA AND MINIMA. The consideration of the greatest or the least value of a variable quantity, that is restricted by certain conditions, is a problem of which several simple cases were investigated by the early Greek geometers. Thus in Euclid iii. 7, 8 we find the determination of the greatest and least right lines that can be drawn from a point to the circumference of a circle. But the most characteristic problem of the kind in Euclid is that contained in vi. 27, 28, 29. Thus prop. 27, when reduced to its simplest form, is equivalent to the statement that if a right line be bisected the rectangle under the segments is greater than that under those made by any other point of division. Props. 29 and 30 are, when considered algebraically, reducible to the solution of the equations $x(a-x)=b^2$ and $x(a+x)=b^2$, coupled with the determination of the maximum value of b for which the solution of the former is possible (see Matthiessen, *Grundzüge der antiken und modernen Algebra*, Leipsic, 1878). Apollonius extended the investigation of Euclid, bk. iii., to the problem of the greatest and least distances of a point from an ellipse, showing that it depended on drawing normals from the point to the curve; and he reduced the latter problem to finding the points of intersection of the ellipse with a certain hyperbola.

The next remarkable problems on maxima and minima are said to have been investigated by Zenodorus,[1] and were preserved by Pappus and Theon of Alexandria. Of these we may mention the following:—(1) among regular polygons of equal perimeter that of the greatest number of sides contains the greatest area; (2) of polygons of the same perimeter and the same number of sides the regular polygon contains the greatest area; (3) the circle contains a greater area than any other curve or polygon of the same perimeter; (4) the sphere contains the greatest volume for a given superficial area.

In the progress of mathematics the terms maxima and minima have come to be used to imply, not the absolutely greatest and least values of a variable magnitude, but the value which it has at the moment it ceases to increase and begins to decrease, or *vice versa*. For example, if it be said that the height of the barometer is a maximum at any instant it means that up to that time the barometer was rising and then began to fall. In this way it is possible that there should be several maxima and minima in the course of one day, and that one of the minima should be greater than one of the maxima.

The theory of maxima and minima, in the differential calculus point of view, is very simple. Thus, if u be a given function of a variable x, the values of x for which u has a maximum or a minimum value are, in general, determined by the equation $\frac{du}{dx}=0$. Again, if u be a function of two variables x and y, then the maximum or minimum values of u must satisfy the equations $\frac{du}{dx}=0$ and $\frac{du}{dy}=0$. There is, however, no real maximum or minimum solution if $\left(\frac{d^2u}{dxdy}\right)^2$ is greater than $\frac{d^2u}{dx^2}\frac{d^2u}{dy^2}$. A short account of this method, illustrated by examples, is given in vol. xiii. pp. 23, 24.

John Bernoulli's problem (*Acta Eruditorum*, June 1696) of the "brachystochrone," *i.e.*, of the curve of quickest descent under the action of gravity, differed essentially

[1] Montucla (*Hist. de Math.*, tom. i. p. 113) erroneously attributed these theorems on isoperimetry to Pythagoras, but his statement is based on a misinterpretation of a passage in Diogenes Laertius. See Bretschneider, *Die Geometrie vor Euklides*, pp. 89, 90.

from all problems on maxima and minima which had been previously solved. In this he introduced into mathematics the conception of a new and most important class of problems. James Bernoulli, also, in his solution of this problem of his brother, proposed a more general question, which may be stated as follows:—"Of all curves of the same length described on a given base to determine one such that the area of a second curve, each of whose ordinates is a given function of the corresponding ordinate, or arc, of the first, may be a maximum, or a mininum." Such problems were styled "isoperimetrical," and come under a class now called *relative* maxima and minima, in which the maximum or minimum curve is to be determined, not from all possible curves, but from among those which possess a given property. The investigations of the Bernoullis were extended and generalized by other eminent mathematicians, but more especially by Euler, and culminated in the invention of the calculus of variations, with an appropriate notation, by Lagrange.

MAXIMIANUS, MARCUS AURELIUS VALERIUS, surnamed HERCULIUS, Roman emperor from 286 to 305, and again in a doubtful manner for some time prior to 308, was by birth a Pannonian peasant, but achieved great distinction in the course of long service in the army in almost every quarter of the empire, and, having been made Cæsar by Diocletian in 285, received the title of Augustus in the following year (April 1, 286) with the honorary appellation of Herculius. In 287 he suppressed the rising of the peasants (Bagaudæ) in Gaul, but in 289, after a three years' struggle, his colleague and he were compelled to acquiesce in the assumption by his lieutenant Carausius of the title of Augustus in Britain. After 292, Maximian left the care of the Rhine frontier to Constantius Chlorus, who had been designated Cæsar in that year, but in 297 his arms achieved a rapid and decisive victory over the barbarians of Mauretania, and in November 303 he shared at Rome the triumph of Diocletian, the last pageant of the kind ever witnessed by that city. On May 1, 305, the day of Diocletian's abdication, he also, but without his colleague's sincerity, divested himself of the imperial dignity at Milan, which had been his capital, and retired to a villa in Lucania; in the following year, however, he was induced by his son Maxentius to reassume the purple. In 307 he brought the emperor Severus a captive to Rome, and also compelled the retreat of Galerius, but in 308 he was himself driven by Maxentius from Italy into Illyricum, whence again he was compelled to seek refuge at Arles, the court of his son-in-law Constantine. Here a false report was received, or invented, of the death of Constantine, at that time absent on the Rhine, and Maximian at once grasped at the succession, but was soon driven to Marseilles, where, having been delivered up to his pursuers, he strangled himself in 310 (February).

MAXIMIANUS, GALERIUS VALERIUS, usually referred to by his name GALERIUS, Roman emperor from 305 to 311, was born near Sardica in Dacia, and originally followed his father's occupation, that of a herdsman, whence his surname of Armentarius. He served with distinction as a soldier under Aurelian and Probus, and in 292 was designated Cæsar along with Constantius, receiving in marriage Diocletian's daughter Valeria, and at the same time having assigned to him as his special charge the care of the Illyrian provinces. In 296, at the beginning of the Persian war, he was removed from the Danube to the Euphrates; his first campaign ended in a crushing defeat on the same field as that which had proved fatal to Crassus, but in 297, advancing through the mountains of Armenia, and taking the enemy by surprise, he gained a victory over Narses by which his military reputation was more than restored. In 305, on the abdication of Diocletian and Maximian, he at once assumed the title of Augustus, along with Constantius his former colleague, and, having procured the promotion to the rank of Cæsar of Severus, a faithful servant, and Daza (Maximinus), his nephew, he hoped on the death of Constantius to become sole master of the Roman world. This scheme, however, was defeated by the sudden elevation of Constantine at York on the death of his father, and by the action of Maximian and Maxentius in Italy. After an unsuccessful invasion of Italy in 307 he elevated his friend Licinius to the rank of Augustus, and, moderating his ambition, devoted the few remaining years of his life "to the enjoyment of pleasure and to the execution of some works of public utility." He died—of the *morbus pedicularis*, it is said—in May 311. It was at the instance of Galerius that the first of the celebrated edicts of persecution against the Christians was published, on February 24, 303, and this policy of repression was maintained by him until the appearance of the general edict of toleration, running in his own name and in those of Licinius and Constantine.

MAXIMILIAN I. (1459-1519), holy Roman emperor, the son of the emperor Frederick III., was born on the 22d of March 1459. In 1477 he married Mary, daughter of Charles the Bold of Burgundy, thus securing for his family the possessions of the house of Burgundy; and by the marriage of his son Philip with the infanta Joanna in 1496 he prepared the way for the association of Spain with the empire under his grandson, Charles V. In 1486 Maximilian was chosen king of the Romans, and in 1493, after the death of his father, he succeeded to the imperial throne. During the reign of Frederick III. the system of private war created profound discontent, and there were urgent demands for the reform of imperial institutions. Maximilian was never thoroughly in sympathy with this movement, but at his first diet, in 1495, he declared a perpetual public peace; and he did something for the restoration of order by the establishment, in the same year, of the imperial chamber (*Reichskammergericht*), and, in 1501, of the imperial Aulic council (*Reichshofrath*). Another important change was the division of Germany into six, afterwards (in 1512) into ten, circles (*Kreise*), over each of which was placed a captain with a force for the punishment of disturbers of the peace. Standing troops, called Landsknechte, were for the first time organized by Maximilian, who also improved the artillery then in use, and issued good police regulations. He encouraged science, art, and literature, devoted much attention to the universities, especially those of Vienna and Ingolstadt, collected mediæval poems, and caused copies to be made of ancient chronicles and other important manuscripts. Through the influence of his second wife, Blanca Sforza, daughter of Duke Galeazzo Sforza of Milan, he was induced to contend for supremacy in Milan and Naples; but his resources were inadequate for war on equal terms with the kings of France, Charles VIII. and Louis XII. In 1499 he carried on an unsuccessful war with the Swiss confederates, the result of which was that, by the peace of Basel, the confederates became practically independent of the empire. On the other hand, he was singularly fortunate in increasing the power of the house of Austria. By the death of his cousin, the archduke Sigismund, he inherited Tyrol; he also received Görz, Gradisca, the Pusterthal, and a part of Bavaria; and by the marriage of two of his grandchildren with children of the king of Hungary and Bohemia he took the first step towards the ultimate incorporation of these countries with the Austrian hereditary territories. He wrote several books, and planned the "Weiss-Kunig," a kind of poetical autobiography, completed by his private secretary, Treizsaurwein von Erentreiz. Maximilian had some part also in the preparation of *Theuerdank*, an allegory setting forth adventures in connexion with his marriage with Mary of Burgundy. At Wels, in Upper Austria, on the 12th of January 1519, he died.

See Klüpfel, *Kaiser Maximilian I.*, 1864.

MAXIMILIAN II. (1527-1576), holy Roman emperor, son and successor of Ferdinand I., was born at Vienna on the 1st of August 1527. He was of a mild and tolerant disposition, and in youth received a favourable impression of Protestantism from his tutor, Wolfgang Severus,—an impression which was not effaced by a residence of three years at the Spanish court. In 1562 he became king of Bohemia and king of the Romans, in 1563 king of Hungary, and in 1564 emperor. At the time of his accession to the imperial throne Hungary was at war with Turkey. The sultan Soliman II. was conciliated by the cession of all the territories he had conquered in Hungary, and by the promise of a yearly tribute of 300,000 florins. Soon afterwards Soliman renewed the war on behalf of the prince of Transylvania; but after his death in 1566 his successor, Selim, concluded with Maximilian an armistice of eight years. Maximilian's brothers, Ferdinand and Charles, fought incessantly against Protestantism in their respective lands; but it was tolerated by Maximilian in Austria, Bohemia, and Hungary. His authority, however, was greatly limited by the influence of the Jesuits. He died on the 12th of October 1576. Of his eight children (six sons and two daughters) two—Rudolph II. and Matthias—became emperors.

See Koch, *Quellen zur Geschichte des Kaisers Maximilian II.*, 1857-61; and Wertheimer, *Zur Geschichte des Türkenkriegs Maximilians II.*, 1875.

MAXIMILIAN (1832-1867), archduke of Austria (Ferdinand Maximilian Joseph) and emperor of Mexico, was the second son of the archduke Francis Charles, and was born in Vienna on July 6, 1832. He was trained for the navy, and ultimately attained a high command in that branch of his country's service. In February 1857 he was appointed governor of the Lombardo-Venetian kingdom, and in the same year he married the Princess Charlotte, daughter of Leopold I., king of the Belgians. On the outbreak of the war of 1859, he retired into private life, chiefly at Trieste, until 1863, when at the instance of Napoleon III. he accepted the crown which had been offered to him by the notables of Mexico. He landed at Vera Cruz on May 28, 1864, but from the commencement of his reign found himself involved in difficulties of the most serious kind, which in 1866 made apparent to almost every one outside of Mexico the necessity for his abdicating. This, however, he declined to do. Withdrawing, in February 1867, to Querétaro, he there sustained a siege for several weeks, but on May 15 resolved to attempt an escape through the enemy's lines. He was, however, arrested before he could carry out this resolution, and, after trial by court martial, was condemned to death. The sentence was carried out on June 19, 1867. His remains were conveyed to Vienna, where they were buried in the imperial vault early in the following year. See MEXICO. Maximilian's papers were published in 1867 in seven volumes, under the title *Aus meinem Leben, Reiseskizzen, Aphorismen*, &c.

MAXIMINUS, CAIUS JULIUS VERUS, Roman emperor from 235 to 238, was of barbarian parentage, his father being a Goth and his mother an Alan, and was born in a village on the confines of Thrace, where his immense stature and enormous feats of strength first drew the attention of the emperor Septimius Severus. From being a shepherd he became a soldier, and under Caracalla rose to the rank of centurion. He carefully absented himself from court during the reign of Elagabalus, but rose to the first military command under his successor Alexander Severus. On March 19, 235, the troops saluted him emperor, and shortly afterwards Alexander was put to death. The three years of his reign, which were spent wholly in the camp, were marked by great cruelty and oppression; the widespread discontent thus produced culminated in a revolt in Africa and the assumption of the purple by GORDIANUS (*q.v.*). Maximin, who was in Pannonia at the time, marched against Rome, and passing over the Julian Alps descended on Aquileia; while detained before that city he and his son were murdered in their tent by a body of prætorians. Their heads were cut off and despatched to Rome, where they were burnt on the Campus Martius by the exultant crowd (May 238).

MAXIMINUS, GALERIUS VALERIUS, Roman emperor from 308 to 314, was originally an Illyrian shepherd, and bore the name of Daza. His mother was a sister of him who afterwards became the emperor Galerius. He rose to high distinction after he had joined the army, and in 305 he was raised by his uncle to the rank of Cæsar, with the honorary appellation of Jovius, Syria and Egypt being the government assigned to him. In 308, after the elevation of Licinius, he insisted on receiving the title of Augustus; on the death of Galerius in 311 he succeeded to the supreme command of the provinces of Asia, and, when Licinius and Constantine began to make common cause with one another, Maximin entered into a secret alliance with Maxentius. He came to an open rupture with Licinius in 313, sustained a crushing defeat in the neighbourhood of Heraclea on April 30th, and, having fled with extraordinary celerity first to Nicomedia and afterwards to Tarsus, perished at the latter city in August following. His death was variously ascribed "to despair, to poison, and to the Divine justice." Maximin, in every respect a worthless character, has a bad eminence in the annals of the Christian church as having renewed persecution after the publication of the toleration edict of Galerius.

MAXIMUS, the name of four Roman emperors. In chronological order the first was M. Clodius Pupienus Maximus, who was associated with Balbinus in the imperial dignity by the senate for a short time in 238, before and after the death of the hated Maximin. The second was Magnus Clemens Maximus, a native of Spain, who shared the imperial dignity with Valentinian and Theodosius from 383 to 388. He had accompanied Theodosius on several expeditions, and from 368 held high military rank in Britain. The disaffection of the Roman troops towards the emperor Gratian found expression in 383 in the proclamation of Maximus as emperor,—whether with or without his complicity in the act is uncertain. Voluntarily or under compulsion Maximus forthwith attacked Gratian in Gaul, and drove him from Paris to Lyons, where the fugitive was murdered. Circumstances made it difficult for Theodosius at the time to avenge the death of his colleague by war, and an agreement was therefore come to by which Maximus was recognized as Augustus and sole emperor in Gaul, Spain, and Britain, while Valentinian was to remain unmolested in Italy and Illyricum, Theodosius retaining his sovereignty in the East. A prosperous reign of four years having tempted Maximus, in 387, to pass the Alps, Valentinian was speedily put to flight, while the invader established himself in Milan, and for the time became master of Italy. Theodosius now took vigorous measures: advancing a powerful army by land, he utterly defeated the western troops at Siscia (Sciszek) in Pannonia, and, passing the Julian Alps with great rapidity, came upon Maximus, who had fled to Aquileia, seized him, and caused him to be beheaded (August 388). The third, Maximus Tyrannus, was made emperor in Spain by the Roman general Gerontius, who had rebelled against Constantine in 408. After the defeat of Gerontius at Arles, and his subsequent death in 411, Maximus renounced the imperial title and was permitted by Constantine to retire into private life. About 418 he rebelled again, but, failing in his attempt, was seized, carried into Italy, and put to death at Ravenna in 422. Lastly, Petronius Maximus was a member of the higher Roman nobility, and had held a large number of public offices, including those of præfectus Romæ (420) and of præfectus Italiæ (439–441 and 445). He was one of the intimate associates of Valentinian, who received his assistance in the palace intrigues which led to the death of Aetius in 454; but a brutal outrage committed on the wife of Maximus by the emperor turned his friendship into the bitterest hatred. Maximus was proclaimed emperor immediately after Valentinian's murder in March 455, but reigned for less than three months, having been murdered by some Burgundian mercenaries as he was flying before the Vandals, who, invited by Eudoxia, the widow of Valentinian, had landed at the mouth of the Tiber (May or June 455).

MAXIMUS, St, abbot of Chrysopolis, known as "the Confessor" from his orthodox zeal in the Monothelite controversy, or as "the monk," was born of noble parentage at Constantinople about the year 580. Educated with great care, he early became distinguished by his talents and acquirements, and some time after the accession of the emperor Heraclius in 610 was made his private secretary. In 630 he abandoned the secular life and entered the monastery of Chrysopolis (Scutari), actuated, it was believed, less by any longing for the life of a recluse than by the dissatisfaction he felt with the Monothelite leanings of his master. The date of his promotion to the abbacy is uncertain. In 633 he was one of the party of Sophronius at the council of Alexandria; and in 645 he was again in Africa, when he held in presence of the governor and a number of bishops the disputation with Pyrrhus, the deposed and banished patriarch of Constantinople, which resulted in the (temporary) conversion of his interlocutor to the Dyothelite view. In the following year several African synods, held under the influence of Maximus, declared for orthodoxy. In 649, after the accession of Martin I., he went to Rome, and did much to fan the zeal of the new pope, who in October of that year held the (first) Lateran synod, by which not only the Monothelite doctrine but also the moderating *ecthesis* of Heraclius and *typus* of Constans II. were anathematized. About 653 Maximus, for the part he had taken against the latter document especially, was apprehended by order of Constans and carried a prisoner to Constantinople, and in 655, after repeated examinations, in which he maintained his theological opinions with memorable constancy, was banished to Byzia in Thrace, and afterwards to Perberis. In 662 he was again brought to Constantinople and was condemned by a synod there to be scourged, to have his tongue cut out by the root, and to have his right hand chopped off. After this sentence had been carried out he was again banished to Lazica, where he died on August 13, 662. He is venerated as a saint both in the Greek and in the Latin Church,—in the former on January and on August 12th and 13th, in the latter on August 13th.

A collection of his works, which are of importance for the history of the Monothelite controversy, was undertaken by Combefis, who published two volumes in 1675 (*S. Maximi Confessoris, Græcorum Theologi, eximiique Philosophi Opera*), but did not live to complete his labours. A list of the more important of the writings of Maximus, with bibliographical details, will be found in Smith's *Dictionary of Biography and Mythology*; an exhaustive "Catalogue raisonné," by Wagenmann, occurs in vol. ix. (1881) of the new edition of Herzog's *Real-Encyklopädie*. The details of the disputation with Pyrrhus and of the martyrdom are given very fully and clearly in Hefele's *Conc.-gesch.*, vol. iii.

MAXWELL, James Clerk (1831–1879), was the last representative of a younger branch of the well-known Scottish family of Clerk of Penicuik. He was educated at the Edinburgh Academy (1840–47) and the university of Edinburgh (1847–50). Entering at Cambridge in 1850, he spent a term or two in Peterhouse, but afterwards migrated to Trinity. He took his degree in 1854 as second wrangler, and was declared equal with the senior wrangler of his year in the higher ordeal of the Smith's prize examination. He held the chair of natural philosophy in Marischal College, Aberdeen, from 1856 till the fusion of the two colleges there in 1860. For eight years subsequently he held the chair of physics and astronomy in King's College, London, but resigned in 1868 and retired to his estate of Glenlair in Kirkcudbrightshire. He was summoned from his seclusion in 1871 to become the first holder of the newly-founded professorship of experimental physics in Cambridge; and it was under his direction that the plans of the Cavendish laboratory were prepared. He superintended every step of the progress of the building and of the purchase of the very valuable collection of apparatus with which it was equipped at the expense of its munificent founder the duke of Devonshire (chancellor of the university, and one of its most distinguished alumni). So far for the outline of Maxwell's career, as regards dates, official work, &c. The rest belongs almost exclusively to mathematical and physical science. For more than half of his brief life he held a prominent position in the very foremost rank of natural philosophers. His contributions to scientific societies began in his fifteenth year, when Professor J. D. Forbes communicated to the Royal Society of Edinburgh a short paper of his on a mechanical method of tracing Cartesian ovals. In his eighteenth year, while still a student in Edinburgh, he contributed two valuable papers to the *Transactions* of the same society—one of which, "On the Equilibrium of Elastic Solids," is remarkable, not only on account of its intrinsic power and the youth of its author, but also because in it he laid the foundation of one of the most singular discoveries of his later life, the temporary double refraction produced in viscous liquids by shearing stress. Immediately after taking his degree, he read to the Cambridge Philosophical Society a very novel memoir *On the Transformation of Surfaces by Bending*. This is one of the few purely mathematical papers he published, and it exhibited at once to experts the full genius of its author. About the same time appeared his elaborate memoir *On Faraday's Lines of Force*, in which he gave the first indication of some of those extraordinary electrical investigations which culminated in the greatest work of his life. He obtained in 1859 the Adams prize in Cambridge for a very original and powerful essay *On the Stability of Saturn's Rings*. From 1855 to 1872 he published at intervals a series of valuable investigations connected with the *Perception of Colour* and *Colour-Blindness*. For the earlier of these he received the Rumford medal in 1860. The instruments which he devised for these investigations were simple and convenient, but could not have been thought of for the purpose except by a man whose knowledge was co-extensive with his ingenuity. One of his greatest investigations bore on the *Kinetic Theory of Gases*. Originating with D. Bernoulli, this theory was advanced by the successive labours of Herapath, Joule, and particularly of Clausius, to such an extent as to put its general accuracy beyond a doubt. But by far the greatest developments it has received are due to Maxwell, part of whose mathematical work has recently been still further extended in some directions by Bolzmann. In this field Maxwell appears as an experimenter (on the laws of gaseous friction) as well as a mathematician. His two latest papers deal with this branch of physics; one is an extension and simplification of some of Bolzmann's chief results, the other treats of the kinetic theory as applied to the motion of the radiometer. He has written an admirable text-book of the *Theory of Heat*, which has already (1882) gone through several editions, and a very excellent elementary treatise on *Matter and Motion*. Even this, like his other and larger works, is full of valuable matter, worthy of the most attentive perusal not of students alone but of the very foremost scientific men.

But the great work of his life was devoted to electricity. He began by reading with the most profound admiration and attention the whole of Faraday's extraordinary self-revelations, and proceeded to translate the ideas of that master into the succinct and expressive notation of the mathematicians. A considerable part of this translation was accomplished during his career as an undergraduate in Cambridge. The writer had the opportunity of perusing the MS. on *Faraday's Lines of Force*, in a form little different from the final one, a year before Maxwell took his degree. His great object, as it was also the great object of Faraday, was to overturn the idea of action at a distance. The splendid researches of Poisson and Gauss had shown how to reduce all the phenomena of statical electricity to mere attractions and repulsions exerted at a distance by particles of an imponderable on one another. Sir W. Thomson had, in 1846, shown that a totally different assumption, based upon other analogies, led (by its own special mathematical methods) to precisely the same results. He treated the resultant electric force at any point as analogous to the *flux of heat* from sources distributed in the same manner as the supposed electric particles. This paper of Thomson's, whose ideas Maxwell afterwards developed in an extraordinary manner, seems to have given the first hint that there are at least two perfectly distinct methods of arriving at the known formulæ of statical electricity. The step to magnetic phenomena was comparatively simple; but it was otherwise as regards electro-magnetic phenomena, where current electricity is essentially involved. An exceedingly ingenious, but highly artificial, theory had been devised by Weber, which was found capable of explaining all the phenomena investigated by Ampère, as well as the induction currents of Faraday. But this was based upon the assumption of a distance-action between electric particles, whose intensity depended on their relative motion as well as on their position. This was, of course, even more repugnant to Maxwell's mind than the statical distance-action developed by Poisson. The first paper of Maxwell's in which an attempt at an admissible physical theory of electromagnetism was made was communicated to the Royal Society in 1867. But the theory, in a fully developed form, first appeared in his great treatise on *Electricity and Magnetism* (1873). This work, already in a second edition, is one of the most splendid monuments ever raised by the genius of a single individual. Availing himself of the admirable generalized coordinate system of Lagrange, Maxwell has shown how to reduce all electric and magnetic phenomena to stresses and motions of a material medium, and, as one preliminary, but excessively severe, test of the truth of his theory, has shown that (if the electromagnetic medium be that which is required for the explanation of the phenomena of light) the velocity of light in vacuo should be numerically the same as the ratio of the electromagnetic and electrostatic units. We do not as yet certainly know either of these quantities very exactly, but the means of the best determinations of each separately agree with one another more closely than do the various values of either. There seems to be no longer any possibility of doubt that Maxwell has taken the first grand step towards the discovery of the true nature of electrical phenomena. Had he done nothing but this, his fame would have been secured for all time. But, striking as it is, this forms only one small part of the contents of his truly marvellous work.

One of his last great contributions to science was his editing (with copious original notes) the *Electrical Researches of the Hon. Henry Cavendish*, which had been altogether unappreciated by the witlings to whom they had previously been confided. It now appears that Cavendish, already famous by many other researches (such as the mean density of the earth, the composition of water, &c.), must be looked on as, in his day, a man of Maxwell's own stamp as a theorist, and an experimenter of the very first rank.

This encyclopædia has been, in its scientific aspects, greatly indebted to Clerk Maxwell. The articles ATOM, ATTRACTION, CAPILLARITY, DIFFUSION, ETHER, &c., were intended as parts merely of one comprehensive system, in which a general résumé of all that is known of the properties of matter should be given in simple yet profound completeness. The reader of these articles cannot but feel how much has been lost when this splendid series cannot be completed by its initiator.

In private life Clerk Maxwell was one of the most lovable of men, a sincere and unostentatious Christian. Though perfectly free from any trace of envy or ill-will, he yet showed on fit occasion his contempt for that pseudo-science which seeks for the applause of the ignorant by professing to reduce the whole system of the universe to a fortuitous sequence of uncaused events.

His collected works will shortly be issued from the Pitt press; and an extended biography, by his former school-fellow and lifelong friend Professor Campbell, has just been published (1882). (P. G. T.)

MAXWELL, SIR WILLIAM STIRLING-, BART. (1818–1878), man of letters, the only son of Mr Archibald Stirling of Keir, Perthshire, and of Elizabeth, second daughter of Sir John Maxwell, seventh baronet of Pollok, Renfrewshire, was born at Kenmure, near Glasgow, in 1818. William Stirling was educated at Trinity College, Cambridge, where he graduated in 1839, and afterwards he spent some years on the Continent chiefly in France and Spain. Having succeeded his father as proprietor of Keir in 1846 (when he was made vice-lieutenant of Perthshire), he in 1852 entered parliament as member for that county; and he was several times re-elected. On the death of his uncle in 1865 he succeeded to the baronetcy and estates of Pollok, in respect of which he assumed the additional name of Maxwell. In the same year he became deputy-lieutenant of Lanarkshire, and a like office was conferred on him in Renfrewshire in 1870. The services which his talent, energy, and wealth enabled him to render to literature were recognized in a great variety of ways by numerous universities; in 1863 he was chosen lord rector of St Andrews, in 1871 the same honour was conferred by Edinburgh, and in 1875 he became chancellor of Glasgow. In the following year he was created a Knight of the Thistle, being the only commoner of the order. He died at Venice on January 15, 1878.

Sir W. Stirling-Maxwell's works, which are invariably characterized by thoroughness of workmanship and refinement of literary taste, were in some cases issued for private circulation only, and almost all of them are now exceedingly rare. They include an early volume of verse (*Songs of the Holy Land*, 1847), and several volumes containing costly reproductions of old engravings, along with valuable explanatory matter. His best-known publications are *Annals of the Artists of Spain* (1848; 2d ed., 1853), *The Cloister Life of Charles V.* (1852; 3d ed., 1853), and *Velazquez and his Works* (1855). A life of *Don John of Austria*, from his posthumous papers, is now (1882) in the press.

MAY, the fifth month of our modern year, was the third of the old Roman calendar. The name is of doubtful origin. Ovid (*Fasti*, v. 483–90) suggests the three derivations of *majestas*, *majores* (the *patres* of the old Roman city), and *Maia*, the mother of Mercury, to whom the Romans were accustomed to sacrifice on the first day of the month. It was considered unlucky among the Romans to contract marriages during this month, on account of the celebration of the Lemuria,—a superstition of which traces are still to be found among ourselves. In the Roman Catholic Church May is known as "the month of Mary."

May-day is the name given to the first day of the month in England, when, according to ancient custom, all ranks of the people rose at early dawn and went out "a-Maying" to welcome the advent of spring. The customs of the day chiefly took their rise with the Romans. In the southern counties of England they differ materially from those of the northern and western. That of gathering branches of trees and flowers, to deck the person, is still observed in many places.

The May-Pole was once general throughout the country. The assemblage of the people, sanctioned by the presence of the priests, marching on May morning in procession to some neighbouring wood, returned in triumph with the pole, round which were suspended flowers, boughs, and other tokens of the spring season. On one of these festive occasions, Henry VIII. assembled his court at Shooter's Hill; and Queen Elizabeth also used to keep "May Games" at Greenwich. The May-pole, once fixed, often remained until nearly the end of the year; and there were some specially made of durable wood, which remained for many years, and were from time to time resorted to at other seasons of festivity. The last May-pole erected in London, 100 feet in height, was on the spot where the church in the Strand now stands, near Somerset House. Being taken down in 1717–18 it was conveyed to Wanstead Park in Essex, where it was fixed as part of the support of a large telescope set up by Sir Isaac Newton. The May Lady, Maulkin, Jack in the Green, and Morris Dancing are merely variations in the mode of representing the goddess Flora. The chimney sweepers, who are now the principal performers, are probably more interested than any other class in May sports. For, as the commencement of summer deprives them in a considerable degree of their business occupation, they naturally seek to avail themselves of the customary liberality of festive meetings.

The other principal fixed days observed and noted in the month are May 9, Half-Quarter-Day, and May 15, Whitsunday term,—not to be confounded with Whit Sunday, which is a movable feast.

MAYA. See Mexico.

MAYBOLE, a burgh of barony and market-town of Scotland, in the county of Ayr, 9 miles south of Ayr on the railway to Stranraer, is built on the face of a hill gently sloping to the south. The characteristic features of the place are the old family mansions in the main street, the castle of the earls of Cassilis, and the old church ruins with the Cassilis burial-place. It has recently increased considerably in size, and it is now busy with various manufacturing industries in addition to its staple trade of shoemaking. The population was 3797 in 1871 and 4474 in 1881. New waterworks to supply 60,000 gallons daily were commenced in 1882; the site of the reservoir, about 3 miles south-east of the town, is almost that of the remarkable Lochspouts crannog (see *Ayr and Wigton Arch. and Hist. Collections*, vol. iii.; and Munro, *Ancient Scottish Lake Dwellings*, 1882).

A charter was granted to the town by Duncan in 1193; and the church was bestowed in 1213 on the Cistercian nunnery at North Berwick. In 1516 Maybole became a burgh of regality, and in 1639 the seat of the head courts of Carrick; but the independence of its local government was long contested by the superiors, the earls of Cassilis. Cotton weaving was introduced in the 18th century.

See J. Paterson, *History of Ayr and Wigton*, vol. ii., 1864.

MAYENCE. See Mainz.

MAYENNE, a department of north-western France, three-fourths of which formerly belonged to Lower Maine and the remainder to Anjou, lies between 47° 45′ 10″ and 48° 34′ 30″ N. lat., and 0° 2′ E. and 1° 14′ W. long., and is bounded on the N. by Manche and Orne, on the E. by Sarthe, on the S. by Maine-et-Loire, and on the W. by Ille-et-Vilaine, having a maximum length from north to south of 51 miles, a breadth of 39 miles, and an area of 1996 square miles. Its ancient geological formations connect it with Brittany. The surface is agreeably undulated; forests are numerous, and the beauty of the cultivated portions is enhanced by the hedgerows and lines of trees by which the farms are divided. The highest point of the department, and indeed of the whole north-west of France, is the Mont des Avaloirs (1368 feet). Hydrographically Mayenne belongs to the basins of the Loire, the Vilaine, and the Sélune; the first-mentioned has the larger part of the entire area. The principal stream is the Mayenne, which passes successively from north to south through the three most important towns—Mayenne, Laval, and Château-Gontier; by means of weirs and sluices it is navigable below Mayenne, but steamers do not ascend past Château-Gontier. The chief affluents are the Jouanne on the left, and on the right the Colmont, the Ernée, and the Oudon. A small area in the east of the department drains by the Erve into the Sarthe; the Vilaine rises in the west, and in the north-west the Sélune flows into the English Channel. The climate of Mayenne, which is that of the Sequanian region, is generally healthy except in the neighbourhood of the numerous marshes. The temperature is lower and the moisture of the atmosphere greater than in the neighbouring departments; the rainfall is above the average for France.

Of the entire area two-thirds are arable, and a twentieth is under wood. A large number of horned cattle are reared (98,000 oxen, 150,000 cows), and in no other French department are so many horses (92,500) found within the same area; the breed, that of Craon, is famed for its strength. Craon has also given its name to the most prized breed of pigs in western France. There are 83,000 pigs in the department, 80,000 sheep, and 5000 goats. Mayenne produces excellent butter, poultry, and game, and a large quantity of honey. The cultivation of the vine is very limited, and the most common beverage is cider, of which nearly 9,000,000 gallons are annually made. Agriculture is in a flourishing condition; in 1878 were produced upwards of 3½ million bushels of wheat, ¾ million of meslin, nearly an equal amount of rye, 1½ million of barley, 2 million of oats, and nearly 3 million bushels of potatoes, besides a large quantity of flax and hemp. The timber grown is chiefly beech, oak, birch, elm, and chestnut. The department produces a little iron-ore and manganese; it is rich in anthracite and coal, of which, however, the annual production has recently decreased from 80,000 tons to 60,000. Marble and granite, limestone, slate, and porphyry are quarried; the last-named material is capable of a fine polish, and is also used for paving the streets of Paris. There are several chalybeate springs. The industries include iron and brass founding, brick and tile making, brewing, the manufacture of candles, cotton, linen, and woollen thread, and the production of various textile fabrics (that of ticking being the specialty of the department), agricultural implement making, wood and marble sawing, tanning, dyeing, and the like. The population in 1881 was 343,167. The arrondissements are those of Laval, Château-Gontier, and Mayenne.

Mayenne, capital of an arrondissement in the above department of France, is an old feudal town irregularly built on two hillocks which overlook the river Mayenne, at the point where the railway from Caen to Laval is joined by that from Fougères to Alençon. The old castle still has towards the river five towers, one of which has retained its conical roof; the vaulted chambers and chapel are ornamented in the style of the 13th century; the building is now used as a prison. The church of Notre Dame, dating partly from the 12th century, is the only other building of any special interest. In the Place de Cheverus is a statue, by David of Angers, to the cardinal of that name, who was born in Mayenne. The chief industry of the place is the cloth manufacture, which occupies 8000 persons in the town and neighbourhood. The population in 1876 was 10,098.

Mayenne had its origin in the castle built here by Juhel, the son of Geoffroy of Maine, in the beginning of the 11th century. It was besieged by William the Conqueror, and afterwards by the earl of Salisbury; and the possession of it was disputed by the Royalists and the Leaguers, as also by the Republicans and the Vendeans.

MAYER, JOHANN TOBIAS (1723–1762), one of the greatest of last century's astronomers, was born at Marbach in Würtemberg, February 17, 1723. He was brought up at Esslingen in comparatively poor circumstances, and as a mathematician was mainly self-taught. He had already published several original geometrical tracts when, in 1746, he entered Homann's cartographic establishment at Nuremberg. Here he introduced many improvements in map-making, and gained a scientific reputation which led (in 1751) to his election to the chair of economy and mathematics in the university of Göttingen. In 1754 he became superintendent of the observatory, where he laboured with great zeal and success till his death, February 20, 1762. His first important astronomical work was a careful investigation of the libration of the moon (*Kosmographische Nachrichten*, Nuremberg, 1750), the elements of which and the position of the moon's axis of rotation he determined with much greater accuracy than had previously been done. His great fame rests on his lunar tables, which were published in 1753 along with new solar tables, and transmitted to England in 1755. These tables, which were compared by Bradley with the Greenwich observations, and found to be sufficiently accurate to determine the longitude at sea to within half a degree, solved the problem of practically determining longitude anywhere on the earth's surface. An improved set was afterwards published in London (1770), as also the theory (*Theoria Lunæ juxta Systema Newtonianum*, 1767) upon which the tables are based. They were sent to England by his widow, who in consideration received from the British Government a grant of £3000. Appended to the London edition of the solar and lunar tables are two short tracts,—the one on determining longitude by lunar distances, together with a description of the repeating circle (invented by Mayer in 1760), the other on a formula for atmospheric refraction, which applies a remarkably accurate correction for temperature.

Mayer left behind him a considerable quantity of manuscript, part of which was collected by Lichtenberg and published in one volume (*Opera Inedita*, Göttingen, 1775). It contains, amongst other papers, an easy and accurate method for calculating eclipses; an essay on colour, in which three primary colours are recognized; a catalogue of nine hundred and ninety-eight zodiacal stars; and a memoir, the earliest of any real value, on the proper motion of fixed stars, which was originally communicated to the Göttingen Royal Society in 1760. The other part still remains in manuscript, and includes papers on atmospheric refraction (dated 1755), on the motion of Mars as affected by the perturbations of Jupiter and the Earth (1756), and on terrestrial magnetism (1760 and 1762). In these last Mayer seeks to explain the magnetic action of the earth by a simple hypothesis. He supposes a small bar-magnet to be placed with its centre at the earth's centre, and calculates the position of equilibrium of a second small magnet at any given point on the earth's surface, assuming the law of magnetic attraction and repulsion to be that of the inverse square. Though the values of the declination and dip calculated according to this theory do not agree with the observed values, Mayer must be credited with the first really definite attempt to establish a mathematical theory of magnetic action, and as the first who gave any experimental evidence in favour of the inverse square of the distance as the law of force. See Hansteen's *Magnetismus der Erde*.

MAYER, JULIUS ROBERT (1814–1878), was born at Heilbronn, Nov. 25, 1814, studied medicine at Tübingen, Munich, and Paris, and, after a journey to Java in 1840 as surgeon of a Dutch vessel, obtained a medical post in his native town. He claims recognition as an independent *a priori* propounder of the "First Law of Thermodynamics," but more especially as having early and ably applied that law to the explanation of many remarkable phenomena, both cosmical and terrestrial. His first little paper on the subject, "Bemerkungen über die Kräfte der unbelebten Natur," appeared in 1842 in Liebig's *Annalen*, five years subsequent to the republication, in the same journal, of an extract from the great memoir of MOHR (*q.v.*). Mayer's statements as to the "indestructibility of force" (as he calls it) were based almost entirely upon scholastic dicta, such as *causa æquat effectum*, &c. The main experimental fact which he adduces in support of his reasoning as to the convertibility of work and heat is a mere repetition, in a very inadequate form, of a curious experiment made by Dr Reade of Cork, who found (*Nicholson's Journal*, xx., 1808, p. 113) that water was sensibly heated after being violently shaken in a phial. But Dr Reade states explicitly the precautions he had taken to protect the phial and its contents from heating by the hand of the operator,—an important detail which is unnoticed by Mayer.

It has been repeatedly claimed for Mayer that he calculated the value of the dynamical equivalent of heat, indirectly no doubt, but in a manner altogether free from error, and with a result according almost exactly with that obtained by Joule after years of patient labour in direct experimenting. Mayer assumed that the heat developed by compression of air is the equivalent of the work spent in the compression. If we had independent proof of this the result would undoubtedly follow.[1] And it has been urged that the man who, by a single burst of genius, reached at once the goal which others had been painfully seeking, merits an amount of fame commensurate with that due to discoverers like Newton or Galileo. This claim on Mayer's behalf was first shown to be baseless by Thomson and Tait ("Energy," *Good Words*, 1862). This article gave rise to a long but lively discussion. A calm and judicial annihilation of the claim is to be found in a brief article by Stokes, *Proc. Roy. Soc.*, 1871, p. 54. See also Maxwell's *Theory of Heat*, chap. xiii. Mayer entirely ignored the grand fundamental principle laid down by Sadi Carnot, a principle which has done even more for physics than has the conservation of energy itself, viz., that nothing can be concluded as to the relation between heat and work from an experiment in which the working substance is left at the end of an operation in a different physical state from that in which it was at the commencement. Mayer has also been styled the discoverer of the fact that heat consists in (the energy of) motion, a matter settled at the very end of the 18th century by Rumford and Davy. In the teeth of this statement we have Mayer's own words, "We might much rather assume the contrary,—that in order to become heat, motion must cease to be motion."

Mayer's real merit consists in the fact that, having for himself made out, on inadequate and even questionable grounds, the conservation of energy, and having obtained (though by inaccurate reasoning) a numerical result correct so far as his data permitted, he applied the principle with great power and insight to the explanation of numerous physical phenomena. His papers, which have been republished in a single volume with the title *Die Mechanik der Wärme* (2d ed., Stuttgart, 1874), are of extremely unequal merit. But some, especially those on *Celestial Dynamics* and *Organic Motion*, are admirable examples of what really valuable work may be effected by a man of high intellectual powers, in spite of imperfect information and defective logic.

Different, and, it would appear, exaggerated, estimates of Mayer are given in Dr Tyndall's papers in the *Phil. Mag.*, 1863–64 (whose avowed object was "to raise a noble and a suffering man to the position which his labours entitled him to occupy"), and in the extraordinary treatise by Dühring, *Robert Mayer, der Galilei des neunzehnten Jahrhunderts*, Chemnitz, 1880. Some of the simpler facts of the case are summarized by Tait in the *Phil. Mag.*, 1864, ii. p. 289.

MAYHEM (MAIM), an old term of the law signifying an assault whereby the injured person is deprived of a member proper for his defence in fight, *e.g.*, an arm, a leg, a fore tooth, &c. The loss of an ear, jaw tooth, &c., was not mayhem. The most ancient punishment in English law was retaliative—*membrum pro membro*, but ultimately at common law fine and imprisonment. Various statutes were passed aimed at the offence of maiming and dis-

[1] Séguin, three years before, had assumed that the work done by steam or any other expanding substance is the equivalent of the heat which disappears during the expansion. A similar idea, but more accurately expressed, is to be found in Mohr's paper, above referred to.

figuring, which is now dealt with by section 18 of 24 & 25 Vict. c. 100. Mayhem may also be the ground of a civil action, which had this peculiarity that the court on sight of the wound might increase the damages awarded by the jury.

MAYKOP, a town of the Caucasus, Russia, in the province of Kuban, on the Byelaya, a tributary of the Kuban, 93 miles to the south-east of Yekaterinodar, the capital of the province. Formerly it was merely a fortified "stanitsa" (village of Cossacks) and the centre for military operations against western Caucasus. But, owing to its position in a very fertile country where settlers from Russia found plenty of rich soil which had been abandoned by the natives, Maykop has become a wealthy town, and its population has rapidly increased to 22,550. Most of them are still agriculturists, but others are engaged in a brisk trade in the produce obtained from the large and wealthy stanitsas of the surrounding district.

MAYNOOTH, a village in the county of Kildare, province of Leinster, Ireland, is situated on the Royal Canal and on the Midland Great Western Railway, 15 miles north-west of Dublin. The Royal Catholic College of Maynooth, instituted by the Irish parliament in 1765, is the chief seminary for the education of the Roman Catholic clergy of Ireland. It was supported by a parliamentary grant of £26,000 a year, which at the disestablishment of the Irish Church in 1869 was commuted by the payment of a capital sum fourteen times its amount. The building is a fine Gothic structure by Pugin, erected by a parliamentary grant obtained in 1846. Near the college stand the ruins of Maynooth Castle, built in 1426, and formerly the residence of the Fitzgerald family. It was besieged in the reign of Henry VIII., in that of Edward VI., and during the Cromwellian wars, when it was demolished. The beautiful mansion of the duke of Leinster is about a mile from the town.

MAYO, a maritime county on the west coast of Ireland, province of Connaught, is bounded N. and W. by the Atlantic Ocean, N.E. by Sligo, E. by Roscommon, S.E. and S. by Galway. Its greatest length from north to south is about 75 miles, and its greatest breadth about 65 miles. The total area is 1,318,129 acres, or 2060 square miles.

About two-thirds of the boundary of Mayo is formed by sea, and the coast is very much indented, and abounds in picturesque scenery. The principal inlets are Killary Harbour between Mayo and Galway; Clew Bay, in which are the harbours of Westport and Newport; Blacksod Bay and Broad Haven, which form the peninsula of the Mullet; and Killala Bay between Mayo and Sligo. The islands are very numerous, the principal being Inishturk (area 1445 acres, and population 132 in 1881), near Killary Harbour; Clare Island (area 3949 acres, population 62) at the mouth of Clew Bay, where there are many islets all formed of drift; and Achil (area 35,838 acres, population 5070), the largest island in Ireland. In the eastern half of the county, where Carboniferous rocks prevail, the surface is comparatively level, with occasional hills consisting chiefly of granite and slate. The western half is very mountainous, but there are a few valleys adjoining the sea-shore. A great portion of the coast extending from Killala to Clew Bay consists of Old Red and Yellow Sandstone. The remainder of the mountainous region consists chiefly of quartzite or alternating beds of quartzite and granite or gneiss schist. Muilrea (2688 feet) is included in a mountain range, lying between Killary Harbour and Lough Mask, which belongs to the Upper Silurian formation. The next highest summits are Nephin (2530 feet), to the west of Lough Conn, and Croagh Patrick (2370 feet), to the south of Clew Bay. The river Moy flows northwards, forming the boundary of the county with Sligo, and falls into Killala Bay. The courses of the other streams are short, and except when swollen by rains their volume is small. The principal lakes are Lough Mask and Lough Corrib, on the borders of the county with Galway, and Loughs Conn, Carrah, Castlebar, Cullin, and Carrowmore. Limestone is abundant, and also iron ore, which, however, is not smelted, from want of fuel. There are several valuable slate quarries; and ochres, granite, and manganese are found.

Agriculture.—There are some very fertile regions in the level portions of the county, but in the mountainous districts the soil is poor, the holdings are subdivided beyond the possibility of affording proper sustenance to their occupiers, and, except where fishing is combined with agricultural operations, the circumstances of the peasantry are among the most wretched of any district of Ireland.

In 1881 there were 179,343 acres, or less than one-eighth of the whole area, under crops, while 545,040 were pasture, 10,702 woods, and 521,673 waste. The total number of holdings in 1881 was 37,693, of which 22,914 were less than 15 acres in extent, and 9386 between 15 and 30 acres. The following table shows the areas under the principal crops in 1855 and 1882:—

	Wheat.	Oats.	Other Cereals.	Potatoes.	Turnips.	Other Green Crops.	Flax.	Meadow and Clover.	Total.
1855	4,638	83,543	5,396	59,037	9,556	2,193	745	18,229	183,337
1882	1,083	61,125	3,016	54,594	7,960	3,964	286	43,363	175,391

Horses between 1855 and 1882 increased from 17,531 to 18,050, of which 12,150 were used solely for agricultural purposes. The number of cattle in 1855 was 153,583, and in 1882 it was 162,331, of which 53,153 were milch cows. Sheep in 1855 numbered 265,448, and in 1882 only 225,509, although in 1880 there were as many as 271,282. Pigs in 1882 numbered 62,227, goats 5987, and poultry 632,432. According to the latest return the land was divided among 1483 proprietors, who possessed 1,308,367 acres, at an annual rateable value of £310,140, the rateable value per acre being 4s. 8d. The average size of the properties was 882 acres. No fewer than 21 proprietors, possessed upwards of 10,000 acres, and of these 8 possessed upwards of 20,000, viz., Marquis of Sligo, 114,881 acres; Viscount Dillon, 83,749; Sir R. W. H. Palmer, Bart., 80,990; Earl of Lucan, 60,570; T. S. Carter, 37,773; G. Clive, 35,229; Earl of Arran, 29,644; C. H. Knox, 24,374.

Manufactures and Trade.—Coarse linen and woollen cloths are manufactured to a small extent. There are very productive fishing banks on the coast, especially in the neighbourhood of the islands, and the Moy is a fine river for salmon.

Railways.—The Great Northern and Western Railway crosses the county from near Ballyhaunis to Westport, and a branch from it runs north to Ardnaree near Killala Bay.

Administration and Population.—The county includes nine baronies and seventy-three parishes. It is in the Connaught circuit. Assizes are held at Castlebar, and quarter sessions at Ballina, Ballinrobe, Bellmullet, Castlebar, Claremorris, Swineford, and Westport. There are twenty-two petty sessions districts within the county, and portions of two other districts. It includes the seven poor-law unions of Bellmullet, Castlebar, Claremorris, Killala, Newport, Swineford, and Westport, and part of the unions of Ballina, Ballinrobe, and Castlerea. It is in the Dublin military district, subdistrict of Galway; and there are barrack stations at Castlebar, Ballinrobe, Westport, Foxford, and Ballaghaderreen. In the Irish parliament two members were returned for the county, and two for the borough of Castlebar, but at the Union Castlebar was disfranchised.

From 77,508 in 1760 the population gradually increased till in 1841 it was 388,887, but in 1851 it had diminished to 274,499, in 1871 to 246,030, and in 1881 to 245,212, of whom 119,421 were males and 125,791 females. The county contains a portion (with 4318 inhabitants) of the township of Ballina, the townships of Castlebar, 3855, and Westport, 4469, and the town of Ballinrobe, 2286. The number of emigrants from 1st May 1851 to 31st December 1881 was 85,431. The number of emigrants in 1881 was 4469, or a proportion of 18·4 to every 1000 of the population. The death-rate to every 1000 of the population for 10 years ending 31st March 1881 was 13·8, the birth-rate 27·1, and the marriage-rate 3·9. Roman Catholics in 1881 numbered 238,262, Episcopalians 5575, Presbyterians 925, and Methodists 275. In 1881 as many as 8808 persons could speak Irish only, and 138,930 Irish and English.

History and Antiquities.—The name given by Ptolemy to the inhabitants of this district of Ireland was Nagnatæ. Erris in Mayo was the scene of the landing of the chief colony of the Firbolgs, and the battle which is said to have resulted in the overthrow and almost annihilation of this tribe took place also in this county, at Moytura near Cong. Along with the greater part of Connaught it was granted by King John to Hubert de Burgo, but after the rebellion against William de Burgo, third earl, headed by Mac William Oughter, the whole province of Connaught remained nearly independent of British rule till the time of Elizabeth. In the eleventh year of her reign Mayo was made shire ground, taking its name from the monastery of Maio or Mageo, which was the see of a bishop. Even, however, after this period the Mac Williams continued to exercise very great authority. Large confiscations of the estates in the county were made in 1586, on the termination of the wars of 1641, and after the restoration of the Stuarts. Killala was the scene of the landing of a French squadron in connexion with the rebellion of 1798.

There are four round towers in the county,—at Killala, Turlogh, Meelick, and Bal or Ballagh. The monasteries were numerous, and many of them of considerable importance—the principal being those at Mayo, Ballyhaunis, Cong, Ballinrobe, Ballintober, Burrishoole, Cross or Holycross in the peninsula of Mullet, Moyne, Rosserick, and Strade. Of the old castles the most notable are Downpatrick, on a cliff 300 feet in height projecting into the sea, Rockfleet near Newport, said to have been built by the celebrated Grace O'Malley, Ballylahan Castle near Foxford, and Deel Castle near Ballina, at one time the residence of the earls of Arran.

MAYOR. See MUNICIPALITY.

MAYOTTA. See COMORES, vol. vi. p. 220.

MAYSVILLE, a city of the United States, the capital of Mason county, Kentucky, lies on the south bank of the Ohio, 69 miles north-east of Lexington by rail. Settled in 1784 and incorporated in 1833, it has grown into a busy place of 5220 inhabitants (1880), with several good public buildings, flour-mills, plough-factories, &c., and is one of the principal hemp-markets in the States.

MAZAMET, an industrial town in the department of Tarn, France, stands on the northern slope of the Montagnes Noires (part of the Cevennes), and on the Arnette, a tributary of the Tarn by the Agout. In last century it was an insignificant village, but at present it has 14,000 inhabitants, an increase of prosperity due to the introduction by M. Houlès (whose statue stands in the public square) of the manufacture of a particular kind of woollen fabric sold almost exclusively in France. The factories, driven by water-power, have a total of 45,000 spindles, and an annual turnover of from 15 to 18 millions of francs. Mazamet is connected by a branch line of railway with the town of Castres.

MAZANDARÁN, a province of northern Persia, lying between the Caspian Sea and the Elbúrz range, and bounded E. and W. by the provinces of Astrábád and Gílán respectively, is 220 miles in length and 60 miles in (mean) breadth, with an area of about 10,000 square miles and a population estimated at from 150,000 to 200,000. Mazandarán comprises two distinct natural regions presenting the sharpest contrasts in their relief, climate, and products. In the north the Caspian is encircled by the level and swampy lowlands, varying in breadth from 10 to 30 miles, partly under impenetrable jungle, partly under rice, cotton, sugar, and other crops. This section is fringed northwards by the sandy beach of the Caspian, here almost destitute of natural harbours, and rises somewhat abruptly inland to the second section, comprising the northern slopes and spurs of the Elbúrz, which approach at some points within 1 or 2 miles of the sea, and which are almost everywhere covered with dense forest. The lowlands, rising but a few feet above the Caspian, and subject to frequent floodings, are extremely malarious, while the highlands, culminating with the magnificent Damávand (18,600 feet), enjoy a tolerably salubrious climate. But the climate, generally hot and moist in summer, is everywhere capricious and liable to sudden changes of temperature, whence the prevalence of rheumatism, dropsy, and especially ophthalmia, noticed by all travellers. Snow falls heavily on the uplands, where it often lies for weeks on the ground. The direction of the long sandbanks at the river mouths, which project with remarkable uniformity from west to east, shows that the prevailing winds blow from the west and north-west. The rivers themselves, of which there are as many as fifty, are little more than mountain torrents, all rising on the northern slopes of Elbúrz, flowing mostly in independent channels to the Caspian, and subject to sudden freshets and inundations along their lower course. The chief are the Safed-rúd on the Gílán frontier, the Lár, Hari-rúd, Alam-rúd, Rústam-rúd, and Hárez, and all are well stocked with trout, mullet (safed máhí), carp, sturgeon, and other fish, which with rice form the staple food of the inhabitants, and supply large quantities of caviare for the Russian market. Near their mouths the rivers, running counter to the prevailing winds and waves of the Caspian, form long sand-hills 20 to 30 feet high and about 200 yards broad, behind which are developed the so-called *múrd-áb*, or "dead waters," stagnant pools and swamps characteristic of this coast, and a chief cause of its unhealthiness.

The province abounds in iron ores and in mineral pitch in every state of transition from pure petroleum to the finest naphtha. The chief cultivated plants are rice, cotton, sugar, a little silk, and fruits in great variety, including several kinds of the orange, lemon, and citron. Some of the slopes are covered with extensive thickets of the pomegranate, and the wild vine climbs to a great height round the trunks of the forest trees. These woodlands are haunted by the tiger, panther, bear, wolf, and wild boar in considerable numbers. Of the domestic animals, all remarkable for their small size, the chief are the black, humped cattle somewhat resembling the Indian variety, the yabu (a sturdy breed of horses), and sheep and goats.

Kinneir, Frazer, and other observers speak unfavourably of the Mazandaráni people, whom they describe as very ignorant and bigoted, arrogant, rudely inquisitive, and almost insolent towards strangers. The peasantry, however, although called the "Bœotians of Persia," are far from dull, and betray much shrewdness where their interests are concerned. In the healthy districts they are stout and well made, and are the most warlike race in Persia, furnishing 5000 cavalry and 12,000 foot to the Government. Of the latter 2000 are always in attendance on the shah at Tehrán. They speak a marked and somewhat rude Persian dialect; but a Túrki idiom closely akin to the Turkoman is still current amongst the foreign tribes, although they have mostly already passed from the nomad to the settled state. Of these intruders the most numerous are the Modaunlú, Khojehvand, and Abdul Maleki, originally of Lek or Kurd stock, besides branches of the royal Afshár and Kájár tribes of Túrki descent. All these are exempt from taxes in consideration of their military service.

The export trade is chiefly with Russia through Bákú, where broadcloths, flour, saffron, and bar iron are taken in exchange for the white and coloured calicoes, caviare, rice, and raw cotton of Mazandarán. Owing to the almost impenetrable character of the country, there are scarcely any roads accessible to wheeled carriages, and the great causeway of Shah Abbas has in many places even disappeared under the jungle. Two routes, however, lead to Tehrán, one by Firoz Koh, 180 miles long, the other by Lariján, 144 miles long, both in tolerably good repair. Except where crossed by these routes the Elbúrz forms an almost impassable barrier to the south.

The administration is in the hands of the prince governor, who appoints most of the beglerbegs and governors of the nine districts of Amól, Bárfarósh, Mashhad-i-Sar, Sárí, Ashraf, Farah-ábád, Tennacorben, Kellauristak, and Kújúr into which the province is divided. There is fair security for life and property; and, although otherwise indifferently administered, the country is quite free from marauders or local disturbances. The revenue is about 105,000 tománs, of which nothing goes to the state treasury, all being required for the governors, troops, pensions, and police. The capital is Sárí, the other chief towns being Bárfarósh, Mashhad-i-Sar, Ashraf, and Farah-ábád.

MAZARIN, JULES (1602-1661), cardinal, the successor of Richelieu, and forerunner of Louis XIV., was the elder son of Pietro Mazarini, the intendant of the household of Philip Colonna, and of his wife Ortensia Buffalini, a connexion of the Colonnas, and was born at Piscina in the Abruzzi on July 14, 1602. He was educated by the Jesuits at Rome till his seventeenth year, when he accompanied Jerome Colonna as chamberlain to the university of Alcala in Spain. There he distinguished himself more by his love of gambling and his gallant adventures than by study, but made himself a thorough master, not only of the Spanish language and character, but also of that romantic fashion of Spanish love-making which was to help him greatly in after life, when he became the servant of a Spanish queen. On his return to Rome he took his degree as Doctor Utriusque Juris, and then became captain of infantry in the regiment of Colonna, which took part in the war in the Valtelline. During this war he gave proofs of much diplomatic ability, and Pope Urban VIII. entrusted him, in 1629, with the difficult task of putting an end to the war of the Mantuan succession. His success marked him out for further distinction. He was presented to two canonries in the churches of St John Lateran and Sta Maria Maggiore, although he had only taken the minor orders, and had never been consecrated priest; he negotiated the treaty of Turin between France and Savoy in 1632, became vice-legate at Avignon in 1634, and nuncio at the court of France from 1634-36. But he began to wish for a wider sphere than papal negotiations, and, seeing that he had no chance of becoming a cardinal except by the aid of some great power, he accepted Richelieu's offer of entering the service of the king of France, and in 1639 became a naturalized Frenchman. In 1640 Richelieu sent him to Savoy, where the regency of Christine, the duchess of Savoy, and sister of Louis XIII., was disputed by her brothers-in-law, the princes Maurice and Thomas of Savoy, and he succeeded not only in firmly establishing Christine but in winning over the princes to France. This great service was rewarded by his promotion to the rank of cardinal on the presentation of the king of France in December 1641. On the 4th December 1642 Cardinal Richelieu died, and on the very next day the king sent a circular letter to all officials ordering them to send in their reports to Cardinal Mazarin, as they had formerly done to Cardinal Richelieu. Mazarin was thus acknowledged supreme minister, but he still had a difficult part to play. The king evidently could not live long, and to preserve power he must make himself necessary to the queen, who would then be regent, and do this without arousing the suspicions of the king or the distrust of the queen. His measures were ably taken, and when the king died on May 14, 1643, to every one's surprise her husband's minister remained the queen's. The king had by a royal edict cumbered the queen-regent with a council and other restrictions, and it was necessary to get the parlement of Paris to overrule the edict, and make the queen absolute regent, which was done with the greatest complaisance. Now that the queen was all-powerful, it was expected she would at once dismiss Mazarin and summon her own friends to power. One of them, Potier, bishop of Beauvais, already gave himself airs as prime minister, but Mazarin had had the address to touch both the queen's heart by his Spanish gallantry and her desire for her son's glory by his skilful policy abroad, and he found himself able easily to overthrow the clique of Importants, as they were called. That skilful policy was shown in every arena on which the great Thirty Years' War was being fought out. Mazarin had inherited the policy of France during the Thirty Years' War from Richelieu. He had inherited his desire for the humiliation of the house of Austria in both its branches, his desire to push the French frontier to the Rhine and maintain a counterpoise of German states against Austria, his alliances with the Netherlands and with Sweden, and his four theatres of war—on the Rhine, in Flanders, in Italy, and in Catalonia. This is not the place to examine the campaigns of the last five years of the great war (see CONDÉ, TURENNE), but it was Mazarin alone who directed the French diplomacy of the period. He it was who made the peace of Brömsebro between the Danes and the Swedes, and turned the latter once again against the empire; he it was who sent Lionne to make the peace of Castro, and combine the princes of North Italy against the Spaniards, and who made the peace of Ulm between France and Bavaria, thus detaching the emperor's best ally. He made one fatal mistake,—he dreamt of the French frontier being the Rhine and the Scheldt, and that a Spanish princess might bring the Spanish Netherlands as dowry to Louis XIV. This roused the jealousy of the United Provinces, and they made a separate peace with Spain in January 1648; but the valour of the French generals made the skill of the Spanish diplomatists of no avail, for Turenne's victory at Zusmarshausen, and Condé's at Lens, caused the peace of Westphalia to be definitely signed in October 1648. This celebrated treaty belongs rather to the history of Germany than to a life of Mazarin; but two questions have been often asked, whether Mazarin did not delay the peace as long as possible in order to more completely ruin Germany, and whether Richelieu would have made a similar peace. To the first question Mazarin's letters, published by M. Cheruel, prove a complete negative, for in them appears the zeal of Mazarin for the peace. On the second point, Richelieu's letters in many places indicate that his treatment of the great question of frontier would have been more thorough, but then he would not have been hampered in France itself.

We must now notice that strange period of the Fronde which has always been variously treated, for modern historians have written its history from many different standpoints, all of which can be categorically supported from the varying mémoires of the principal actors. Now, however, thanks to the labours of M. Cousin on the *carnets* of Mazarin, which contain the substance of his inmost thoughts, and of M. Cheruel on the letters written to and by Mazarin, it is possible to construct a more accurate and trustworthy history of the Fronde than has ever yet been attempted. It is not, however, intended here to trace the whole history of the Fronde, interesting as that would be, but merely to trace the policy of Mazarin throughout the epoch. The origin of both the Frondes was partly Mazarin's fault. In 1645 the parlement of Paris had protested against certain taxes, and had been checked by a *lit de justice*; and when, in 1648, it united its members in the Chambre de Saint Louis for the general reform of the kingdom, Mazarin and the queen, instead of holding another *lit de justice*, calling the states-general, or transferring the parlement out of Paris, any of which measures would have broken its power, foolishly believed in the influence of the victory of Lens, and threw the people of Paris on the side of the parlement by the arrest of Broussel. The Fronde of the princes and the nobles, on the other hand, was largely due to Mazarin's absorption of political power. These Frondeurs were not, like their ancestors, moved by great religious and political sympathies, but by merely selfish aims for restoring the old licence of duel and intrigue, and were only united in one sentiment, hatred to Mazarin. That this was so was greatly Mazarin's own fault; he had tried consistently to play off Gaston of Orleans against Condé, and their respective followers against each other, and had also, as his *carnets* prove, jealously kept any courtier from getting into the good graces of the queen-regent except by his means, so that it was not unnatural that the nobility should hate him, while the queen found herself surrounded by his creatures alone. Events followed each other quickly; the day of the barricades was followed by the peace of Ruel, the peace of Ruel by the arrest of the princes, by the battle of Rethel, and Mazarin's exile to Brühl before the union of the two

Frondes. It was while in exile at Brühl that Mazarin saw the mistake he had made in isolating himself and the queen, and that his policy of balancing every party in the state against each other had made every party distrust him. So by his counsel the queen, while nominally in league with De Retz and the parliamentary Fronde, laboured to form a purely royal party, wearied by civil dissensions, who should act for her and her son's interest alone, under the leadership of Mathieu Molé, the famous premier president of the parlement of Paris. The new party grew in strength, and in January 1652, after exactly a year's absence, Mazarin returned to the court. Turenne had now become the royal general, and out-manœuvred Condé, while the royal party at last grew to such strength in Paris that Condé had to leave the capital and France. In order to promote a reconciliation with the parlement of Paris, Mazarin had again retired from court, this time to Sedan, in August 1652, but he returned finally in February 1653. Long had been the trial, and greatly had Mazarin been to blame in allowing the Frondes to come into existence, but he had retrieved his position by founding that great royal party which steadily grew until Louis XIV. could fairly have said "L'État, c'est moi." As the war had progressed, Mazarin had steadily followed Richelieu's policy of weakening the nobles on their country estates. Whenever he had an opportunity he destroyed a feudal castle, and by destroying the towers which commanded nearly every town in France, he freed such towns as Bourges, for instance, from their long practical subjection to the neighbouring great lord.

The Fronde over, Mazarin had to build up afresh the power of France at home and abroad. It is to his shame that he did so little at home. Beyond destroying the brick and mortar remains of feudalism, he did nothing for the people. But abroad his policy was everywhere successful, and opened the way for the policy of Louis XIV. He at first, by means of an alliance with Cromwell, recovered the north-western cities of France, though at the price of yielding Dunkirk to the Protector. On the Baltic, France guaranteed the treaty of Oliva between her old allies Sweden, Poland, and Brandenburg, which preserved her influence in that quarter. In Germany he, through Lionne, formed the league of the Rhine, by which the states along the Rhine bound themselves under the headship of France to be on their guard against the house of Austria. By such measures Spain was induced to sue for peace, which was finally signed in the Isle of Pheasants on the Bidassoa, and which is known as the treaty of the Pyrenees. By it Spain recovered Franche Comté, but ceded to France Roussillon, and much of French Flanders; and, what was of greater ultimate importance to Europe, Louis XIV. was to marry a Spanish princess, who was to renounce her claims to the Spanish succession if her dowry was paid, which Mazarin knew could not happen at present from the emptiness of the Spanish exchequer. He returned to Paris in declining health, and did not long survive the unhealthy sojourn on the Bidassoa; after some political instruction to his young master, he passed away at Vincennes on March 9, 1661, leaving a fortune estimated at from 18 to 40 million livres behind him, and his nieces married into the greatest families of France and Italy.

The man who could have had such success, who could have made the treaties of Westphalia and the Pyrenees, who could have weathered the storm of the Fronde, and left France at peace with itself and with Europe to Louis XIV., must have been a great man; and historians, relying too much on the brilliant memoirs of his adversaries, like De Retz, are apt to rank him too low. That he had many a petty fault there can be no doubt; that he was avaricious and double-dealing was also undoubted; and his *carnets* show to what unworthy means he had recourse to maintain his influence over the queen. What that influence was will be always debated, but both his *carnets* and the Brühl letters show that a real personal affection, amounting to passion on the queen's part, existed. Whether they were ever married may be doubted; but that hypothesis is made more possible by M. Cheruel's having been able to prove from Mazarin's letters that the cardinal himself had never taken more than the minor orders, which could always be thrown off. With regard to France he played a more patriotic part than Condé or Turenne, for he never treated with the Spaniards, and his letters show that in the midst of his difficulties he followed with intense eagerness every movement on the frontiers. It is that immense mass of letters, now in course of publication, that prove the real greatness of the statesman, and disprove De Retz's portrait, which is carefully arranged to show off his enemy against the might of Richelieu. To concede that the master was the greater man and the greater statesman does not imply that Mazarin was but a foil to his predecessor. It is true that we find none of those deep plans for the internal prosperity of France which shine through Richelieu's policy. Mazarin was not a Frenchman, but a citizen of the world, and always paid most attention to foreign affairs; in his letters all that could teach a diplomatist is to be found, broad general views of policy, minute details carefully elaborated, keen insight into men's characters, cunning directions when to dissimulate or when to be frank. From first to last the diplomatist peeps forth, and gives the key to his character, and to the causes of his success. Italian though he was by birth, education, and nature, France owed him a great debt for his skilful management during the early years of Louis XIV., and the king owed him yet more, for he had not only transmitted to him a nation at peace, but had educated for him his great servants Le Tellier, Lionne, and Colbert. Literary men owed him also much; not only did he throw his famous library open to them, but he pensioned all their leaders, including Descartes, Voiture, Balzac, and Pierre Corneille. The last-named, the greatest of them all, did not care for Mazarin as a paymaster only, but as a statesman; he was a profound royalist, believing that absolutism alone could save France from the horrors of religious wars, or the selfish turbulence of a Fronde, and to Mazarin he applied, with an adroit allusion to his birthplace, in the dedication of his *Pompée*, the line of Virgil—

"Tu regere imperio populos, Romane, memento."

All the earlier works on Mazarin, and early accounts of his administration, of which the best were Bazin's *Histoire de France sous Louis XIII. et sous le Cardinal Mazarin*, 4 vols., 1846, and Saint-Aulaire's *Histoire de la Fronde*, have been superseded by M. Cheruel's admirable *Histoire de France pendant la minorité de Louis XIV.*, 4 vols., 1879–80, which covers from 1643–51, and its sequel *Histoire de France sous le Ministère de Cardinal Mazarin*, 2 vols., 1881–82, which is the first account of the period written by one able to sift the statements of De Retz and the memoir writers, and rest upon such documents as Mazarin's letters and *carnets*. To M. Cheruel the Government of France has entrusted the task of editing Mazarin's *Letters*, of which two volumes have at present appeared, which must be carefully studied by any student of the history of France. For his "*carnets*" reference must be made to M. Cousin's articles in the *Journal des Savants*; for his early life to Cousin's *Jeunesse de Mazarin*, 1865, and for the careers of his nieces to Renée's *Les Nieces de Mazarin*, 1856. For the Mazarinades or squibs written against him in Paris during the Fronde, see Moreau's *Bibliographie des Mazarinades*, 1850, containing an account of 4082 Mazarinades. On the Fronde, also, consult Gaillardin's *Histoire de Louis XIV.*, 6 vols., 1876–78, and Feillet's interesting *Misère au temps de la Fronde*. For his foreign policy, besides his *Letters*, see Valfrey's *Hugues de Lionne*, and Mignet's *Histoire des Négociations relatives à la Succession d'Espagne*. (H. M. S.)

MAZATLAN, a city and seaport of Mexico, in the state of Cinaloa, on the coast of the Pacific, near the mouth of the Gulf of California, in 23° 18′ N. lat. and 106° 56′ W. long. It occupies an attractive situation, but, as the houses are for the most part low, has not an imposing appearance. The port is often visited by English and American vessels, and is consequently the seat of several consular agents. A large smuggling trade was formerly carried on in much the same lines as the present legitimate traffic—export of bullion, dye-stuffs, and pearls, and import of manufactured goods from Europe and fruits and vegetables from San Francisco. In 1878 the value of the imports was about £600,000, that of the exports about £500,000. The population, which contains a large floating element, was stated at 12,706 in 1871.

MAZEPPA, Ivan Stephanovitch (1644–1709), a Cossack chief, best known as the hero of one of Lord Byron's poems, was born in 1644, of a poor but noble family, at Mazepintzui in the palatinate of Podolia. At an early age he became a page at the court of John Casimir, king of Poland. After some time he returned to his native province; but, engaging in an intrigue with a Polish matron of high rank, he was detected by the injured husband, and was sentenced to be bound naked on the back of an untamed horse. The animal on being let loose galloped off to its native wilds of the Ukraine. Mazeppa, half-dead and insensible, was released from his fearful position, and restored to animation by some poor peasants. In a short time his agility, courage, and sagacity rendered him popular among the Cossacks. He was appointed secretary and adjutant to Samoilovitch, their hetman or chief, and succeeded that functionary in 1687. The title of prince was afterwards conferred upon him by his friend and patron, Peter the Great, who long believed confidingly in his good faith, and banished or executed as calumnious traitors all who, like Palei, Kotchubey, and Iskra, ventured to accuse him of conspiring with the enemies of Russia. Bent, however, upon casting off the Russian yoke, Mazeppa became, in his seventieth year, and after much hesitation and inconstancy of purpose, an ally of the Swedish monarch, Charles XII. After the disastrous battle of Pultowa, fought, it is said, by his advice, Baturin, his capital, was taken and sacked by Menshikoff, and his name anathematized throughout the churches of Russia, and his effigy suspended from the gallows. A wretched fugitive, he escaped to Bender, but only to end his life by poison in 1709. Pushkin made Mazeppa the hero of his drama "Pultowa."

MAZZARA DEL VALLO, a city of Italy, on the coast of Sicily, in the province Trapani, 13 miles by rail south-east of Marsala. It is surrounded by a wall 37 feet in height, strengthened by towers rising at intervals; and it possesses a castle and a cathedral, both founded by Count Roger in the 11th century. The harbour is spacious but badly sheltered from the south winds. The population of the city was 11,756 in 1871; that of the commune was 10,999 in 1861 and 13,505 in 1881.

Mazara or Mazaris appears from Diodorus Siculus (xiii. 54) to have been a trading establishment of Selinus, and it was captured by the Carthaginian general in 409 B.C. on his march against that city. It was in this neighbourhood that the Saracens landed in 827 A.D.; and the name of Val di Mazzara long indicated one of the three divisions of Sicily.

MAZZINI, GIUSEPPE (1805–1872), Italian patriot, was born on June 22, 1805, at Genoa, where his father, Giacomo Mazzini, was a physician in good practice, and a professor in the university. His mother is described as having been a woman of great personal beauty, as well as of active intellect and strong affections. During infancy and childhood his health was extremely delicate, and it appears that he was nearly six years of age before he was quite able to walk; long before this, however, he had learned to read, and otherwise begun to show great intellectual precocity. His first tutor was an old priest who taught him Latin, but his omnivorous reading was not directed by any master. At the age of thirteen he began to attend classes in the faculty of arts at the university; he afterwards studied anatomy with a view to following his father's profession, but finally (1826) graduated in laws. Apart from his professional studies, he took lessons in music, English, and fencing. Of his student days little more is recorded than that his exceptional abilities as well as the remarkable generosity and benevolence of his impulses and aims were quickly recognized by his comrades,—his professors, however, having frequent occasion to complain of his disregard for conventional rules. As to his inner life during this period, we have only one brief but significant sentence; "for a short time," he says, "my mind was somewhat tainted by the doctrines of the foreign materialistic school; but the study of history and the intuitions of conscience—the only tests of truth—soon led me back to the spiritualism of our Italian fathers." For some time after his admission as an advocate Mazzini was occupied in the Ufficio dei Poveri; but, although he seems to have discharged the duties arising from this with zeal and success, he never really overcame his repugnance to the dry and technical details of legal practice. The natural bent of his genius was towards literature, and, in the course of the four years of his nominal connexion with the legal profession, he wrote a considerable number of essays and reviews, some of which have been wholly or partially reproduced in the critical and literary volumes of his *Life and Writings*. His first essay, characteristically enough on "Dante's Love of Country," was sent to the editor of the *Antologia Fiorentina* in 1826, but did not appear until some years afterwards in the *Subalpino*. He was an ardent supporter of romanticism as against what he called "literary servitude under the name of classicism"; and in this interest all his critiques (as, for example, that of Giannoni's *Exile* in the *Indicatore Livornese*, 1829) were penned. But in the meantime the "republican instincts" which he tells us he had inherited from his mother had been developing, and his sense of the evils under which Italy was groaning had been intensified; and at the same time he became possessed with the idea that Italians, and he himself in particular, "*could* and therefore *ought* to struggle for liberty of country." His literary articles accordingly became more and more suggestive of advanced liberalism in politics, and led to the suppression by Government of the *Indicatore Genovese* and the *Indicatore Livornese* successively. Having joined the Carbonari, he soon rose to one of the higher grades in their hierarchy, and was entrusted with a special secret mission into Tuscany; but, as his acquaintance grew, his dissatisfaction with the organization of the society increased, and he was already meditating the formation of a new association having closer bonds of union and more definite aims when shortly after the French revolution of 1830 he was betrayed, while initiating a new member, to the authorities of Piedmont. He was imprisoned in the fortress of Savona on the western Riviera for about six months, when, a conviction having been found impracticable through deficiency of evidence, he was released, but upon conditions involving so many restrictions of his liberty that he preferred the alternative of leaving the country. He withdrew accordingly into France, living chiefly in Marseilles. While in his lonely cell at Savona, in presence of "those symbols of the infinite, the sky and the sea," with a greenfinch for his sole companion, and having access to no books but "a Tacitus, a Byron, and a Bible," he had finally become aware of the great mission or "apostolate" (as he himself called it) of his life; and soon after his release his prison meditations took shape in the programme of the organization which was destined soon to become so famous throughout Europe, that of *La Giovine Italia*, or Young Italy. Its publicly avowed aims were to be the liberation of Italy both from foreign and domestic tyranny, and its unification under a republican form of government; the means to be used were education, and, where advisable, insurrection by guerrilla bands; the motto was to be "God and the people," and the banner was to bear on one side the words "Unity" and "Independence" and on the other "Liberty," "Equality," and "Humanity," to describe respectively the national and the international aims. In April 1831 Charles Albert, "the ex-Carbonaro conspirator of 1821," succeeded Charles Felix on the Sardinian throne, and towards the close of that year Mazzini, making himself, as he afterwards confessed, "the interpreter of a hope which he did not share," wrote the new king a letter, published at Marseilles, urging him to take the lead in the impending struggle for Italian independence. Clandestinely reprinted, and rapidly circulated all over Italy, its bold and outspoken words produced a great sensation, but so deep was the offence it gave to the Sardinian Government that orders were issued for the immediate arrest and imprisonment of the author should he attempt to cross the frontier. Towards the end of the same year appeared the important Young Italy "Manifesto," the substance of which is given in the first volume of the *Life and Writings* of Mazzini; and this was followed soon afterwards by the society's *Journal*, which, smuggled across the Italian frontier, had great success in the objects for which it was written, numerous "congregations" being formed at Genoa, Leghorn, and elsewhere. Representations were consequently made by the Sardinian to the French Government, which issued in an order for Mazzini's withdrawal from Marseilles (August 1832); he lingered for a few months in concealment, but ultimately found it necessary to retire into Switzerland. From this point it is somewhat difficult to follow the career of the mysterious and terrible conspirator who for twenty years out of the next thirty led a life of voluntary imprisonment (as he himself tells us) "within the four walls of a room," and "kept no record of dates, made no biographical notes, and preserved no copies of letters." In 1833, however, he is known to have been concerned in an abortive revolutionary movement which took place in the Sardinian army; several executions took place, and he himself was laid under sentence of death. Before the close of the same year a similar movement in Genoa had been planned, but failed through the youth and inexperience of the leaders. At Geneva, also in 1833, Mazzini set on foot *L'Europe Centrale*, a journal of which one of the main objects was the emancipation of Savoy; but he did not confine himself to a merely literary agitation for this end. Chiefly through his agency a considerable body of German, Polish, and Italian exiles was organized, and an armed invasion of the duchy planned. The frontier was actually crossed on February 1, 1834, but the attack ignominiously broke down without a shot having been fired. Mazzini, who personally accompanied the expedition, is no doubt correct in attributing the failure to dissensions with the Carbonari leaders in Paris, and to want of a cordial understanding between himself and the Savoyard Ramorino, who had been chosen as military leader. In April 1834 the "Young Europe" association "of men believing in a future of liberty, equality, and fraternity for all mankind, and desirous of consecrating their thoughts and actions to the realization of that future" was formed, also under the influence of Mazzini's enthusiasm; it was followed soon afterwards by a "Young Switzerland" society, having for its leading idea the formation of an Alpine confederation, to include Switzerland, Tyrol, Savoy, and the rest of the Alpine chain as well. But *La Jeune Suisse* newspaper was compelled to stop within a year, and in other respects the affairs of the struggling patriot became embarrassed. He was permitted to remain at Grenchen in Solothurn for a while, but at last the Swiss diet, yielding to strong and persistent pressure from abroad, exiled him about the end of 1836. In January 1837 he arrived in London, where for many months he had to carry on a hard fight with poverty and the sense of spiritual loneliness so touchingly described by himself in the first volume of the *Life and Writings*. Ultimately, as he gained command of the English language, he began to earn a livelihood by writing review articles, some of which have since been reprinted, and are of a high order of literary merit; they include papers on "Italian Literature since 1830" and "Paolo Sarpi" in the *Westminster Review*, articles on "Lamennais," "George Sand," "Byron and Goethe" in the *Monthly Chronicle*, and on "Lamartine," "Carlyle," and "The Minor Works of Dante" in the *British and Foreign Review*. In 1839 he entered into relations with the revolutionary committees sitting in Malta and Paris, and in 1840 he originated a working men's association, and the weekly journal entitled *Apostolato Popolare*, in which the admirable popular treatise "On the Duties of Man" was commenced. Among the patriotic and philanthropic labours undertaken by Mazzini during this period of retirement in London may be mentioned a free evening school conducted by himself and a few others for some years, at which several hundreds of Italian children received at least the rudiments of secular and religious education. The most memorable episode in his life during the same period was perhaps that which arose out of the conduct of Sir James Graham, the home secretary, in systematically, for some months, opening Mazzini's letters as they passed through the British post-office, and communicating their contents to the Neapolitan Government—a proceeding which brought about the arrest and execution of the brothers Bandiera, Austrian subjects, who had been planning an expedition against Naples. The prolonged discussions in parliament, and the report of the committee appointed to inquire into the matter, did not, however, lead to any practical result, unless indeed the incidental vindication of Mazzini's character, which had been recklessly assailed in the course of debate. Mazzini did not share the enthusiastic hopes everywhere raised in the ranks of the Liberal party throughout Europe by the first acts of Pius IX., in 1846, but at the same time he availed himself, towards the end of 1847, of the opportunity to publish a letter addressed to the new pope, indicating the nature of the religious and national mission which the Liberals expected him to undertake. The leaders of the revolutionary outbreaks in Milan and Messina in the beginning of 1848 had long been in secret correspondence with Mazzini; and their action, along with the revolution in Paris, brought him early in the same year to Italy, where he took a great and active interest in the events which dragged Charles Albert into an unprofitable war with Austria; he actually for a short time bore arms under Garibaldi immediately before the re-occupation of Milan, but ultimately, after vain attempts to maintain the insurrection in the mountain districts, found it necessary to retire to Lugano. In the beginning of the following year he was nominated a member of the short-lived provisional government of Tuscany formed after the flight of the grand-duke, and almost simultaneously, when Rome had, in consequence of the withdrawal of Pius IX., been proclaimed a republic, he was declared a member of the constituent assembly there. A month afterwards, the battle of Novara having again decided against Charles Albert in the brief struggle with Austria, into which he had once more been drawn, Mazzini was appointed a member of the triumvirate, with supreme executive power. The opportunity he now had for showing the administrative and political ability which he was believed to possess was more apparent than real, for the approach of the professedly friendly French troops soon led to hostilities, and resulted in a siege which terminated, towards the end of June, with the assembly's resolution to discontinue the defence, and Mazzini's indignant resignation. That he succeeded, however, for so long a time, and in circumstances so adverse, in maintaining a high degree of order within the turbulent city is a fact that speaks for itself. His diplomacy, backed as it was by no adequate physical force, naturally showed at the time to very great disadvantage, but his official correspondence and proclamations can still be read with admiration and intellectual pleasure, as well as his eloquent vindication of the revolution in his published "Letter to MM. de Tocqueville and De Falloux."

The surrender of the city on June 30 was followed by Mazzini's not too precipitate flight by way of Marseilles into Switzerland, whence he once more found his way to London. Here in 1850 he became president of the National Italian Committee, and at the same time entered into close relations with Ledru-Rollin and Kossuth. He had a hand in the abortive rising at Mantua in 1852, and again, in February 1853, a considerable share in the formidable insurrection which broke out at Milan; once more, in 1854, he had gone far with preparations for renewed action when his plans were completely disconcerted by the withdrawal of professed supporters, and by the action of the French and English Governments in sending ships of war to Naples. The year 1857 found him yet once more in Italy, where, for complicity in short-lived emeutes which took place at Genoa, Leghorn, and Naples, he was again laid under sentence of death. Undiscouraged in the pursuit of the one great aim of his life by any such incidents as these, he returned to London, where he edited his new journal *Pensiere ed Azione*, in which the constant burden of his message to the overcautious practical politicians of Italy was—"I am but a voice crying *Action*; but the state of Italy cries for it also. So do the best men and people of her cities. Do you wish to destroy my influence? *Act.*" The same tone was at a somewhat later date assumed in the letter he wrote to Victor Emmanuel, urging him to put himself at the head of the movement for Italian unity, and promising republican support. As regards the events of 1859–60, however, it may be questioned whether, through his characteristic inability to distinguish between the ideally perfect and the practically possible, he did not actually hinder more than he helped the course of events by which the realization of so much of the great dream of his life was at last brought about. As has been said elsewhere (vol. xiii. p. 487), if Mazzini was the prophet of Italian unity, and Garibaldi its knight errant, to Cavour alone belongs the honour of having been the statesman by whom it was finally accomplished. After the irresistible pressure of the popular movement had led to the establishment not of an Italian republic but of an Italian kingdom, Mazzini could honestly enough write, "I too have striven to realize unity under a monarchical flag," but candour compelled him to add, "The Italian people are led astray by a delusion at the present day, a delusion which has induced them to substitute material for moral unity and their own reorganization. Not so I. I bow my head sorrowfully to the sovereignty of the national will; but monarchy will never number me amongst its servants or followers." In 1865, by way of protest against the still uncancelled sentence of death under which he lay, Mazzini was elected by Messina as delegate to the Italian parliament, but, feeling himself unable to take the oath of allegiance to the monarchy, he never took his seat. In the following year, when a general amnesty was granted after the cession of Venice to Italy, the sentence of death was at last removed, but he declined to accept such an "offer of oblivion and pardon for having loved Italy above all earthly things." In May 1869 he was again expelled from Switzerland at the instance of the Italian Government for having conspired with Garibaldi; after a few months spent in England he set out (1870) for Sicily, but was promptly arrested at sea and carried to Gaeta, where he was imprisoned for two months. Events soon made it evident that there was little danger to fear from the contemplated rising, and the occasion of the birth of a prince was seized for restoring him to liberty. The remainder of his life, spent partly in London and partly at Lugano, presents no noteworthy incidents. For some time his health had been far from satisfactory, but the immediate cause of his death was an attack of pleurisy with which he was seized at Pisa, and which terminated fatally on March 10, 1872. The Italian parliament by a unanimous vote expressed the national sorrow with which the tidings of his death had been received, the president pronouncing an eloquent eulogy on the departed patriot as a model of disinterestedness and self-denial, and one who had dedicated his whole life ungrudgingly to the cause of his country's freedom. A public funeral took place at Pisa on March 14, and the remains were afterwards conveyed to Genoa.

The published writings of Mazzini, mostly occasional, are very voluminous, and have nowhere been exhaustively collected. The fullest edition of them is that begun by himself and continued by Satti (*Scritti editi e inediti di Giuseppe Mazzini*, 10 vols., 1861–80); many of the most important are found in the partially autobiographical work already referred to (*Life and Writings of Joseph Mazzini*, 6 vols., 1864–70), and the two most systematic—"Thoughts upon Democracy in Europe," a remarkable series of criticisms on Benthamism, St-Simonianism, Fourierism, and other economic and socialistic schools of the day, and the treatise "On the Duties of Man," an admirable primer of ethics, dedicated to the Italian working class—will be found in a volume entitled *Joseph Mazzini, a Memoir*, by Mrs E. A. Venturi (London, 1875). Mazzini's "first great sacrifice," he tells us, was "the renunciation of the career of literature for the more direct path of political action," and as late as 1861 we find him still recurring to the long-cherished hope of being able to leave the stormy arena of politics and consecrate the last years of his life to the dream of his youth. He had specially contemplated three considerable literary undertakings,—a volume of *Thoughts on Religion*, a popular *History of Italy*, to enable the working classes to apprehend what he conceived to be the "mission" of Italy in God's providential ordering of the world, and a comprehensive collection of translations of ancient and modern classics into Italian. None of these was actually achieved. No one, however, can read even the briefest and most occasional writing of Mazzini without gaining some impression of the simple grandeur of the man, the lofty elevation of his moral tone, his unwavering faith in the living God, who is ever revealing Himself in the progressive development of humanity. His last public utterance is to be found in a highly characteristic article on Renan's *Réforme Morale et Intellectuelle*, finished on March 3, 1872, and published in the *Fortnightly Review* for February 1874. (J. S. BL.)

MAZZOLA. See PARMIGIANO.

MEAD, RICHARD (1673–1754), physician, was born on August 11, 1673, at Stepney (near London), where his father, at one time minister of the parish, had been ejected for nonconformity in 1662. He was sent to Utrecht, where he studied for three years under Grævius; having decided to follow the medical profession, he then went to Leyden and attended the lectures of Hermann and Pitcairn. In 1695 he graduated in philosophy and physic at Padua, and in the following year he returned to his native place, entering at once on a successful practice. His *Mechanical Account of Poisons* appeared in 1702, and in 1703 he was admitted to the Royal Society, to whose *Transactions* he contributed in that year a paper on the parasitic nature of scabies. In the same year he was also elected physician to St Thomas's Hospital, and appointed to read anatomical lectures at the Surgeons' Hall. On the death of Radcliffe in 1714 Mead became the recognized head of his profession; he attended Queen Anne on her death-bed, and in 1727 was appointed physician to George II., having previously served him in that capacity when he was prince of Wales. He died on February 16, 1754. For his place in the annals of medical science see MEDICINE, p. 811 of the present volume.

Besides the *Mechanical Account of Poisons*, of which a second edition appeared in 1708, Mead published a treatise *De Imperio Solis et Lunæ in Corpora Humana et Morbis inde Oriundis* (1704), *A Short Discourse concerning Pestilential Contagion, and the Method to be used to prevent it* (1720), *De Variolis et Morbillis Dissertatio* (1747), *Medica Sacra, sive de Morbis insignioribus qui in Bibliis memorantur Commentarius* (1748), *On the Scurvy* (1749), and *Monita et Præcepta Medica* (1751). A *Life* of Mead by Dr Maty appeared in 1755.

MEADVILLE, a city of the United States, county seat of Crawford county, Pennsylvania, on the left bank of French Creek, a tributary of the Alleghany river, and at the junction of the Franklin branch with the main line of the New York, Pennsylvania, and Ohio Railroad, 102 miles from Salamanca. It is a well-built town, maintains a large trade with the oil regions, and has railway and other machine works, glass works, woollen mills, and paper mills. The Meadville theological school was established by the Unitarians in 1844; and Allegheny College, opened in 1816 as a Presbyterian Church institution, has been carried on since 1833 by the Methodist Episcopal Church. Meadville was founded by General David Mead as a fortified post in 1789. In 1816 it had only 400 inhabitants; but the number was 3702 in 1860, 7103 in 1870, and 8860 in 1880.

MEASLES (*Morbilli*, *Rubeola*; German, *Masern*; French, *Rougeole*), an acute infectious disease occurring mostly in children. It appears to have been known from an early period in the history of medicine, mention being made of it in the writings of Rhazes and others of the Arabian physicians in the 10th century. For long, however, its specific nature was not recognized, and it was held to be a variety of small-pox. After the non-identity of these two diseases had been established, measles and scarlet fever continued to be confounded with each other; and in the account given by Sydenham of epidemics of measles in London in 1670 and 1674 it is evident that even that accurate observer had not as yet clearly perceived their pathological distinction, although it would seem to have been made a century earlier by Ingrassias, a physician of Palermo. It is only within a comparatively recent period that measles has come to be universally regarded as a distinct and independent malady.

Like the other eruptive fevers (exanthemata), to which class of diseases measles belongs, its progress is marked by several stages more or less sharply defined.

After the reception of the contagion into the system a period of incubation or latency precedes the development of the disease, during which scarcely any disturbance of the health is perceptible. This period appears to vary in duration, but it may be stated as generally lasting for from ten to fourteen days, when it is followed by the invasion of the symptoms specially characteristic of measles. These consist in the somewhat sudden onset of acute catarrh of the mucous membranes. Sneezing, accompanied with a watery discharge, sometimes bleeding, from the nose, redness and watering of the eyes, cough of a short, frequent, and noisy character, with little or no expectoration, hoarseness of the voice, and occasionally sickness and diarrhœa, are the chief local phenomena of this stage. But along with these there is well-marked febrile disturbance, the temperature being elevated (102°–104° F.), and the pulse rapid, while headache, thirst, and restlessness are usually present to a greater or less degree. In some instances, however, these initial symptoms are so slight that they almost escape notice, and the child is allowed to associate with others at a time when, as will be afterwards seen, the contagion of the disease is most active. In rare cases, especially in young children, convulsions usher in, or occur in the course of, this stage of invasion, which lasts as a rule for four or five days, the febrile symptoms, however, showing some tendency to undergo abatement after the second day. On the fourth or fifth day after the invasion, sometimes later, rarely earlier, the characteristic eruption appears on the skin, being first noticed on the brow, cheeks, chin, also behind the ears, and on the neck. It consists of small spots of a dusky red or crimson colour, slightly elevated above the surface, at first isolated, but tending to become grouped together into patches of irregular, occasionally crescentic, outline, with portions of skin free from the eruption intervening. The face acquires a swollen and bloated appearance, which, taken along with the catarrh of the nostrils and eyes, is almost characteristic, and renders the diagnosis at this stage a matter of no difficulty. The eruption spreads downwards over the body and limbs, which are soon thickly studded with the red spots or patches. Sometimes these become confluent over a considerable surface, giving rise to a larger area of uniform redness. The rash continues to come out for two or three days, and then begins to fade in the order in which it first showed itself, namely, from above downwards. By the end of about a week after its first appearance scarcely any trace of the eruption remains beyond a faint staining of the skin. Occasionally during convalescence slight peeling of the epidermis takes place, but much less frequently and distinctly than is the case in scarlet fever. At the commencement of the eruptive stage the fever, catarrh, and other constitutional disturbance, which were present from the beginning, become aggravated, the temperature often rising to 105° or more, and there is headache, thirst, furred tongue, and soreness of the throat, upon which red patches similar to those on the surface of the body may be observed. These symptoms usually decline as soon as the rash has attained its maximum, and often there occurs a sudden and extensive fall of temperature, indicating that the crisis of the disease has been reached. In favourable cases convalescence proceeds rapidly, the patient feeling perfectly well even before the rash has faded from the skin.

Measles may, however, occur in a very severe or malignant form, in which the symptoms throughout are of urgent character, the rash but feebly developed, and of dark purple hue, while there is great prostration of strength, accompanied with intense catarrh of the respiratory or gastro-intestinal mucous membrane. Such cases, always of serious import, are happily rare, occurring mostly in circumstances of bad hygiene, both as regards the individual and his surroundings. On the other hand, cases of measles are often met with of so mild a form throughout that the patient can scarcely be persuaded to submit to treatment.

Measles as a disease derives its chief importance in the view of medical men from the risk, by no means slight, of certain complications which are apt to arise during its course, more especially inflammatory affections of the respiratory organs. These are most liable to occur in the colder seasons of the year and in very young and delicate children. It has been already stated that irritation of the respiratory passages is one of the symptoms characteristic of measles, but that this subsides with the decline of the eruption. Not unfrequently, however, these symptoms, instead of abating, become aggravated, and bronchitis of the capillary form (see BRONCHITIS), or pneumonia, generally of the diffuse or lobular variety (see PNEUMONIA), impart a gravity to the case which it did not originally possess. By far the greater proportion of the mortality in measles is due to its complications, of which those just mentioned are the most common, but which also include inflammatory affections of the larynx, with attacks resembling croup, and also diarrhœa assuming a dysenteric character. Or there may remain as direct results of the disease chronic ophthalmia, or discharge from the ears, with deafness, and occasionally a form of gangrene affecting the tissues of the mouth or cheeks and other parts of the body, leading to disfigurement and even endangering life.

Apart, however, from those immediate risks, it deserves to be borne in mind that in measles there appears to be a tendency in many cases for the disease to leave behind a weakened and vulnerable condition of the general health, which may render children, previously robust, delicate and liable to chest complaints, and is in not a few instances the precursor of some of those tubercular affections to which the period of childhood and youth is liable.

These various effects or sequelæ of measles plainly indicate that although in itself a comparatively mild ailment, it cannot safely be regarded with indifference. Indeed it is doubtful whether any other disease of early life demands more careful watching as to its influence on the health. Happily many of those attending evils now alluded to may by proper management be averted.

Measles is a disease of the earlier years of childhood. Like other infectious maladies, it is admittedly rare, though not unknown, in nurslings or infants under six months old. It is comparatively seldom met with in adults, but this is simply due to the fact that most persons have undergone an attack in early life, since, where this has not been the case, the old suffer equally with the young. All races of men appear liable to this disease, provided that which constitutes the essential factor in its origin and spread exists, namely, contagion. Some countries enjoy long immunity from outbreaks of measles, but it has frequently been found in such cases that when the contagion has once been introduced the disease extends with great rapidity and virulence. This was shown in two well-known instances in recent times,—namely, the epidemic in the Faroe Islands in 1846, where, within six months after the arrival of a single case of measles, more than three-fourths of the entire population were attacked and many perished; and the similarly produced and still more destructive outbreak in Fiji in 1875, in which it was estimated that about one-fourth of the inhabitants were cut off by the disease within a period of about three months (see FIJI). In both these cases the great mortality has been ascribed to the complications of the malady, specially induced by over-crowding, by insanitary surroundings, the absence of proper nourishment and nursing for the sick, and the utter prostration and terror of the people, rather than to any marked malignancy in the type of the disease.[1] Not a few authorities, however, while fully recognizing the baneful effect of these unfavourable conditions, are yet disposed to hold that epidemics of this kind, when occurring in what might be termed a virgin soil, are apt to possess an innate severity. In many lands, such as the United Kingdom, measles is rarely absent, especially from large centres of population, where sporadic cases are found in greater or less number at all seasons. Every now and then epidemics arise from the extension of the disease among those members of a community who have not been in some measure protected by a previous attack. There are few diseases so contagious as measles, and its rapid spread in epidemic outbreaks is no doubt due to the well-ascertained fact that contagion is most potent in the earlier stages, even before its real nature has been evinced by the characteristic appearances on the skin. Hence the difficulty of timely isolation, and the readiness with which the disease is spread in schools and families. There is little doubt too that the contagion may be carried from one place to another by persons themselves unaffected, as well as by clothing, &c., although its tenacity and activity in this respect is apparently much less marked than that of small-pox or scarlet fever. Of the nature of the infecting agent nothing certain is known. Recent investigations into the mode of origin of others of the acute infectious diseases, and the discovery in the blood and tissues in the case of some of them of lower forms of organic life (bacilli), which can be isolated and can by inoculation be made to communicate the particular malady to which they are related, give countenance to the opinion, now widely entertained, that the infecting principle of the exanthemata is of this nature. The subject, however, is still under investigation, and more information is wanting before definite statements can be made. Second attacks of measles are occasionally observed, but they are rare.

[1] *Transactions of the Epidemiological Society.* London, 1877.

Treatment.—The treatment of measles embraces the preventive measures to be adopted in the case of an outbreak by the isolation of the sick at as early a period as possible. Epidemics have often, especially in limited localities, been curtailed by such a precaution. In families with little house accommodation this measure is frequently, for the reason already referred to regarding the communicable period of the disease, ineffectual; nevertheless where practicable it ought to be tried, for it is a grave error needlessly to expose the healthy children in a family to the risk of infection under the idea that they must necessarily take the disease at some time or other. The unaffected children should likewise be kept from school for a time (probably about three weeks from the outbreak in the family would suffice if no other case occur in the interval), and all clothing in contact with the patient should be subjected to disinfection or thorough washing. In extensive epidemics it is often desirable to close the schools of a locality for a time. As regards special treatment, in an ordinary case of measles little is required beyond what is necessary in febrile conditions generally. Confinement to bed in a somewhat darkened room, into which, however, air is freely admitted in such a manner as to avoid the risk of draughts, light nourishing liquid diet (soups, milk, &c.), and mild diaphoretic remedies such as the acetate of ammonia or ipecacuanha, are all that is necessary in the febrile stage. When the catarrhal symptoms are very severe, the hot bath or warm packing to the body generally or to the chest and throat afford relief, and the same measures may with advantage be adopted should the eruption be but feebly developed or tend to recede, and especially should convulsions set in. The serious chest complications of measles are to be dealt with by those measures applicable for the relief of the particular symptoms (see BRONCHITIS, PNEUMONIA). The inhalation of vapour and the use of the preparations of ammonia are of special efficacy. Diarrhœa is treated by the usual remedies, including carefully administered doses of Dover's powder, chalk, &c. During convalescence the patient must be guarded from exposure to cold, and for a time after recovery the state of the health ought to be watched with the view of averting the evils, both local and constitutional, which but too often follow this disease.

German Measles (*Rötheln*, or *Epidemic Roseola*) is a term applied to a contagious eruptive disorder having certain points of resemblance to measles, and, according to some observers, also to scarlet fever, but exhibiting its distinct individuality in the fact that it protects from neither of these diseases. It occurs most commonly in children, and is occasionally seen in extensive epidemics. Beyond confinement to the house in the eruptive stage, which, from the slight symptoms experienced, is often difficult of accomplishment, no special treatment is called for. There is little doubt that the disease is often mistaken for true measles, and many of the alleged second attacks of the latter malady are probably cases of rötheln. The chief points of difference are the following:—

1. The absence of distinct premonitory symptoms, the stage of invasion, which in measles is usually of four days' duration, and accompanied with well-marked fever and catarrh, being in rötheln either wholly absent or exceedingly slight, enduring only for one day.

2. The eruption of rötheln, which, although as regards its locality and manner of progress similar to measles, differs somewhat in its appearance, the spots being of smaller size, paler colour, and with less tendency to grouping in crescentic patches. The rash attains its maximum in about one day, and quickly disappears. There is no accompanying increase of temperature in this stage as in measles.

3. The milder character of the symptoms of rötheln throughout its whole course, and the absence of complications and of liability to subsequent impairment of health such as have been seen to appertain to measles. (J. O. A.)

MEASUREMENT. We propose in the first place to enter into some detail on the fundamental principles of the theory of measurement, and in doing so it will be necessary to sketch the very remarkable theory established by Riemann and other mathematicians as to the foundations of our geometrical knowledge.

Every system of geometrical measurement, as indeed the whole science of geometry itself, is founded on the possibility of transferring a fixed figure from one part of space to another with unchanged form. We are so familiar with this process that we are apt not to realize its importance until very special attention has been directed to the subject. We therefore propose to make a logical examination of the nature of the assumptions involved in the possibility of moving a figure in space so that it shall undergo no alteration. We shall find that we require to postulate certain suppositions with regard to the nature of space and to the measurement of distances.

It will facilitate the conception of this somewhat difficult subject to consider the case of hypothetical reasoning beings which Sylvester described as being infinitely attenuated bookworms confined to infinitely thin sheets of paper. We suppose such two-dimensional beings to be absolutely limited to a certain surface. They could have no conception of space except as of two dimensions. The movement of a point would for them form a line, the movement of a line would form a surface. They could conduct their measurements and form their geometrical theories. They would be able to draw the shortest lines between two points, these lines being what we would call geodesics. To these two-dimensioned geometers geodesics would possess many of the attributes of straight lines in ordinary space. If the surface to which the beings were confined were actually a plane, then the geometry would be the same as our geometry. They would find that only one straight line could be drawn between two points, that through a point only one parallel to a given line could be drawn, and that the ends of a line would never meet even though the line be prolonged to infinity.

We might also suppose that intelligent beings could exist on the surface of a sphere. Their straightest line between two points would be the arc of the great circle joining those two points. They would also find that a second geodesic could be drawn joining the two points, this being of course the remaining part of the great circle. A curious exception would, however, be presented by two points diametrically opposite. An infinite number of geodesics can be drawn between these points and all those geodesics are of equal length. The axiom that there is one shortest line between two given points would thus not hold without exception. There would be no parallel lines known to the dwellers on the sphere. It would be found by them that every two geodesics must intersect, not only in one, but even in two points. The sum of the three angles of a triangle would for them not be constant. It would always be greater than two right angles, and would increase with the area of the triangle. They would thus have no conception of similarity between two geometrical figures of different sizes. If two triangles be constructed which have their sides proportional, the angles of the larger triangle would be greater than the corresponding angles of the smaller triangle.

It is thus plain that the geometrical axioms of the sphere-dwellers must be very different from those of the plane-dwellers. The different axioms depend upon the different kinds of space which they respectively inhabit, while their logical powers are identical. In one sense, however, the dwellers on the sphere and on the plane have an axiom in common. In each case it will be *possible for a figure to be moved about without alteration of its dimensions.* A spherical triangle can be moved on the surface of a sphere without distortion just as a plane triangle may be moved in a plane. The sphere-dwellers and the plane-dwellers would be equally able to apply the test of congruence. It is, however, possible to suppose reasoning beings confined to a space in which the translation of a rigid figure is impossible. Take, for instance, the surface of an ellipsoid or even a spheroid such as the surface of the earth itself. A triangle drawn on the earth at the equator could not be transferred to the surface of the earth near the pole and still preserve all its sides and all its angles intact.

If a surface admits of a figure being moved about thereon so as still to retain all its sides and all its angles unaltered, then that surface must possess certain special properties. It can be shown that, if a surface is to possess this property, a certain function known as the "measure of curvature" is to be constant. The measure of curvature is the reciprocal of the product of the greatest and least radii of curvature. We do not now enter into the proof, but it is sufficiently obvious that a sphere of which the radius is the geometric mean between the greatest and least radii of curvature at each point will to a large extent osculate the surface, so that a portion of the surface in the neighbourhood of the point will, generally speaking, have the same curvature as the sphere. If the sphere thus determined be the same at all the different points of the surface, then the curvature of the different parts of the surface will on the whole resemble that of the sphere, and therefore we cannot be surprised that the surface possessing this property will admit the displacement of a rigid figure thereon without derangement of its form.

We are thus conducted to a kind of surface the geometry of which is similar to that of the plane, but in which the axiom of parallels does not hold good. In this surface the radii of curvature at every point have opposite signs, so that the measure of curvature which is zero for the plane and positive for the sphere is negative for the surface now under consideration. This surface has been called the "pseudosphere," and its nature has been investigated by Beltrami.[1] In the geometry of two dimensions we can thus have either a plane or a sphere or a pseudosphere which are characterized by the property that a surface may be moved about in all directions without any change either in the lengths of its lines or in the magnitudes of its angles. The axiom which assumes that there is only one geodesic connecting two points marks off the plane and the pseudosphere from the sphere. The axiom that only one parallel can be drawn through a given point to a given line marks off the plane from the pseudosphere. The geometry of Euclid is thus specially characterized among all conceivable geometries of two dimensions by the following three axioms—(1) the mobility of rigid figures, (2) the single geodesic between two points, (3) the existence of parallels.

A very interesting account of this theory will be found in Clifford's *Lectures and Essays*, vol. i. p. 317. We shall follow to some extent the method employed by him in order to obtain an idea of the important conception which is called the "curvature of space." Suppose a geodesic be drawn on a surface of constant curvature. Then a piece of the surface adjoining this geodesic can be slid along the curve so as all the time to fit in close contact therewith. If the piece of surface be turned to the other side of the geodesic it will still fit along this side. A

[1] *Saggio di Interpretazione della Geometria non-Euclidea*, Naples, 1868; "Teoria fondamentale degli sparii di curvatura constante," *Annali di Matematica*, ser. ii. tom. ii. pp. 232–55. Both papers have been translated into French by J. Houël (*Annales Scientifiques de l'École Normale*, tom. v., 1869). An exceedingly interesting account of the whole subject will be found in Helmholtz, *Popular Lectures on Scientific Subjects*, translated by Atkinson, second series, London, 1881, pp. 27–71.

line possessing this property is called by Leibnitz a straight line. It can be easily shown that a geodesic drawn on a figure will also be a geodesic when the figure is transferred to any other position. Suppose that the figure be divided into two parts A and B by the geodesic; then the part B can be moved round so as to lie upon A, and the boundary lines of the two portions will be coincident. Now let the two parts while superposed be translated to any other position, then the piece B may be slid off and back to its original position with regard to A. It must still fit, because the whole figure might have been translated before the subdivision took place. It follows that the division between A and B having been a geodesic in its original position will continue to be a geodesic however the figure may be translated.

In a similar way we obtain the conception of a plane. According to Leibnitz's definition a plane is a surface such that if a portion of the space contiguous thereto be slid along the surface it will continuously fit, and if the portion of space be transferred to the other side of the surface it will fit also. This definition has no meaning except we assume that the bodies may be translated in space without derangement of their dimensions. From any point we can imagine a doubly infinite number of geodesics radiating in all directions; if a plane be drawn through the point, then all the geodesics touching the plane at that point form what may be called a "geodesic surface." It is shown that geodesic surfaces of this description can alone fulfil the conditions by which planes are to be defined. A doubly infinite number of geodesic surfaces can be drawn through every point. If a rigid body be divided into two parts by a geodesic plane, then no matter how the body be displaced the plane of section will still be geodesic. The plane of section may be made to pass through any point, and the body may then be given such an aspect as shall cause the section to coincide with any geodesic surface through the point, but this necessarily involves that the section shall fit each geodesic surface, in other words, that *all the geodesic surfaces shall have a constant curvature.*

The point which we have now gained is one of very great importance. In our ordinary conceptions of space the geodesic surfaces are of course our ordinary planes, and the common curvature they possess is zero, but the condition that rigid bodies shall be capable of translation with unaltered features does not require that the curvatures shall be zero, it merely requires that the curvatures shall be constant. If we add, however, the postulate of similarity, then the curvatures must be zero. The postulate of similarity requires that it shall be possible to construct a figure on any scale and anywhere similar to a given figure. This practically includes the ordinary doctrine of parallels. Lobatchewsky developed the system of geometry on the supposition that the space had a constant curvature different from zero. In this geometry the parallels can be drawn through a given point to a given line, and, to quote Clifford—

> "The sum of the three angles of a triangle is less than two right angles by a quantity proportional to the area of the triangle. The whole of this geometry is worked out in the style of Euclid, and the most interesting conclusions are arrived at, particularly in the theory of solid space, in which a surface turns up which is not plane relatively to that space but which for the purpose of drawing figures upon it is identical with the Euclidean plane."

The most comprehensive mode of viewing the whole theory is that adopted by Riemann in his celebrated memoir "Ueber die Hypothesen welche der Geometrie zu Grunde liegen," 1854 (*Abhandl. der königl. Gesellsch. zu Göttingen*, vol. xiii.).[1] The analytical treatment of this subject possesses one obvious advantage. The use of symbols only admits of deductions on purely logical principles. There is not therefore the risk of tacitly introducing other axioms in addition to those with which we started.

Magnitudes which have only one dimension present the theory of measurement in its simplest form. The length of a straight line may be taken as an illustration of a one-dimensioned magnitude. The velocity of a moving particle, the temperature of a heated body, the electric resistance of a metal, all these and many others are instances of one-dimensioned magnitude, the measure of which is to be expressed by a single quantity. But there may be magnitudes which require more than a single measurement for their complete specification. Take, for instance, a four-sided field which has been duly surveyed. Of what is the measurement of this field to consist? If the number of acres in the field be all that is required then the area is expressed by a simple reference to a number of standard acres. If, however, the entire circumstances of the field are to be brought into view, then a simple statement of the area is not sufficient. It can be easily shown that the surveyor must ascertain five independent quantities before the details of the shape of the field can be adequately defined. Four of these quantities may naturally be the lengths of the four sides of the field, the fifth may be one of the angles, or the area, or the length of one of the diagonals. Speaking generally, we may say that five distinct measurements will be necessary to define the field adequately. The actual choice of the particular measurements to be made is to a great extent arbitrary. The only condition absolutely necessary is that they shall be all independent and free from ambiguity. Once these five quantities are ascertained then all the other features of the figure are absolutely determined. For instance, the four sides and the diagonal being ascertained by measurement, then the other diagonal, the four angles, and the area can all be computed by calculation. The five quantities would determine everything about the field except its actual position on the surface of the earth. If we further desired to have the field exactly localized certain other quantities must be added. The latitude and the longitude of one specified corner of the field would completely indicate that corner, while the azimuth of one side from that corner would complete the definition of its position. We are thus led to see that for the complete delineation of every circumstance relating to the shape of the field and its locality eight different measurements have been required. Two sets of eight measurements differing in any particular can never indicate the same field. It is very important to notice that the *number* of quantities required is quite independent of the particular nature of the measurements adopted. We might for instance have simply measured the latitude and the longitude of each of the four corners of the field. Once these quantities are known, then the shape of the field, its area, its angles, and its diagonals have all been implicitly determined. Here again we see that as two quantities are required to localize each of the four corners, so eight quantities will be required to fully determine the whole field.

In the operations of analytical geometry we are accustomed to specify the position of a point by the relation which it bears to certain fixed axes. By means of certain quantities, either altogether linear or partly linear and partly angular, we are enabled to specify the position of the point with absolute definiteness. These quantities

[1] A translation of this paper was published by Clifford in *Nature* (vol. viii. Nos. 183, 184, pp. 14–17, 36, 37), and has been reprinted in the collected edition of Clifford's *Works*, 1882, pp. 55–69. For a bibliography of higher-space and non-Euclidean geometry, see articles by George Bruce Halsted in the *American Journal of Mathematics Pure and Applied*, i. 261–276, 384, 385; ii. 65–70.

are called the coordinates of the point. In a similar though more extended sense we may use the word "coordinates" to express the group of eight magnitudes which we have found to be adequate to the complete specification of the field. By the measurement of the field in the most complete sense of the term we mean the measurement of its eight coordinates.

Suppose that an object is completely specified by n coordinates, then every different group of n coordinates will specify a different object. The entire group of such objects will form what is called a continuously extended manifoldness. The singly extended manifoldness may be most conveniently illustrated by the conception of time, the various epochs of which are the elements in the manifoldness. Space is a triply extended manifoldness whereof the elements are points. All conceivable spheres form a quadruply extended manifoldness. All conceivable triangles in space form a manifoldness of nine dimensions. The number of coordinates required to specify the position of an element in a manifoldness is thus equal to the order of the manifoldness itself. It is important to observe that the elements of the manifoldness may be themselves objects of no little complexity. Thus, for instance, the conics forming a confocal group constitute the elements of a singly extended manifoldness.

The essential feature of a singly extended manifoldness is that a continuous progress of an element can take place only in two directions, either forwards or backwards. But a singly extended manifoldness may be regarded as itself an element in a manifoldness of a higher order. Thus the points on a circle form a singly extended manifoldness, while the circle itself is one element of the manifoldness which consists of a series of concentric circles. The system of concentric circles may in like manner be regarded as an element in the manifoldness which embraces all systems of concentric circles whose centres lie along a given line. We are thus led to conceive of a multiply extended manifoldness as made up by the successive composition of singly extended manifoldnesses.

It follows from the conception of a manifoldness that in the case of a singly extended manifoldness the position of every element must be capable of being completely specified by a single quantity. It becomes natural to associate with each element of the manifoldness a special numerical magnitude. These magnitudes may vary from $-\infty$ to $+\infty$; to each magnitude will correspond one element of the manifoldness, and conversely each element of the manifoldness is completely specified whenever the appropriate number has been assigned. It is quite possible to have this association of numerical magnitude with the actual position of an element independent of any ordinary metrical relations of the system; it will, however, most usually be found that the numerical magnitudes chosen are such as admit of direct interpretations for the particular manifoldness under consideration. Thus, for instance, in the case of the system of concentric circles it will be natural to associate with each circle its radius, and the position of each circle in the manifoldness will thus be completely defined by the radius. So also in the case of that singly extended manifoldness which consists of colours, it will be natural to employ as the number which specifies each particular colour the wave-length to which that particular colour corresponds.

If the elements of such a manifoldness can receive a simultaneous displacement, then it is plain that to each element in the original position will correspond an element in the second position. Let x and y be the numerical magnitudes correlated to these two elements. Then, since the relation must be of the one-to-one type, it is necessary that the magnitudes x and y must be connected by an equation of the type

$$axy + bx + cy + d = 0.$$

It follows from this that there are a pair of elements which are common to both systems, for if $x = y$ we have the equation

$$ax^2 + (b+c)x + d = 0.$$

The original equation may be written in the form

$$axy + (b-\omega)x + (c+\omega)y + d = 0,$$

and whatever value ω may have this equation will lead to the same quadratic for the two common elements. We thus have a singly infinite number of displacements which are compatible with the condition that the two fundamental elements shall remain unaltered, and it is displacements of this kind which express the movements of a rigid system.

The position of a point is to be defined by three coordinates. In our ordinary conception of coordinates the position of the point is defined by certain measurements, and thus it would seem that the very mention of coordinates had already presupposed the idea of distance. This, however, need not be the case. We can assume a point in space to be completely defined by three purely numerical quantities. It will be supposed that to each group of three coordinates corresponds one point, and that conversely to one point will correspond three coordinates and no ambiguity is to be present. This latter consideration will exclude from our present view such cases as those where the position of a point is defined by a line and two angles, because angles are subject to a well-known ambiguity amounting to any even multiple of π. In this case it would not be true that to one point corresponds one set of coordinates, although the converse may be correct.

It is necessary to understand clearly the nature of the suppositions which are made with regard to space by this assumption. Let x, y, z and x', y', z' be the coordinates of two points a and a'. Now x, y, z can change continuously by any law into x', y', z'. Each intermediate stage will give the coordinates of a point. It must thus be possible to pass continuously in an infinite number of ways from the point a to the point a'. We thus assume that space is continuous when we have assumed that its points are represented by coordinates. It must be observed that we predicate nothing as to space which is not involved in the fact that to each point corresponds one group of three coordinates. To some extent the considerations now before us will apply to any other continuous manifoldness which requires three coordinates for the complete specification of its elements. Take, for instance, a musical note. It can be specified accurately by its pitch, intensity, and timbre. These three quantities may be regarded as the three coordinates which will discriminate one sound from the rest. The manifoldness comprising all musical notes is, however, very different from the manifoldness which embraces all the points of space. Each of these manifoldnesses is no doubt continuous, and each of them is of three dimensions, but the conception of distance can have no place in the musical manifoldness. This is due to the absence from the musical manifoldness of anything parallel with the conception of rigidity in the space manifoldness. These remarks will show that the conception of "distance" is something of a special type even in a three-dimensioned continuous manifoldness.

There are also other three-dimensioned and continuous manifoldnesses from which the conception of distance is also absent. Take, for instance, the manifoldness which embraces all the circles that can lie in a given plane. The points of such a manifoldness are the circles. It is three-dimensioned, for two coordinates will be required for the centre of each circle and one for its radius. It is obviously a continuous manifoldness, for one circle may by infinitely graduated modifications pass into any other. Yet from this manifoldness also the conception of distance is absent. There is no intelligible relation of one circle to another which is analogous to the distance which we require to determine.

We shall now give the investigation of Helmholtz, by which the analytical form of the function expressing the distance is to be ascertained (*Göttingen Nachrichten*, 1868, pp. 193 *sq.*).

It must be remembered that our definition of a point will be purely analytical. Suppose three different scales of pure quantity each extending from $-\infty$ to $+\infty$. Each of these scales is perfectly continuous, so that, no matter how close any two elements in the scale may be, it is always possible to conceive the insertion of an infinite number of intermediate elements. A point is to be defined for our present purpose as a group of three numerical magnitudes taken one from each of the three scales. This conception may be stated more generally. We can conceive n different numerical scales. Then a group of n numbers, one from each scale, will define an element of a continuous n-fold manifoldness.

It will be obvious that unless the theory of distance possess a special character it will not be possible for a rigid body to exist. Take, for instance, five points in a rigid body ABCDE. There are ten different pairs of points and ten corresponding distances; all these ten distances must remain unchanged when the body is displaced. We may assume the position of A arbitrarily. Then after the dislpacement B must be placed at the right distance from A, but will only be limited by this condition to a certain surface, C must be placed at the right distance from A and from B, thus C will be limited to a certain curve. D must be placed at the proper distances from A, from B, and from C. These conditions will be sufficient to define D with complete definiteness. In the same way E will be completely defined by its distances from A, B, and C, but as D and E are thus fully defined we have no guarantee that the distance DE shall retain, after the translation, the same value which it had before. This then indicates that the function which is to express the distance must have a very special form. Any arbitrary function of the six coordinates of the two points would in general not fulfil the condition that the distance DE after the transformation will retain the same value as it had before. If a greater number of points than five be taken, the conditions which a rigid system must fulfil become still more numerous.

Let x, y, z be the coordinates of a point in a rigid body free to rotate around a point. We shall assume that x, y, z is in the vicinity of the fixed point, and that the displacement of the body is such that a second point remains unaltered. In other words, the displacement is to be a rotation around a line joining the two points, and we shall also assume that when this rotation has been completed every point will be restored to its original position. Let η be the angle of rotation around the axis, then x, y, z will all be functions of η, and we may assume that the following equations will hold—

$$\frac{dx}{d\eta}=a_0x+b_0y+c_0z$$

$$\frac{dy}{d\eta}=a_1x+b_1y+c_1z$$

$$\frac{dz}{d\eta}=a_2x+b_2y+c_2z\,.$$

In the first place it is plain that these differential coefficients must be functions of x, y, z, and, these functions being expanded in ascending powers, we may omit all powers above the first. It will also be obvious that the absolute terms must be zero as the origin is by hypothesis to be a fixed point. As the displacement is a rotation, it follows that the differential coefficients must be zero for certain values of x, y, z different from zero, but this involves the condition

$$\begin{vmatrix} a_0, & b_0, & c_0 \\ a_1, & b_1, & c_1 \\ a_2, & b_2, & c_2 \end{vmatrix}=0\,.$$

We now proceed to solve the three linear differential equations by the well-known process. If we multiply the three equations by l, m, n respectively, and if we determine l, m, n so that

$$lh=la_0+ma_1+na_2$$

$$mh=lb_0+mb_1+nb_2$$

$$nh=lc_0+mc_1+nc_2,$$

where h is another constant determined by the equation

$$\begin{vmatrix} a_0-h, & a_1, & a_2 \\ b_0, & b_1-h, & b_2 \\ c_0, & c_1, & c_2-h \end{vmatrix}=0\,,$$

the differential equations then give

$$\frac{d}{d\eta}(lx+my+nz)=h(lx+my+nz),$$

whence $$lx+my+nz=Ce^{h\eta}.$$

We have already seen that one of the values of h must be zero, whence if the other values be h_1 and h_2 we have the three equations

$$l_0x+m_0y+n_0z=A$$

$$l_1x+m_1y+n_1z=Be^{h_1\eta}$$

$$l_2x+m_2y+n_2z=Ce^{h_2\eta}.$$

It is plain that h_1 and h_2 cannot be real quantities, for then the quantities $l_1x+m_1y+n_1z$ and $l_2x+m_2y+n_2z$ could attain any values from $-\infty$ to $+\infty$ according to the variations in η. If h_1 and h_2 are imaginary then will also the corresponding values of l, m, n be imaginary. We therefore write

$$h_1=\theta+\omega i \qquad h_2=\theta-\omega i$$

$$l_1=\lambda_0+\lambda_1 i \qquad l_2=\lambda_0-\lambda_1 i$$

$$m_1=\mu_0+\mu_1 i \qquad m_2=\mu_0-\mu_1 i$$

$$n_1=\nu_0+\nu_1 i \qquad n_2=\nu_0-\nu_1 i$$

so that $$\lambda_0x+\mu_0y+\nu_0z=Ae^{\theta\eta}\cos(\omega y+c)$$

$$\lambda_1x+\mu_1y+\nu_1z=Ae^{\theta\eta}\sin(\omega y+c);$$

in which case we have

$$(\lambda_0x+\mu_0y+\nu_0z)^2+(\lambda_1x+\mu_1y+\nu_1z)^2=Ae^{2\theta\eta}.$$

But it is plain that unless θ be zero the left-hand side of this equation will be susceptible of indefinite increase, which is contrary to our hypothesis. We are therefore entitled to assume that $\theta=0$. The two roots of the cubic for h must, therefore, be pure imaginaries, and thus we have the condition

$$a_0+b_1+c_2=0\,.$$

Finally we have for the determination of x, y, z the following three equations :—

$$l_0x+m_0y+n_0z=\text{const.}$$

$$\lambda_0x+\mu_0y+\nu_0z=A\cos(\omega y+c)$$

$$\lambda_1x+\mu_1y+\nu_1z=A\sin(\omega y+c)\,.$$

It will simplify the subsequent calculations if we now make such a transformation of the coordinates as will enable us to write

$$X=l_0x+m_0y+n_0z$$

$$Y=\lambda_0x+\mu_0y+\nu_0z$$

$$Z=\lambda_1x+\mu_1y+\nu_1z\,.$$

We shall then have from the results just obtained

$$\frac{dX}{d\eta}=0$$

$$\frac{dY}{d\eta}=-\omega Z$$

$$\frac{dZ}{d\eta}=+\omega Y\,.$$

The movement corresponding to η is such as leaves unaltered all points of which the Y and the Z are equal to zero.

Let us now suppose another displacement to be given to the system by a rotation η' about another axis so chosen that all the points for which $X=0$ and $Z=0$ shall remain unaltered. For this condition to be fulfilled we must have the equation

$$\frac{dX}{d\eta'}=\alpha_0X+0+\nu_0Z$$

$$\frac{dY}{d\eta'}=\alpha_1X+0+\nu_1Z$$

$$\frac{dZ}{d\eta'}=\alpha_2X+0+\nu_2Z\,,$$

for then each side of these equations will be equal to zero for points which make X and Z zero. The condition that the roots of h shall be purely imaginary gives us

$$\alpha_0+\nu_2=0\,.$$

If the body receives both the rotation η and the rotation η' then the joint effect of these two rotations must be equal to that of a single rotation ϕ, so that

$$\frac{dX}{d\phi}=\frac{dX}{d\eta}+\frac{dX}{d\eta'}$$
$$\frac{dY}{d\phi}=\frac{dY}{d\eta}+\frac{dY}{d\eta'}$$
$$\frac{dZ}{d\phi}=\frac{dZ}{d\eta}+\frac{dZ}{d\eta'};$$

or uniting the two sets of equations we have

$$\frac{dX}{d\phi}=\alpha_0X+0\ \ +\nu_0Z$$
$$\frac{dY}{d\phi}=\alpha_1X+0\ \ +(\nu_1-\omega)Z$$
$$\frac{dZ}{d\phi}=\alpha_2X+\omega Y+\nu_2Z\,.$$

As this movement must also be a rotation, the three right-hand members must be capable of being rendered zero for certain values of X, Y, Z, and therefore we have (remembering that $\alpha_0+\nu_2=0$)

$$\begin{vmatrix}\alpha_0, & 0, & \nu_0\\ \alpha_1, & 0, & \nu_1-\omega\\ \alpha_2, & \omega, & -\alpha_0\end{vmatrix}=0\,.$$

This condition reduces to

$$\omega\alpha_0(\nu_1-\omega)-\omega\alpha_1\nu_0=0\,,$$

or

$$\alpha_0\omega^2+\omega(\alpha_1\nu_0-\alpha_0\nu_1)=0\,.$$

This equation must be satisfied for every value of ω; for, whatever be the amplitudes of the two rotations, they must when compounded be equal to a single rotation. We therefore have the conditions

$$\alpha_0=0$$
$$\alpha_1\nu_0=0\,.$$

To satisfy the latter condition either α_1 or ν_0 must be equal to zero. We must examine which of these two conditions is required by the problem. Since α_0 is equal to zero we have

$$\frac{dX}{d\eta'}=\nu_0Z$$
$$\frac{dY}{d\eta'}=\alpha_1X+\nu_1Z$$
$$\frac{dZ}{d\eta'}=\alpha_2X\,.$$

If ν_0 were zero then the first equation would show X to be constant; and the result would be that

$$Y=\alpha_1X\eta+\tfrac{1}{2}\alpha_2\nu_1X\eta^2+\text{const.};$$

or, in other words, Y would be susceptible of indefinite increase with the increase of η. The supposition $\nu_0=0$ is therefore precluded, and we are forced to admit that $\alpha_1=0$. The three equations then reduce to

$$\frac{dX}{d\eta'}=\nu_0Z$$
$$\frac{dY}{d\eta'}=\nu_1Z$$
$$\frac{dZ}{d\eta'}=\alpha_2X\,.$$

If the body receives a rotation η'' about an axis which leaves X and Y unaltered, we then have

$$\frac{dX}{d\eta''}=f_0X+g_0Y+0$$
$$\frac{dY}{d\eta''}=f_1X+g_1Y+0$$
$$\frac{dZ}{d\eta''}=f_2X+g_2Y+0\,.$$

The condition that the two roots of h shall be purely imaginary gives us

$$f_0+g_1=0\,.$$

Let this rotation and the first rotation be communicated together. The resulting rotation could have been produced by a rotation χ, and thus we have

$$\frac{dX}{d\chi}=\frac{dX}{d\eta}+\frac{dX}{d\eta''}$$
$$\frac{dY}{d\chi}=\frac{dY}{d\eta}+\frac{dY}{d\eta''}$$
$$\frac{dZ}{d\chi}=\frac{dZ}{d\eta}+\frac{dZ}{d\eta''}\,.$$

Substituting, we obtain as before

$$\frac{dX}{d\chi}=f_0X+g_0Y+0$$
$$\frac{dY}{d\chi}=f_1X+g_1Y-\omega Z$$
$$\frac{dZ}{d\chi}=f_2X+(g_2+\omega)Y+0\,;$$

and as before the condition must be fulfilled

$$\begin{vmatrix}f_0, & g_0, & 0\\ f_1, & g_1, & -\omega\\ f_2, & g_2+\omega, & 0\end{vmatrix}=0\,;$$

or, expanding,

$$\omega f_0(g_2+\omega)-\omega f_2g_0=0\,.$$

This can only be satisfied for all values of ω if $f_0=0$ and if

$$f_2g_0=0\,.$$

To determine whether g_0 can be zero, we have the equations

$$\frac{dX}{d\eta''}=g_0Y$$
$$\frac{dY}{d\eta''}=f_1X$$
$$\frac{dZ}{d\eta''}=f_2X+g_2Y\,.$$

It can be shown that if g_0 were zero then we should have Z capable of indefinite increase; and hence we see that f_2 must be zero, so that the three equations have the form

$$\frac{dX}{d\eta''}=g_0Y$$
$$\frac{dY}{d\eta''}=f_1X$$
$$\frac{dZ}{d\eta''}=g_2Y\,.$$

Let us now see whether these equations will fulfil the necessary condition for a rotation ψ. If

$$\frac{dX}{d\psi}=\frac{dX}{d\eta'}+\frac{dX}{d\eta''}$$
$$\frac{dY}{d\psi}=\frac{dY}{d\eta'}+\frac{dY}{d\eta''}$$
$$\frac{dZ}{d\psi}=\frac{dZ}{d\eta'}+\frac{dZ}{d\eta''}\,,$$

we shall then have by substitution

$$\frac{dX}{d\psi}=0+g_0Y+\nu_0Z$$
$$\frac{dY}{d\psi}=f_1X+0+\nu_1Z$$
$$\frac{dZ}{d\psi}=\alpha_2X+g_2Y+0\,.$$

But, if this is to represent a rotation,

$$f_1g_2\nu_0+\alpha_2g_0\nu_1=0\,.$$

As this is always to be true, even suppose g_0, f_1, and g_2 for instance were multiplied by a common factor, it is plain that we must have

$$f_1g_2\nu_0=0$$

and

$$\alpha_2g_0\nu_1=0\,.$$

The first condition is to be satisfied by making g_2 zero; for neither of the other possible solutions is admissible if the coordinates are to be presented from indefinite increase. In a similar way the second condition requires that ν_1 must be zero.

Resuming now the three groups of equations, they are as follows:—

$$\frac{dX}{d\eta}=0\ ,\quad \frac{dX}{d\eta'}=\nu_0Z\ ,\quad \frac{dX}{d\eta''}=g_0Y$$
$$\frac{dY}{d\eta}=-\omega Z\ ,\quad \frac{dY}{d\eta'}=0\ ,\quad \frac{dY}{d\eta''}=f_1X$$
$$\frac{dZ}{d\eta}=+\omega Y\ ,\quad \frac{dZ}{d\eta'}=\alpha_2X\ ,\quad \frac{dZ}{d'\eta''}=0\,.$$

Finally let us suppose that the body receives all three motions simultaneously. The resulting motion must still be a rotation, and thus we have the condition

$$\begin{vmatrix}0, & g_0, & \nu_0\\ f_1, & 0, & -\omega\\ \alpha_2, & +\omega, & 0\end{vmatrix}=0\,,$$

which when expanded gives

$$\omega(f_1\nu_0 - \alpha_2 g_0).$$

It is therefore necessary that

$$f_1\nu_0 - \alpha_2 g_0 = 0.$$

But, as this is homogeneous in the two component rotations involved, it does not follow that the separate terms of this equation must necessarily be zero. We satisfy this condition by writing

$$kf_1 = -g_0$$

and $$k\alpha_2 = -\nu_0.$$

Let the body next receive *any* displacement, $\delta\eta$, $\delta\eta'$, and $\delta\eta''$, then we have in general

$$\delta X = \frac{dX}{d\eta}\delta\eta + \frac{dX}{d\eta'}\delta\eta' + \frac{dX}{d\eta''}\delta\eta'',$$

with similar equations for δY and δZ.

By substitution these equations become

$$\delta X = -\alpha_2 kZ\delta\eta' - kf_1 Y\delta\eta''$$

$$\delta Y = -\omega Z\delta\eta + f_1 X\delta\eta''$$

$$\delta Z = +\omega Y\delta\eta + \alpha_2 X\delta\eta'.$$

If we multiply the first of these equations by X, the second by kY, and the third by kZ, and add, we find

$$X\delta X + kY\delta Y + kZ\delta Z = 0$$

or $$X^2 + kY^2 + kZ^2 = \text{const.}$$

Here we have attained the fundamental property which the coordinates must satisfy. If k be equal to unity then we have the well-known condition of ordinary space and ordinary rectangular coordinates, but it will be seen that there is nothing in the preceding investigation to make it necessary that k should be unity. There are therefore a singly infinite variety of spaces in which it is possible for a rigid body to be displaced. The different values of k thus correspond to the different "curvatures" which a space might have while it still retained the fundamental property which is necessary for measurement by congruence.

It will now be proper to study the special characteristics of the space with which we are familiar. It has been called flat space or homaloidal space to distinguish it from other spaces in which the curvature is not zero. It is manifest that the characteristic features of our space are not necessarily implied in the general notion of an extended quantity of three dimensions and of the mobility of rigid figures therein. The characteristic features of our space are not necessities of thought, and the truth of Euclid's axioms, in so far as they specially differentiate our space from other conceivable spaces, must be established by experience and by experience only.

The special feature of our space, by which it is distinguished from spherical space on the one hand and pseudospherical space on the other hand, depends upon what Riemann calls the measure of curvature. If the sum of the three angles of a triangle is to be two right angles, and if the geometrical similarity of large figures and small figures is to be possible, then the measure of curvature must be zero. Now all measurements that can be made seem to confirm the axiom of parallels and seem to show the measure of curvature of our space to be indistinguishable from zero.

It can be proved that the amount by which the three angles of a triangle would differ from two right angles in curved space depends upon the area of the triangle. The greater the area of the triangle the greater is the difference. To test the famous proposition, Euclid i. 32, it will therefore not be sufficient to measure small triangles. It might be contended that in small triangles the difference between the sum of the three angles and two right angles was so small as to be inextricably mixed up with the unavoidable errors of measurement. Seeing therefore that small triangles obey the law, it is necessary to measure large triangles, and the largest triangles to which we have access are, of course, the triangles which the astronomers have found means of measuring. The largest available triangles are those which have the diameter of the earth's orbit as a base and a fixed star at the vertex. It is a very curious circumstance that the investigations of annual parallax of the stars are precisely the investigations which would be necessary to test whether one of these mighty triangles had the sum of its three angles equal to two right angles. It must be admitted that the parallax-seeking astronomers have never yet found any reason to think that there is any measurable difference. If there were such a difference it would probably be inextricably mixed up with the annual parallax itself. Were space really pseudospherical, then stars would exhibit a real parallax even if they were infinitely distant. Astronomers have sometimes been puzzled by obtaining a negative parallax as the result of their labours. No doubt this has generally or indeed always arisen from the errors which are inevitable in inquiries of this nature, but if space were really curved then a negative parallax might result from observations which possessed mathematical perfection.

It must, however, be remembered that even the triangles of the parallax investigations are utterly insignificant when compared with the dimensions of space itself. Even the whole visible universe must be only an unconceivably small atom when viewed in its true relation to infinite space. It may well be that even with the parallax triangles our opportunities of testing the proposition are utterly inadequate to pronounce on the presence or absence of curvature in space. It must remain an open question whether if we had large enough triangles the sum of the three angles would still be two right angles.

Helmholtz illustrates the subject by considering the representation of space which is obtained in a spherical mirror. A mirror of this kind represents the objects in front of it in apparently fixed positions behind the mirror. The images of the sun and of other distant objects will lie behind the mirror at a distance equal to its focal length, or, to quote the description of Helmholtz—

"The image of a man measuring with a rule a straight line from the mirror would contract more and more the farther he went, but with his shrunken rule the man in the image would count out exactly the same number of centimetres as the real man. And in general all geometrical measurements of lines or angles made with regularly varying images of real instruments would yield exactly the same results as in the outer world. All congruent bodies would coincide on being applied to one another in the mirror as in the outer world. All lines of sight in the outer world would be represented by straight lines of sight in the mirror. In short I do not see how men in the mirror are to discover that their bodies are not rigid solids and their experiences good examples of the correctness of Euclid's axioms. But if they could look out upon our world as we can look into theirs, without overstepping the boundary, they must declare it to be a picture in a spherical mirror, and would speak of us just as we speak of them; and if two inhabitants of the different worlds could communicate with one another, neither so far as I can see would be able to convince the other that he had the true, the other the distorted relations. Indeed I cannot see that such a question would have any meaning at all so long as mechanical considerations are not mixed up with it."

A very important contribution to this subject has been made by Professor Simon Newcomb, entitled "Elementary Theorems Relating to the Geometry of a Space of Three Dimensions and of Uniform Positive Curvature in the Fourth Dimension," see *Jour. f. d. reine und angewandte Math.*, vol. lxxxiii., Berlin, 1877.

He commences by assuming the three following postulates:—

1 "That space is triply extended, unbounded, without properties dependent either upon position or direction, and possessing such planeness in its smallest parts that both the postulates of the Euclidean geometry and our common conceptions of the relations of the parts of space are true for every indefinitely small region in space."

2. "That this space is affected with such curvature that a right line shall always return into itself at the end of a finite and real distance 2D without losing in any part of its course that symmetry with respect to space on all sides of it which constitutes the fundamental property of our conception of it."

3. "That if two right lines emanate from the same point making the indefinitely small angle α with each other, their distance apart

at the distance r from the point of intersection will be given by the equation

$$s=\frac{2aD}{\pi}\sin\frac{r\pi}{2D}."$$

Newcomb also assumes that two straight lines intersect only in a single point. He defines a "complete right line" as one returning into itself, as supposed in postulate 2. Any small portion of it is to be conceived as a Euclidean right line. The locus of all complete right lines passing through the same point and touching a Euclidean plane through that point will be called a "complete plane."

A "region" will mean any indefinitely small portion of space in which we are to conceive of the Euclidean geometry as holding true.

Newcomb then proceeds to demonstrate the following propositions.

I. All complete right lines are of the same length 2D. Hence D is the greatest possible distance at which the points can be situated, it being supposed that the distance is measured on the line of least absolute length.

II. The complete plane is a Euclidean plane in every region of its extent.

III. Every system of right lines passing through a common point A and making an indefinitely small angle with each other are parallel to each other in the region A′ at distance D.

IV. If a system of right lines pass in the same plane through A the locus of their most distant points will be a complete right line.

V. The locus of all the points at distance D from a fixed point A is a complete plane, and indeed a double plane if we consider as distinct the coincident surfaces in which the two opposite lines meet.

VI. Conversely, all right lines perpendicular to the same complete plane meet in a point at the distance D on each side of the plane.

VII. For every complete right line there is a conjugate complete right line such that every point of the one is at distance D from every point of the other.

VIII. Any two planes in space have as a common perpendicular the right line joining their poles, and intersect each other in the conjugate to that right line.

IX. If a system of right lines pass through a point, their conjugates will be in the polar plane of that point. If they also be in the same plane the conjugates will all pass through the pole of that plane.

X. The relation between the sides a, b, c of a plane triangle in curved space and their opposite angles A, B, C will be the same as in a Euclidean spherical triangle of which the corresponding sides are $\frac{a\pi}{2D}, \frac{b\pi}{2D}, \frac{c\pi}{2D}$.

XI. Space is finite, and its total volume admits of being definitely expressed by a number of Euclidean solid units which is a function of D.

XII. The total volume of space is $\frac{8D^3}{\pi}$.

XIII. The two sides of a complete plane are not distinct, as in a Euclidean surface.

XIV. If moving along a right line we erect an indefinite series of perpendiculars each in the same Euclidean plane with the one which precedes it, then on completing the line and returning to our starting point, the perpendiculars will be found pointing in a direction the opposite of that with which we started.

Newcomb concludes thus: "It may be also remarked that there is nothing within our experience which will justify a denial of the possibility that the space in which we find ourselves may be curved in the manner here supposed. It might be claimed that the distance of the farthest visible star is but a small fraction of the greatest distance D, but nothing more. The subjective impossibility of conceiving of the relation of the most distant points in such a space does not render its existence incredible. In fact our difficulty is not unlike that which must have been felt by the first man to whom the idea of the sphericity of the earth was suggested in conceiving how by travelling in a constant direction he could return to the point from which he started without during his journey feeling any sensible change in the direction of gravity."

A sketch of the non-Euclidean geometry is given by Professor G. Chrystal in the *Proc. Roy. Soc. Edin.*, vol. x., session 1879-80. The study of this paper is recommended to all who desire to study the elements of what has been called "pangeometry." A more extensive work, which contains the theories of Riemann and Helmholtz, is J. Frischauf's *Elemente der absoluten Geometrie*, Leipsic, 1876.

A fundamental step in the abstract theory of measurement was taken by Professor Cayley in his "Sixth Memoir upon Quantics," *Philosophical Transactions*, vol. cxlix. (1859). The theory thus originated by Cayley has been more fully developed by Klein in his memoir "Ueber die nicht-Euclidische geometrie," *Mathematische Annalen*, vol. iv. p. 573. We shall here enter into this theory in some detail, for in it lies the true foundation of geometrical measurement. A sketch of the theory was given by the author of the present article in *Hermathena*, No. vi. pp. 500-541, Dublin, 1879.

This theory may be regarded merely as a more generalized method of measuring distances and angles in ordinary space, but the results to which it leads are in many respects identical with those to which we are conducted by the theory just discussed. For instance, Newcomb's principle as to the length of the shortest distance between two points never exceeding a certain magnitude is common to his theory and to Cayley's. The theory of Cayley has, however, claims on our attention of a special kind. We here deal with the space with which Euclid has made us familiar, only observing that it is the *measurements* in that space which are to be conducted on a more general principle.

We commence by assuming the existence of a certain surface called the "fundamental quadric," often called "the absolute." By the aid of this quadric and an arbitrary constant c we determine the generalized distance between the points in accordance with the following definition:—*The distance between two points is equal to* c *times the logarithm of the anharmonic ratio in which the line joining the two points is divided by the fundamental quadric.*

Let us first test this theory by a very obvious principle which any theory of distance ought to fulfil. It is plain that, if P, Q, R be three collinear points, then in ordinary measurement we ought to have

$$PQ+QR=PR;$$

but it is easy to see that this condition is fulfilled in the generalized measurement. Let the line PQ cut the fundamental quadric in the two points X, Y, then we have

$$PQ=c\log(PX\div PY)-c\log(QX\div QY)$$
$$QR=c\log(QX\div QY)-c\log(RX\div RY)$$
$$PR=c\log(PX\div PY)-c\log(RX\div RY);$$

whence, as in the ordinary measures,

$$PQ+QR=PR.$$

It is also obvious that in the generalized as in the ordinary measures

$$(PQ)=-(QP),$$

and that the distance between the coincident points is equal to zero.

From an obvious property of logarithms we also learn the important fact that the generalized distance between the points is indeterminate to the extent of any integral number of the periods $2ci\pi$.

The distance from any point to its harmonic conjugate with respect to the two fundamental points is equal to $ci\pi$. We thus see that the distance between any two harmonic conjugates is constant. It is usual to make the arbitrary constant c equal to $-i\div 2$, in which case we see that the distance between the two harmonic conjugates is equal to $\pi\div 2$. It can also be shown that, if the two absolute points on a right line coalesce, then the generalized system of measurement degrades to the ordinary system. The two absolute points are at an infinite distance from every other point, so that in the generalized system of measurement every right line has two points at infinity, and in general all the points in space which lie at infinity are situated on the fundamental quadric.

In ordinary geometry we define a circle to be the locus of a point which is at a constant distance from a given point. In the more generalized geometry we retain the same definition of the circle, only observing that the distance to be constant must be expressed in the generalized manner. The plane of course cuts the absolute in a conic section, so that the determination of the circle whose centre is C is the following problem in conic sections:—Through a fixed point O a straight line OP is drawn which cuts a given conic in the points X, Y; determine the locus of P so that the anharmonic ratio (O, P, X, Y) shall remain constant.

This problem is most readily solved by projecting the conic into a circle the centre of which is the projection of O. The problem then assumes the very simple form. On the diameter of a fixed circle a point P′ is taken so that the anharmonic ratio of the four points consisting of P′, the centre O′, and the two points in which the line O′P′ cuts the circle remains constant. It is required to find the locus of P′. The solution is obvious, and hence we learn that a conic which has double contact with the fundamental conic is a *circle* in the generalized sense, and the centre of that circle is the pole of the chord of contact.

A system of conics which have double contact with the fundamental conic in the same two points form a system of concentric circles, and the centre of the system is the pole of the chord of contact. We are accustomed in ordinary geometry to admit that every circle passes through the two imaginary circular points at infinity. This is the specialized form of the general theorem which asserts that every circle has double contact with the fundamental conic. The two theorems indeed coincide if the fundamental conic degrades to the infinity of ordinary measurement.

A critical case is presented when the chord through O coincides with either of the two tangents which may be drawn from O to the fundamental conic. The two fundamental points then coincide, and hence the distance between any two points on a tangent to the fundamental conic is equal to zero. We have thus the curious result that in every system of concentric circles, including even the fundamental conic itself, the two points common to the system of circles are at the distance zero from the centre of the system. In fact the pair of tangents from the centre may be regarded as a conic having double contact with the fundamental conic, and therefore forming one of the circles of the concentric system of which the radius is zero.

The reader will at once perceive the analogy to a well-known phenomenon in ordinary geometry. The equation in rectangular coordinates

$$x^2+y^2=0$$

denotes *either* a circle of which the radius is zero *or* the pair of lines

$$x\pm\sqrt{-1}y=0;$$

in the latter case we are obliged to admit that the distance of any point on either of these lines from their intersection is equal to zero.

We have now to consider the displacement of a rigid figure, and we shall for the present speak only of a plane movement. We shall first show that it is possible for a plane figure to receive such a displacement that the distance between every two points in the figure after the displacement is equal to what it was before.

Let x, y, z be the trilinear coordinates of a point in a plane, and suppose that x', y', z' are the coordinates of the position to which this point is transferred in accordance with the linear transformation

$$x'=ax+by+cz$$
$$y'=a'x+b'y+c'z$$
$$z'=a''x+b''y+c''z.$$

There are in general three points in the plane which are not altered by this transformation; for, if we assume

$$x'=\rho x, \qquad y'=\rho y, \qquad z'=\rho z,$$

we have for ρ the cubic equation

$$\begin{vmatrix} a-\rho, & b, & c \\ a', & b'-\rho, & c' \\ a'', & b'', & c''-\rho \end{vmatrix}=0.$$

The three values of ρ which satisfy this equation determine the coordinates of the three points. It is natural to take the sides of the triangle formed by these three points as the three lines of reference, in which case, if α, β, γ be constants, the system of equations assume the simple form

$$x'=\alpha x, \qquad y'=\beta y, \qquad z'=\gamma z.$$

It is easily shown that four collinear points before the transformation are collinear after the transformation, and that their anharmonic ratio is unaltered.

This general form of linear transformation must be specialized in order to represent the movement. As no finite movement can either bring a point to infinity or from infinity, it is obvious that the displacement must be such as to leave the fundamental conic unaltered. It is easily seen that the specification of the transformation in its general form requires eight constants; viz., the ratios of the nine quantities a, b, c, a', b', c', a'', b'', c''. We may imagine five of these constants to be disposed of by the provision that the conic shall remain unaltered. There will still remain three disposable constants to give variety to the possible displacements.

Although the fundamental conic will coincide with itself after the transformation, yet it *generally* happens that each point thereon will slide along the conic during the transformation. It is, however, very important to observe that there are two exceptions to this statement.

Let O, A, B, C be four points upon the fundamental conic which by transformation move into the positions O′, A′, B′, C′. If OX be one of the double rays of the systems OA, OB, OC and OA′, OB′, OC′, and if we use the ordinary notation for anharmonic pencils, then we have

$$O(A, B, C, X)=O(A', B', C', X).$$

But the anharmonic ratio subtended by four points on a conic at any fifth point is constant, whence

$$O(A', B', C', X)=O'(A', B', C', X),$$

and therefore

$$O(A, B, C, X)=O'(A', B', C', X).$$

Suppose the transformation moved X to X′, then since the anharmonic ratio of a pencil is unaltered by transformation we have

$$O(A, B, C, X)=O'(A', B', C', X');$$

whence

$$O'(A', B', C', X)=O'(A'B'C'X');$$

but this can only be true if the rays O′X and O′X′ are coincident, in which case X and X′ are coincident, whence it follows that the point X has remained unaltered notwithstanding the transformation. Similar reasoning applies to the point Y defined by the other double ray, and hence we have the following theorem:—

In that linear transformation of the points in a plane which constitutes a generalized movement, there are two points upon the fundamental conic which remain unchanged.

It also follows that the tangents to the fundamental conic at the points X and Y, as well as the chord of contact, must remain unaltered. These two tangents and their chord of contact must therefore form the triangle of reference to which we were previously conducted by the general theory of this transformation.

It will now easily appear how a transformation of this kind is really a displacement of a rigid plane. The distance between each pair of points is expressed by an anharmonic ratio; such ratios are unchanged by the transformation, and the two points which lay on the absolute originally are also there after the transformation. It therefore appears that the distance in the generalized sense between every pair of points is unchanged by the transformation. In other words, a rigid system will admit of a displacement of the kind now under consideration.

If we denote the two tangents at the unaltered points on the conic by $x=0$, $y=0$, and the chord of contact by $z=0$, then the equation to the absolute is

$$xy-k^2z^2=0.$$

Transforming this equation by the substitution

$$x'=\alpha x, \qquad y'=\beta y, \qquad z'=\gamma^2,$$

we see that the condition $\alpha\beta=\gamma^2$ must be fulfilled.

It is very remarkable that the fundamental conic is only one of a family of conics, each of which remains unaltered by the transformation. In fact every generalized circle of which the intersection of the two tangents is the centre has for its equation $xy-h^2z^2$; and, whatever h may be, this circle remains unaltered by the transformation. Hence we have the following remarkable theorem:—

When a plane rigid system is displaced upon itself there is one point O of the system which remains unaltered, and all the circles which have O as their centre remain unaltered also.

It is quite natural to speak of this motion as a "rotation," and thus we may assert the truth in generalized measurement of the well-known theorem in ordinary geometry that

Every displacement of a plane upon itself could have been produced by a rotation of the plane around a certain point in the plane.

Notwithstanding the rotation of the plane round O, the two tangents from O to the fundamental conic and also their chord of intersection, or the polar of O, remain unaltered; each point on the polar of O is displaced along the polar, and we would in ordinary geometry call this motion a translation parallel to the polar. It thus appears that, in the sense now attributed to the words rotation and translation, a rotation round a point is identical with a translation along the polar of the point.

Another point on which the present theory throws light on the ordinary geometry must be here alluded to. We have seen that the two tangents from O to the fundamental conic remain unchanged during the rotation of the plane round O. It certainly does seem paradoxical to assert that a plane, and all it contains are rotated around a point, and that nevertheless this operation does not alter the position of a certain pair of lines in the plane which pass through the point. But have we not precisely the same difficulty in ordinary geometry? Let us suppose that a plane pencil of rays is rotated through an angle θ about the origin. Then a line through the origin whose equation before the rotation was

$$x+hy=0$$

becomes after the rotation

$$x\cos\theta+y\sin\theta+h(y\cos\theta-x\sin\theta)=0.$$

The lines thus represented are of course in general different, but they will be the same if

$$1+h^2=0.$$

It follows that even in ordinary geometry the two lines $x\pm iy=0$ remain unaltered notwithstanding the rotation of the plane which contains them around their intersection. The two lines here referred to are of course those which are drawn through the two circular points at infinity. This paradox is therefore only a degraded form of the property of the tangents to the fundamental conic.

It can also be readily shown that, *if a plane receive two small rotations round two points, then the total rotation produced could have been produced by a single rotation about a certain point on the line joining the two points.*

Let A, B be the two points and P the pole of the line AB, then a rotation round A will displace B along the line PB to an adjacent point B′. The rotation around B will displace A to A′ along the line PA; but, if A′B′ intersects AB in O, then a single rotation about O would have effected the required displacement of A and B, and therefore of the whole line. For, as the point O in the line AB could only move by displacement into the line A′B′, while it can also only move in the direction OP, it must obviously remain unaltered.

We are now in a position to inquire how the magnitude of an angle is to be expressed in the present system of measurement. Our definition of the magnitude of an angle must be made consistent with the supposition that when the angle is carried round by rotation about the vertex the magnitude shall remain unaltered. As anharmonic ratios are unaltered by the rotation, it follows that the anharmonic ratio of the pencil formed by the two legs of the angle and the two tangents to the fundamental conic must remain unaltered. Remembering that the tangents do not move by the rotation, it is natural to choose a function of this anharmonic ratio as the appropriate measure of an angle. The question still remains as to what function should be chosen. The student of ordinary geometry is doubtless aware that the angle between two lines multiplied into $2i$ is equal to the logarithm of the anharmonic ratio of the pencil formed by joining the intersection of the two lines to the two imaginary circular points at infinity. This consideration suggests that the angle between the straight lines in the generalized sense may be appropriately measured by the logarithm of the anharmonic ratio of the pencil formed by the two legs of the angle and the two tangents drawn from their point of intersection to the fundamental conic. There is also a convenience in assuming the angle to be actually *equal* to c times the logarithm of the anharmonic ratio, where c is the same constant as is employed in the expression of the distance. In this case the angle between two lines is by a well-known theorem equal to the distance between their poles. There is here an analogy to a well-known theorem in spherical geometry.

It will now be obvious that, however the angle be situated, its magnitude is unchanged by any displacement of the plane; for, as we have already seen that the displacement does not alter the distance between the poles of the two lines forming the angle, it follows that the magnitude of the angle itself is unaltered.

Just as in the measurement of distance we find a pair of fundamental points on each straight line, so in the measurement of angles we find a pair of fundamental rays in each plane pencil. These rays are the two tangents from the vertex of the pencil to the fundamental conic. In ordinary geometry the two fundamental points on each straight line coalesce into the single point at infinity; but it is exceedingly interesting to observe that even in ordinary geometry the two fundamental rays on each pencil do not coincide. It should also be observed that in the degraded circumstances of ordinary geometry it would be impracticable to employ the *same* constant c for the purpose of both linear and angular measurement.

It is easy to see that the definition of a right angle in the generalized sense is embodied in the statement that "if two corresponding legs of an harmonic pencil touch the fundamental conic then the two other legs are at right angles." We also see that all the perpendiculars to a given line pass through a point, *i.e.*, the pole of the given line; and from a given point a perpendicular can be drawn to a given line by joining the point to the pole of the line. The common perpendicular to two lines is obtained by joining their poles.

The student of modern geometry is already accustomed to think of parallel lines as lines which intersect at infinity, or as lines whose inclination is zero. In speaking of the generalized geometry *in a plane*, we may define that *two straight lines which intersect upon the fundamental conic are parallel.* It thus follows that through any point two distinct parallels can be drawn to a given straight line. The only exception will arise in the case where the given line touches the fundamental conic. This is precisely the case in which the generalized system of measurement degrades to the ordinary system. It will follow that in the present theory of measurement the three angles of a triangle are together not equal to two right angles. In fact, to take an extreme case, we may suppose the three vertices of the triangle to lie upon the fundamental conic. In this case each of the three angles, and therefore their sum, is equal to zero.

A sphere in the generalized system of measurement is the locus of a point which moves at a constant distance from a fixed point. It can therefore be easily shown that a sphere is a quadric which touches the fundamental quadric along its intersection with the polar plane of the centre of the sphere.

In discussing the general case of the displacement of a rigid system it will simplify matters to suppose that the fundamental quadric has real rectilinear generators. It must, however, be understood that the results are not on that account less general. A displacement must not alter the quadric, and must not deform a straight line. Hence it follows that the only effect of a displacement upon a generator of the fundamental quadric will be to convey it to a position previously occupied by a different generator. We shall further suppose that the displacement is such that the two generators to which we have referred belong to the same system. Let A, B, C, D be four generators of the first system which by displacement are brought to coincide with four other generators A′, B′, C′, D′. Let X be one generator of the second system which the displacement brings to X′. Since the anharmonic ratio of the four points in which four fixed generators of the one system are cut by any generator of the other system is constant, we must have, using an obvious notation for anharmonic ratio,

$$X(ABCD) = X'(ABCD);$$

but, since anharmonic ratios are unaltered by displacement, we have

$$X(ABCD) = X'(A'B'C'D'),$$

whence

$$X'(ABCD) = X'(A'B'C'D').$$

It therefore follows that the anharmonic ratio in which four generators cut a fixed generator X′ is equal to the anharmonic ratio in which the four generators after displacement cut the same generator X′.

If P be a generator which passes through one of the double points on X′ determined by the two systems of points in which X′ is cut by the four generators before and after displacement, we must have

$$X(A, B, C, P) = X'(A', B', C', P);$$

hence we see that the generator P will be unaltered by displacement. Similar reasoning applies to the generator which passes through the other double point, and of course to a pair of generators of the second system, and hence we have the following remarkable theorem :—

In the most general displacement of a rigid system two generators of each of the systems on the fundamental quadric remain unaltered.

These four fixed generators are the edges of a tetrahedron. Denoting the four faces of this tetrahedron by the equations

$$x=0,\ y=0,\ z=0,\ w=0,$$

the equation of the fundamental quadric is

$$xz + h^2yw = 0.$$

If the quadric be unaltered by the transformation

$$x' = \alpha x,\ y' = \beta y,\ z' = \gamma z,\ w' = \delta w,$$

then we must have

$$\alpha\gamma = \beta\delta.$$

When this condition is satisfied, then, whatever h may be, every quadric of the family

$$xz + hyw = 0$$

will remain unaltered.

The family of quadrics here indicated are analogous to the right circular cylinders which have for a common axis the screw along which any displacement of a rigid body in ordinary space may be effected.

The two lines

$$x=0,\ z=0$$

and

$$y=0,\ w=0$$

are conjugate polars with respect to the fundamental quadric, and both these lines are unaltered by the displacement. Hence we see that *in any displacement of a rigid system there are two right lines which remain unaltered, and these lines are conjugate polars with respect to the fundamental quadric.*

Since the pole of a plane through one of these lines lies on the other line, it appears that *a rotation of a rigid system about a straight line is identical with a translation of the system along its conjugate polar.*

Clifford has pointed out the real nature of the lines which are to be called parallel in the generalized system of measurement. We have explained that in the plane two parallel lines intersect upon the fundamental conic; in a certain sense also we may consider two lines in space of three dimensions to be parallel whenever they intersect upon the fundamental quadric. This is the view of parallel lines to which we are conducted by simply generalizing the property that two parallel lines intersect at infinity. But we can take a different definition of two parallel lines. Let us, for example, call two lines parallel when they admit of an indefinitely large number of common perpendiculars. It is exceedingly interesting to observe that when this condition is fulfilled in the generalized system of measurement the parallel lines so obtained enjoy many of the properties of ordinary parallel lines. The perpendicular distance between such a pair of parallels is constant, and the angles which they make with any common transversal are equal.

It will be shown in a moment that any pair of straight lines which intersect the same two generators of the same system on the fundamental quadric are parallel in this new sense. The fact is that in the degraded circumstances of ordinary geometry two quite different conceptions have become confused. A pair of lines which intersect on the fundamental quadric and a pair of lines which intersect the same pair of generators of the same kind on the fundamental quadric are quite different conceptions; but when the fundamental quadric degrades to the ordinary infinity then the conceptions coalesce, and each of them is merely a pair of parallel lines in the ordinary sense of the word. The ordinary properties of parallel lines have all their analogues in the generalized geometry, but these analogues are distributed between the two original sources of parallels. Clifford proposes to retain the word "parallel" in non-Euclidean space for that conception which exhibits the more remarkable properties of ordinary space, and defines as follows:—

Straight lines which intersect the same two generators of the same system on the fundamental quadric are parallel.

Let X and Y be two rectilinear generators of the fundamental quadric belonging to the same system, and let A and B be two straight lines which intersect both X and Y. Since AX and AY are tangent planes their poles must lie on X and Y respectively, and therefore A′ (and B′), the polar of A (and B), must intersect both X and Y. The anharmonic ratio of the four points in which X intersects AB, A′B′ respectively is equal to that of the tangent planes drawn at the points where X intersects A′B′, AB respectively; and, as all these tangent planes contain X, their anharmonic ratio must be equal to that in which they are cut by the line Y. It hence follows that the lines X and Y are divided equianharmonically by the four rays A, B, A′, B′, and therefore the four rays A, B, A′, B′ must be all generators of the same system on an hyperboloid. An infinite number of transversals can therefore be drawn to intersect these four rays, that is to say, an infinite number of common perpendiculars can be drawn to the two rays A and B, and it is easy to show that the lengths of all these perpendiculars are equal.

Clifford has proved the very remarkable theorem that rotations of equal amplitude about two conjugate polars have simply the effect of translating every point operated on through equal distances along parallel lines. This property leads to most important consequences, but it would lead us too far to enter into the subject at present.

A memoir by the present writer on the extension of the theory of screws to space of this description will be found in the *Transactions of the Royal Irish Academy*, vol. xxvii. pp. 157–184.

Units of Measurement.—A most excellent account of the units employed in scientific measurements will be found in Professor J. D. Everett's *Units and Physical Constants*, London, 1879. We shall here only give a very brief outline of this branch of the general theory of measurement, referring inquirers to Everett's volume for further details.

Most of the quantities for which measurements are needed can be ultimately expressed by means of (1) a definite length, (2) a definite mass, or (3) a definite interval of time.

It is very important that the units thus referred to should be chosen judiciously, and it must be admitted that the units ordinarily used do not fulfil the conditions which a well-chosen system of units should fulfil. The most scientific system is beyond doubt that which has been suggested by the units committee of the British Association. In this system the unit of length is the *centimetre*, the unit of mass is the *gramme*, and the unit of time is the *second*, and the system is therefore often referred to for brevity as the C.G.S. system. The unit of force is termed the *dyne*, and it is defined to be the force which, acting upon a gramme of matter for a second, generates a velocity of a centimetre per second. The unit of work is the work done by this force working through a centimetre, and this unit is termed the *erg*. The unit of power is the power of doing work at the rate of one erg per second, and the power of an engine can be specified in ergs per second. By the prefixes deca, hecto, kilo, mega, we can express a magnitude equal to the unit multiplied by 10, 100, 1000, or 1,000,000 respectively. On the other hand the prefixes deci, centi, milli, micro, signify the units divided by 10, 100, 1000, or 1,000,000 respectively.

For comparison with the ordinary units the following statements will be useful. The weight of a gramme at any part of the earth's surface is about 980 dynes, or rather less than a kilodyne. The weight of a kilogramme is rather less than a megadyne, being about 980,000 dynes.

The application of these units to electrical and many other measurements will be found in Professor Everett's book already referred to. On the general principles of appliances for measurement, see a paper by Clifford in the *Handbook to the Special Loan Collection of Scientific Apparatus*, 1876, pp. 55–59, reprinted in Clifford's *Mathematical Papers*, pp. 419–23. (R. S. B.)

MEATH, a maritime county of Ireland, in the province of Leinster, is bounded E. by the Irish Sea, S.E. by Dublin, S. by Kildare and King's county, W. by Westmeath, N.W. by Cavan and Monaghan, and N.E. by Louth. Its greatest length north and south is about 40 miles, and its breadth east and west about 45 miles. The total area comprises 578,247 acres, or 904 square miles.

The county forms part of the great limestone plain that occupies the central portion of Ireland. In some districts the surface is variegated by hills and swells, which to the west reach a considerable elevation, although the general features of a fine champaign country are never lost. The coast, which is low and shelving, extends to about 10 miles, but there is no harbour of importance. The Boyne, whose banks are specially beautiful, enters the county at its south-west extremity, and flowing north-east to Drogheda divides it into two almost equal parts. At Navan it receives the Blackwater, which flows south-west from Cavan. The Boyne is navigable for barges as far as Navan, where a canal is carried to Trim. The Royal Canal passes along the southern boundary of the county to Dublin. There are no lakes of importance.

Climate and Agriculture.—The climate is genial and favourable for all kinds of crops, there being less rain than even in the neighbouring counties. The principal substratum is limestone, but there are some districts of clay slate. Except a small portion occupied by the Bog of Allen, the county is very verdant and fertile. The soil is principally a rich deep loam resting on limestone gravel, but varies from a strong clayey loam to a light sandy gravel.

The total number of holdings in 1881 was 11,867, of which 1632 were less than 1 acre in extent, and 4300 between 5 and 15 acres. Only 93 were above 500 acres. According to the agricultural statistics for 1881, the area of arable land was 532,708 acres, or 92·4 per cent. of the whole area of the county, while 9599 acres were under plantations, 11,260 bog and marsh, and 201 barren mountain land. Of the arable land, 60,411 were under tillage, 85,893 meadow and clover, and 386,374 pasture. The following table shows the area under the different crops in 1855 and 1882:—

	Wheat.	Oats.	Other Cereals.	Potatoes.	Turnips.	Other Green Crops.	Flax.	Meadow and Clover.	Total.
1855	18,764	86,831	4,876	19,235	9,904	4,005	266	64,646	208,527
1882	2,783	31,202	1,577	12,071	6,724	3,109	59	82,572	140,097

Horses between 1855 and 1882 have diminished from 23,310 to 15,316, an average of 2·9 to every 100 acres under cultivation, the average for Ireland being 3·2. Cattle in 1855 numbered 135,485, and in 1882 had increased to 176,121, an average of 33 to every 100 acres under cultivation, the average for Ireland being 26·2. Sheep in 1855 numbered 170,582, and in 1882 only 146,749, although in 1880 they were 174,573. Pigs in 1882 numbered 19,709, goats 6398, and poultry 318,968.

According to the latest return the land was divided among 1322 proprietors, who possessed 577,846 acres, with a total annual value of £544,550. The average size of the properties was 436 acres, and the average annual value per acre was 18s. 10d. The following four proprietors possessed more than 10,000 acres each: viz., Earl of Darnley, 21,858 acres; J. L. Naper, 18,863; Marquis of Lansdowne, 12,995; and Lord Athlumney, 10,213.

Manufactures.—Almost the sole industry of the county is agriculture, but coarse linen is woven by hand-looms, and there are a few woollen manufactories.

Railways.—The Dublin and Meath line intersects the county in a north-westerly direction, and separates into several branches, while the Great Western line skirts the southern boundary.

Administration and Population.—The county includes 18 baronies, 146 parishes, and 1626 townlands. Assizes are held at Trim, and quarter sessions at Dunshauglin, Duleek, Kells, Navan, and Trim. Two poor-law unions, Navan and Trim, are wholly within the county, and parts of Ardee, Celbridge, Drogheda, Dunshauglin, Edenderry, Kells, and Old Castle. It is in the Dublin military district, subdistrict of Birr, with barrack stations at Navan and Trim. Ecclesiastically it is in the Meath diocese, with portions in Armagh and Kilmore. Previous to the Union it sent fourteen members to parliament, but now only the two members for the county are returned.

From 81,516 in 1760 the population in 1821 had increased to 159,183, and in 1841 to 183,828, but by 1851 had diminished to 140,768, in 1871 to 95,558, and in 1881 to 87,469, of whom 44,315 were males and 43,154 females. The principal towns are Navan, 3873; Kells, 2822; and Trim, 1586. A portion of the parliamentary borough of Drogheda, including 933 of the inhabitants, is also within the county. The number of births in the county during the ten years ending 3d March 1881 was 21,293, an average of 23·3 to every 1000 of the population; of deaths 16,878, an average of 18·4; of marriages 3165, an average of 3·5; and of emigrants 10,521, an average of 12·1. From 1st May 1851 to 3d March 1881 the total number of emigrants was 49,375. Of the population five years old and upwards in 1881, 22·7 per cent. were illiterate, the percentage in 1871 being 29·9. In 1881 there were 3531 persons able to speak Irish, but none were unable to speak English.

History and Antiquities.—According to Ptolemy, Meath was originally inhabited by the Eblani, whose territory extended from the Boyne to the Liffey. A district known as Meath, and including the present county of Meath as well as Westmeath and Longford, with parts of Cavan, Kildare, and King's county, was in the 2d century formed by Tuathal into a kingdom to serve as mensal land of the Ard Ré or over-king. Afterwards it was divided into Oireamhain, now known as Meath, and Eireamhain, which included the remainder of the old kingdom. The district was frequently subject to invasions from the Danes; they were totally defeated at Tara in 980. About 800,000 acres, including all the present county of Meath, was granted by Henry II. to Hugh de Lacy.

The most remarkable antiquarian remains are two round towers, the one at Kells, and the other in the churchyard of Donoughmore, near Navan. At New Grange, near Slane, there is an artificial cavern of a very peculiar construction. A large rath on Tara hill was the meeting-place of the princes before the Danish invasion, and the seat of a royal palace referred to in the well-known lines of Moore. A stone on the top of the rath is supposed by some to be the stone of destiny where the ancient monarchs of Ireland were crowned. Monastic buildings were very numerous, among the more important ruins being those of Duleek, which is said to have been the first ecclesiastical edifice in Ireland built of stone and mortar; the extensive remains of Bective; and those of Clonard, where also were a cathedral and a very famous college. Of the old fortresses, Trim Castle on the Boyne still presents an imposing appearance. There are also many fine old mansions.

MEAUX, capital of an arrondissement, and an episcopal see, in the department of Seine-et-Marne, France, and formerly chief town of Haute Brie, is situated 28 miles east of Paris, on the Marne, which runs through the town, and on the Paris and Strasburg Railway. The cathedral, dedicated to St Stephen, dates from the 12th century; its restoration was begun thirty years ago. From the top of its western tower (250 feet high), in fine weather, the heights of Montmartre and Mont Valérien, near Paris, can be seen. The building, which is 275 feet long and 105 feet high, consists of a nave, two aisles, a fine transept, a choir, and a sanctuary. The choir contains the statue and the tomb of Bossuet, and the pulpit of the cathedral has been reconstructed with the panels of that from which the "Eagle of Meaux" used to preach. The great window of the south transept contains some magnificent stained glass. The episcopal palace, behind the cathedral, has several very curious old rooms; the buildings of the choir school, which also adjoins the cathedral, are likewise of some architectural and archæological interest.

Meaux is the centre of a considerable trade in corn, cheese, eggs, and poultry; and its mills, on the Marne, provide a great part of the meal with which Paris is supplied. The Canal de l'Ourcq, which surrounds the town, and the Marne, furnish the means of transport. A starch manufactory, a copper and iron foundry, and manufactories of food-pastes, of preserved vegetables, and of agricultural implements are the other principal industrial establishments. About a mile from the town is the sugar factory of Villenoy, which is one of the largest in France. The population of Meaux is 11,740.

In the Roman period Meaux was the capital of the Meldi, a small Gallic tribe. It formed part of the kingdom of Austrasia, and afterwards belonged to the counts of Vermandois and Champagne. Its communal charter dates as far back as 1179. Meaux suffered much from the disorders of the Jacquerie, from the Hundred Years' War, and from the religious wars, during which it was an important Protestant centre. After the League, it was the first town which opened its gates to Henry IV., in 1594. Placed as it is on the highroad of invaders marching on Paris from the east of France, Meaux saw its environs ravaged by the army of Lorraine in 1652, and was laid under heavy requisitions in 1814, 1815, and 1870.

MECCA (مكة, *Makka*), the chief town of the Ḥijáz in Arabia,[1] and the great holy city of Islám, is situated two camel marches (the resting-place being Baḥra or Ḥadda in the Baṭn Marr), or about 45 miles, almost due east, from Jidda, on the Red Sea.[2] Thus on a rough estimate Mecca lies in 21° 30′ N. lat. and 40° E. long.

It is said in the Koran (*sur.* xiv. 40) that Mecca lies in a sterile valley, and the old geographers observe that the whole Ḥaram or sacred territory round the city is almost absolutely without cultivation or date palms, while fruit trees, springs, wells, gardens, and green valleys are found immediately beyond. Mecca in fact lies in the heart of a mass of rough hills, intersected by a labyrinth of narrow valleys and passes, and projecting into the Tiháma or low country on the Red Sea, in front of the great mountain wall that divides the coast lands from the central plateau, though in turn they are themselves separated from the sea by a second curtain of hills forming the western wall of the great Wády Marr. The inner mountain wall is pierced by two and only two great passes, and the valleys descending from these embrace on both sides the Mecca hills. The north-western pass, through which the Nejd traffic descends to the coast, and which also affords the easiest though longest route from Jidda and Mecca to Ṭáif and thence through the true Ḥijáz to Yemen, is the Derb el-Seil or torrent path down the well-watered Wády Marr.[3] This Wády skirts the complex of Mecca hills on the north-west from Zeima by Wády Fáṭima (where it is joined by the great coast road from Medina and Syria) to Ḥadda on the Mecca and Jidda road, a distance of perhaps 50 miles. Main roads converge to Mecca from the three points of the Wády just named, the distance of the city from the last two being about 20 miles. From this side the most prominent of the Mecca hills is the northern "Mountain of Light" (J. Núr). The other pass, which affords a shorter mule road to Ṭáif and the southern highlands, but is not practicable for ordinary baggage camels, descends from the summit of J. Kara, and leads through the great W. Naʿmán, the Wády of the Hodheil, to the plain beneath ʿArafa, the most

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[1] Ḥijáz is here taken in the usual political sense of the word. The Turkish Wály of the Ḥijáz has his winter residence at Mecca and his summer quarters at Ṭáif. In a narrower sense the Ḥijáz is the lofty mountainous country between the central plateau of Nejd (or Negd, as it is called by the natives) and the lowlands of the coast (Tiháma). In this sense El-Asmaʿí reckons Mecca to the Tiháma, and well-informed Arabs still follow him.

[2] A variant of the name Makka is Bakka (*sur.* iii. 90; Bekrí, 155 *sq.*). For other names and honorific epithets of the city see Bekrí, *ut supra*, Azraḳí, p. 197, Yáḳút, iv. 617 *sq.* The lists are in part corrupt, and some of the names (Kúthá and ʿArsh or ʿUrsh, "the huts") are not properly names of the town as a whole.

[3] The upper part of this wády has two branches, W. Leimún and W. Nakhla. In the latter lie the gardens of Sóla and the village of Zeima with its great hot spring (comp. Yáḳút, iii. 197). Above Zeima the path is desert.

easterly of the holy sites connected with Mecca. From this point a tolerably level route skirts the Mecca hills on the south, passing very close to Mecca under the opposite side of J. el-Thaur, is joined or crossed by several roads from the south, including the great lowland Yemen road, and ultimately falls into the road from Mecca to Hadda, a little beyond the pillars that define the Haram. The broad valleys through which this southern road leads are not so well watered as W. Marr, but have several fertile spots and a good deal of land cultivable after rain.[1] From this description the importance of the situation of Mecca will be easily understood. It commands both the great routes connecting the lowlands with central Arabia, and thus has the advantage over Țáif, its former commercial rival, which lies indeed on the inland mountain road from Yemen to Nejd behind Mount Kara, but has no ready connexion with the Tihâma. Mecca, on the contrary, though apparently secluded in its hills from the main valleys—it is in fact not visible from any point till one is quite close to the town—lies in the focus of all the great roads from north to south or from the coast inland, with the single exception of the mountain road behind Kara; and the low passes that intersect the Mecca hills form a series of practicable short cuts connecting all the chief points of the circle of valleys already described.[2]

Holding this position, and situated in a narrow and barren valley quite incapable of supporting an urban population, Mecca must have been from the first a commercial town.[3] In the palmy days of South Arabia it was probably a station on the great incense route, and thus Ptolemy may have learned the name, which he writes Makoraba. At all events, long before Mohammed we find Mecca established in the twofold quality of a commercial centre and a privileged holy place, surrounded by an inviolable territory (the Haram), which was not the sanctuary of a single tribe but a place of pilgrimage, where religious observances were associated with a series of annual fairs at different points in the vicinity.[4] The combination of commerce with religion was no unusual thing in Arabia. Of old the incense trade had its religious features, and indeed in the unsettled state of the country commerce was possible only under the sanctions of religion, and through the provisions of the sacred truce which prohibited war for four months of the year, three of these being the month of pilgrimage, with those immediately preceding and following. The first of the series of fairs in which the Meccans had an interest was at 'Okáz on the easier road between Mecca and Țáif, where there was also a sanctuary, and from it the visiters, drawn from tribes far and near, moved on to points still nearer Mecca (Majanna, and finally Dhu'l-Majáz, on the flank of J. Kabkab behind 'Arafa) where further fairs were held,[5] culminating in the special religious ceremonies of the great feast at 'Arafa, Kuzah (Mozdalifa), and Mecca itself. The system of intercalation in the lunar calendar of the heathen Arabs was designed to secure that the feast should always fall at the time when the hides, fruits, and other merchandise were ready for market,[6] and the Meccans, who knew how to attract the Bedouins by profuse and systematic hospitality, bought up these wares in exchange for imported goods, and so became the leaders of the international trade of Arabia. Their caravans traversed the length and breadth of the peninsula. Syria, and especially Gaza, was their chief goal, and we read that the Syrian caravan intercepted, on its return, at Bedr represented capital to the value of £20,000, an enormous sum for those days.[7]

The victory of Mohammedanism made a vast change in the position of Mecca. The merchant aristocracy became satraps or pensioners of a great empire; but the seat of dominion was removed beyond the desert, and though Mecca and the Hijáz strove for a time to maintain political as well as religious predominance, as will be related under MOHAMMEDAN EMPIRE, the struggle was vain, and terminated on the death of Ibn Zubeyr, the Meccan pretendant to the caliphate, when the city was taken by Hajjáj (692 A.D.). On the other hand, the sanctuary and feast of Mecca received a new prestige from the victory of Islám. Purged of elements obviously heathenish, the Ka'ba (Caaba) became the holiest site, and the pilgrimage the most sacred ritual observance of Mohammedanism, drawing worshippers from so wide a circle that the confluence of the petty traders of the desert was no longer the main feature of the holy season. The pilgrimage retained its importance for the commercial wellbeing of Mecca; to this day the Meccans live by the Hajj—letting rooms, acting as guides and directors in the sacred ceremonies, as contractors and touts for land and sea transport, as well as exploiting for their own advantage the many benefactions that flow to the holy city; while the surrounding Bedouins derive a chief part of their support from the camel-transport it demands and from the subsidies and gifts by which they are engaged to protect or abstain from molesting the pilgrim caravans. But the ancient "fairs of heathenism" were given up, and the traffic of the pilgrim season, sanctioned by the Prophet in *sur.* ii. 194, was concentrated at Miná and Mecca, where most of the pilgrims still have something to buy or sell, so that Miná, after the sacrifice of the feast day, presents the aspect of a huge international fancy fair.[8] In the Middle Ages this trade was much more important than it is now. Ibn Jubair in the 12th century describes the mart of Mecca in the eight days following the feast as full of gems, unguents, precious drugs, and all rare merchandise from India, 'Irák, Khorásán, and every part of the Moslem world.[9]

Mecca, as has been already indicated, lies in a narrow sandy valley running approximately from north to south between the Red Mountain on the west and the loftier chain of J. Abu Kobeys on the east. These ranges, which are partly built on and rise several hundred feet above the valley, so enclose the city that the ancient walls only barred the valley at three points, where three gates led into the town. In the time of Ibn Jubair the gates still stood though the walls were ruined, but now the gates have only left their names to

[1] To this description of the valleys surrounding the Mecca group on three sides, which is mainly drawn from personal observation in 1880, it may be added that there is a direct and easy camel route from Zeima to 'Arafa between the Mecca hills and the mountains of the Hodheil. Taking this fact with the statement of Wákidí (Wellhausen's *Muh. in Med.*, p. 341) that every wády in the sacred territory flows outwards into common ground except that at Tan'im (near the Hudúd on the Medina road, Yákút, i. 879; Ibn Jubair, p. 110) we see that Mecca lies in an isolated group of hills—a sort of outpost of the great mountain wall.

[2] The inland road in ancient times was not so valuable as the coast road to Syria, on account of the scarcity of water (*Muh. in Med.*, p. 100).

[3] Mecca, says one of its citizens, ap. Wákidí (Kremer's ed., p. 196, or *Muh. in Med.*, p. 100), is a settlement formed for trade with Syria in summer and Abyssinia in winter, and cannot continue to exist if the trade is interrupted.

[4] Details as to the inhabitants and constitution of Mecca before Islám will be given under MOHAMMED.

[5] The details are variously related. See Bírúní, p. 328 (E. T., p. 324); Asma'í in Yákút, iii. 705, iv. 416, 421; Azrakí, p. 129 *sq.*; Bekrí, p. 661. Jebel Kabkab is a great mountain occupying the angle between W. Na'mán and the plain of 'Arafa. The peak is due north of Sheddád, the hamlet which Burckhardt (i. 115) calls Shedad. According to Azrakí, p. 80, the last shrine visited was that of the three trees of 'Uzzá in W. Nakhla.

[6] So we are told by Bírúní, p. 62 (E. T., p. 73).

[7] Wákidí, ed. Kremer, pp. 20, 21; *Muh. in Med.*, p. 39.

[8] The older fairs were not entirely deserted till the troubles of the last days of the Omayyads (Azrakí, p. 131).

[9] Ibn Jubair, ed. Wright, p. 118 *sq.*

quarters of the town. At the northern or upper end was the Báb el Ma'lá, or gate of the upper quarter, whence the road continues up the valley towards Miná and 'Arafa as well as towards Zeima and the Nejd. Beyond the gate, in a place called the Ḥajún, is the chief cemetery, said to be the resting-place of many of the companions of Mohammed. Here a cross-road, running over the hill to join the main Medina road from the western gate, turns off to the west by the pass of Kadá, the point from which the troops of the Prophet stormed the city (A.H. 8).[1] Here too the body of Ibn Zubeyr was hung on a cross by Ḥajjáj. The lower or southern gate, at the Masfala quarter, opened on the Yemen road, where the rain-water from Mecca flows off into an open valley. Beyond, there are mountains on both sides; on that to the east, commanding the town, is the great castle, a fortress of considerable strength. The third or western gate, Báb el-'Omra (formerly also Báb el-Záhir, from a village of that name), lay almost opposite the great mosque, and opened on a road leading westwards round the southern spurs of the Red Mountain. This is the way to Wády Fátima and Medína, the Jidda road branching off from it to the left. Considerable suburbs now lie outside the quarter named after this gate; in the Middle Ages a pleasant country road led for some miles through partly cultivated land with good wells, as far as the boundary of the sacred territory and gathering place of the pilgrims at Tan'ím, near the mosque of 'Áisha. This is the spot on the Medína road now called the 'Omra, from a ceremonial connected with it which will be mentioned below.

The length of the sinuous main axis of the city from the furthest suburbs on the Medina road to the suburbs in the extreme north, now frequented by Bedouins, is, according to Burckhardt, 3500 paces.[2] About the middle of this line the longitudinal thoroughfares are pushed aside by the vast courtyard and colonnades composing the great mosque, which, with its spacious arcades surrounding the Ka'ba and other holy places, and its seven minarets, forms the only prominent architectural feature of the city. The mosque is enclosed by houses with windows opening on the arcades and commanding a view of the Ka'ba. Immediately beyond these, on the side facing J. Abu Ḳobeys, a broad street runs south-east and north-west across the valley. This is the Mas'á or sacred course between the eminences of Ṣafá and Merwa, and has been from very early times one of the most lively bazaars and the centre of Meccan life. The other chief bazaars are also near the mosque in smaller streets. The rest of the town presents no points of individual interest, but its general aspect is picturesque; the streets are fairly spacious, though ill-kept and filthy; the houses are all of stone, many of them well-built and four or five stories high, with terraced roofs and large projecting windows as in Jidda—a style of building which has not varied materially since the 10th century (Moḳaddasí, p. 71), and gains in effect from the way in which the dwellings run up the sides and spurs of the mountains. Of public institutions there are baths, ribáṭs or hospices for poor pilgrims from India, Java, &c., a hospital with fifty beds, a public kitchen for the poor, badly administered by the Turkish authorities. A settler from India has recently set up a theological school; but the old colleges around the mosque have long since been converted into lodgings.[3] The minor places of visitation for pilgrims, such as the birth-places of the Prophet and his chief followers, are not notable.[4] Both these and the court of the great mosque are observed to lie beneath the general level of the city, so that it is evident that the site of the town has been gradually raised by accumulated rubbish. The town in fact has little air of antiquity; genuine Arab buildings do not last long, especially in a valley periodically ravaged by tremendous floods when the tropical rains burst on the surrounding hills. The history of Mecca is full of the record of these inundations, unsuccessfully combated by the great dam drawn across the valley by the caliph 'Omar (Ḳuṭb el-Dín, p. 76), and later works of El-Mahdí.[5]

The fixed population of Mecca in 1878 was estimated by Assistant-Surgeon 'Abd el-Razzáḳ at 50,000 to 60,000; but the materials for an estimate are very inadequate where there is so large a floating population—and that not merely at the proper season of pilgrimage, the pilgrims of one season often beginning to arrive before those of the former season have all dispersed. At the height of the season the town is much overcrowded, and the entire want of a drainage system is severely felt. Fortunately good water is tolerably plentiful; for, though the wells are mostly undrinkable, and even the famous Zamzam water very unwholesome and tainted with sewage, the underground conduit from beyond 'Arafa, completed by Sultan Selim II. in 1571, supplies to the public fountains a sweet and light water, containing, according to 'Abd el-Razzáḳ, a large amount of chlorides. The water is said to be free to townsmen, but is sold to the pilgrims at a rather high rate.[6]

Mediæval writers celebrate the copious supplies, especially of fine fruits, brought to the city from Ṭáif and other fertile parts of Arabia. These fruits are still famous; rice and other foreign products are brought by sea to Jidda; mutton is plentifully supplied from the desert.[7] The industries of Mecca all centre in the pilgrimage; the chief object of every Meccan—from the notables and sheikhs, who use their influence to gain custom for the Jidda speculators in the pilgrim traffic, down to the cicerones, pilgrim brokers, lodging-house keepers, and semi-mendicant hangers on at the holy places—being to pillage the visiter in every possible way. Thus the fanaticism of the Meccan is an affair of the purse; the mongrel population (for the town is by no means purely Arab) has exchanged the virtues of the Bedouin for the worst corruptions of Eastern town life, without casting off the ferocity of the desert, and it is hardly possible to find a worse certificate of character than the three parallel gashes on each cheek, called Tashríṭ, which are the customary mark of birth in the holy city. The unspeakable vices of Mecca are a scandal to all Islám, and a constant source of wonder to pious pilgrims.[8] The slave trade, which still

[1] This is the cross-road traversed by Burckhardt (i. 109), and described by him as cut through the rocks with much labour.

[2] Istakhrí gives the length of the city proper from north to south as 2 miles, and the greatest breadth from the Jiyád quarter east of the great mosque across the valley and up the western slopes as two-thirds of the length.

[3] The pious foundations of Mecca have been robbed by their guardians from very early times. See already Ibn Ḥauḳal, p. 25.

[4] For details as to the ancient quarters of Mecca, where the several families or septs lived apart from generation to generation, see Azraḳí, p. 445 *sq.*, and compare Ya'kubí, ed. Juynboll, p. 100. The modern town is best described by Burckhardt, who gives a plan of the city. The minor sacred places are described at length by Azraḳí and Ibn Jubair. They are either connected with genuine memories of the Prophet and his times, or have spurious legends to conceal the fact that they were originally holy stones, wells, or the like, of heathen sanctity.

[5] Beládhorí, in his chapter on the floods of Mecca (p. 53 *sq.*), says that 'Omar built two dams.

[6] The aqueduct is the successor of an older one associated with the names of Zobeyda, wife of Harún el-Rashíd, and other benefactors. But the old aqueduct was frequently out of repair, and seems to have played but a secondary part in the mediæval water supply. Even the new aqueduct gave no adequate supply in Burckhardt's time.

[7] In Ibn Jubair's time (p. 132) large supplies were brought from the Yemen mountains. The revenues of Yemen are still mainly expended on the distribution of grain by the sultan in the Ḥijáz.

[8] The corruption of manners in Mecca is no new thing. See the letter of the caliph Mahdí on the subject; Wüstenfeld, *Chron. Mek.*, iv. 168.

subsists and is very dear to the Arab heart, has connexions with the pilgrimage which are not yet thoroughly cleared up; but there is no doubt that under cover of the pilgrimage a great deal of kidnapping and importation of slaves goes on.

Since the fall of Ibn Zubeyr the political position of Mecca has always been dependent on the movements of the greater Mohammedan world. In the splendid times of the caliphs immense sums were lavished upon the pilgrimage and the holy city; and conversely the decay of the central authority of Islám brought with it a long period of faction, wars, and misery, in which the most notable episode was the sack of Mecca, with circumstances of great barbarity, by the Carmathians at the pilgrimage season of 930 A.D. The victors carried off the "black stone," which was not restored for twenty-two years, and then only for a great ransom, when it was plain that even the loss of the palladium could not destroy the sacred character of the city. Under the Fatimites Egyptian influence began to be strong in Mecca; it was opposed by the sultans of Yemen, while native princes claiming descent from the Prophet—the Háshimite emírs of Mecca, and after them the emírs of the house of Katáda (since 1202)—attained to great authority and aimed at independence; but soon after the final fall of the Abbasids the Egyptian overlordship was definitively established by Sultan Bíbars (1269 A.D.). The Turkish conquest of Egypt transferred the supremacy to the Ottoman sultans (1517), who treated Mecca with much favour, and during the 16th century executed great works in the sanctuary and temple. The Ottoman power, however, became gradually almost nominal, and that of the emírs or sherífs increased in proportion, culminating under Ghálib, whose accession dates from 1786. Then followed the wars of the Wahhábís (see ARABIA, vol. ii. p. 260) and the restoration of Turkish rule by the troops of Mohammed ʿAlí. By him the dignity of sheríf was deprived of much of its weight, and in 1827 a change of dynasty was effected by the appointment of Ibn ʿAun. Since that time the Turkish authority has again decayed, though Mecca is still nominally the capital of a Turkish province, and has a governor-general and a Turkish garrison, while Mohammedan law is administered by a judge sent from Constantinople. But, except within the larger towns, at which troops are stationed, the Turks are practically powerless, and the real sovereign of Mecca and the Ḥijáz is the sheríf, who, as head of a princely family claiming descent from the Prophet, holds a sort of feudal position in the country. The dignity of sheríf (or grand sheríf, as Europeans usually say for the sake of distinction, since all the kin of the princely houses reckoning descent from the Prophet are also named sherífs), is often conceived as a religious pontificate, and anti-Turkish Arabs contend that if the sultan and the sheríf were together in a mosque the latter would lead the prayers as imám; but it is more correct to regard the sheríf as the modern counterpart of the ancient emírs of Mecca already referred to, who were named in the public prayers immediately after the reigning caliph. This dignity long ran in the family of Ḥasan, son of the caliph ʿAlí, with which the present sherífs, in spite of changes of dynasty, still count kindred. The influence of the princes of Mecca has varied from time to time according to the strength of the foreign protectorate in the Ḥijáz or in consequence of feuds among the branches of the house; at present it is for most purposes much greater than that of the Turks. The latter are strong enough to hold the garrisoned towns, and thus the sultan is able within certain limits—playing off one against the other the two rival branches of the aristocracy, viz., the kin of Ghálib and the house of Ibn ʿAun—to assert the right of designating or removing the sheríf, to whom in turn he owes the possibility of maintaining, with the aid of considerable pensions, the semblance of his much-prized lordship over the holy cities. The grand sheríf can muster a considerable force of freedmen and clients, and his kin, holding wells and lands in various places through the Ḥijáz, act as his deputies and administer the old Arabic customary law to the Bedouins. To this influence the Ḥijáz owes what little of law and order it enjoys. After the sherífs the principal family of Mecca is the house of Sheyb, which holds the hereditary custodianship of the Kaʿba.

The Great Mosque and the Kaʿba.—Long before Mohammed the chief sanctuary of Mecca was the Kaʿba, a rude stone building, so named from its resemblance to a monstrous *astragalus* or die, of about 40 feet cube, though the shapeless mass is not really an exact cube or even exactly rectangular.[1] The Kaʿba has been rebuilt more than once since Mohammed purged it of idols and adopted it as the chief sanctuary of Islám, but the old form has been preserved except in secondary details;[2] so that the "Ancient House," as it is titled, is still essentially a heathen temple, adapted to the worship of Islám by the clumsy fiction that it was built by Abraham and Ishmael by divine revelation as a temple of pure monotheism, and that it was only temporarily perverted to idol worship from the time when ʿAmr ibn Lohay introduced the statue of Hobal from Syria[3] till the victory of Islám. This fiction has involved the superinduction of a new mythology about Abraham, Hagar, and Ishmael over the old heathen ritual, which remains practically unchanged. Thus the chief object of veneration is the ancient fetish of the black stone, which is fixed in the external angle facing Ṣafá. The building is not exactly oriented, but this may for convenience be called the south-east corner. Its technical name is the black corner, the others being named the Yemen (south-west), Syrian (north-west), and ʿIráḳ (north-east) corners, from the lands to which they approximately point. The black stone is a small dark mass a span long, with an aspect suggesting volcanic or meteoric origin, fixed at such a height that it can be conveniently kissed by a person of middle size. It was broken by fire in the siege of 683 A.D. (not as many authors relate by the Carmathians), and the pieces are kept together by a silver setting. The history of this heavenly stone, given by Gabriel to Abraham, does not conceal the fact that it was originally a fetish, the most venerated of a multitude of idols and sacred stones which stood all round

[1] The following measurements may be cited:—Ibn ʿAbd Rabbih (10th century), south side 20 cubits, north 21, east and west 25 each (so Azraḳí); Ibn Jubair (12th century), sides 54 and 48 spans, height 29 cubits at the highest or south wall, with a slight fall to the north side where the mízáb or water-spout discharges (Azraḳí, 27 cubits); Burckhardt, sides 18 paces by 14, height 35 to 40 feet. Other modern measures vary considerably. The height was raised by Ibn Zubeyr from 18 to 27 cubits. Compare *Muh. in Med.*, p. 426.

[2] The Kaʿba of Mohammed's time was itself the successor of an older building said to have been destroyed by fire. It was constructed in the still usual rude style of Arabic masonry, with string courses of timber between the stones (like Solomon's temple). The roof rested on six pillars; the door was raised above the ground and approached by a stair (probably on account of the floods which often swept the valley); and worshippers left their shoes under the stair before entering. During the first siege of Mecca (683 A.D.) the building was burned down, and Ibn Zubeyr reconstructed it on an enlarged scale and in better style of solid ashlar work. After his death his most glaring innovations (the introduction of two doors on a level with the ground, and the extension of the building lengthwise to include the Ḥijr) were corrected by Ḥajjáj under orders from the caliph, but the building retained its more solid structure. The roof now rested on three pillars, and the height was raised one-half. The Kaʿba was again entirely rebuilt after the flood of 1626 A.D., but since Ḥajjáj there seem to have been no structural changes.

[3] Hobal was set up within the temple over the pit that contained the sacred treasures. His chief function was connected with the sacred lot to which the Meccans were accustomed to betake themselves in all matters of difficulty.

the sanctuary in the time of Mohammed. The Prophet destroyed the idols, but he left the characteristic form of worship—the *ṭawáf*, or sevenfold circuit of the sanctuary, the worshipper kissing or touching the objects of his veneration—and besides the black stone he recognized the so-called "southern" stone, the same presumably with that which is still touched in the ṭawáf at the Yemen corner (*Muh. in Med.*, pp. 336, 425). The ceremony of the ṭawáf and the worship of stone fetishes was common to Mecca with other ancient Arabian sanctuaries.[1] It was, as it still is, a frequent religious exercise of the Meccans, and the first duty of one who returned to the city or arrived there under a vow of pilgrimage; and thus the outside of the Kaʿba was and is more important than the inside. Islám did away with the worship of idols; what was lost in interest by their suppression has been supplied by the invention of spots consecrated by recollections of Abraham, Ishmael, and Hagar, or held to be acceptable places of prayer. Thus the space of ten spans between the black stone and the door, which is on the east side, between the black and ʿIráḳ corners, and a man's height from the ground, is called the *Multazam*, and here prayer should be offered after the ṭawáf with outstretched arms and breast pressed against the house. On the other side of the door, against the same wall, is a shallow trough which is said to mark the original site of the stone on which Abraham stood to build the Kaʿba. Here the growth of the legend can be traced, for the place is now called the "kneading-place" (Maʿjan) where the cement for the Kaʿba was prepared. This name and story do not appear in the older accounts. Once more, on the north side of the Kaʿba, there projects a low semicircular wall of marble with an opening at each end between it and the walls of the house. The space within is paved with mosaic, and is called the Ḥijr. It is included in the ṭawáf, and two slabs of *verde antico* within it are called the graves of Ishmael and Hagar, and are places of acceptable prayer. Even the golden or gilded *mízáb* (water-spout) that projects into the Ḥijr marks a place where prayer is heard, and another such place is the part of the west wall close to the Yemen corner.

The feeling of religious conservatism which has preserved the structural rudeness of the Kaʿba through so many centuries did not interfere with the adoption of costly surface decoration. In Mohammed's time the outer walls were covered by a vail (or *kiswa*) of striped Yemen cloth. The magnificence of the caliphs substituted a covering of figured brocade, and the sultan still sends with each pilgrim caravan from Cairo a new kiswa of black brocade, adorned with a broad band embroidered with golden inscriptions from the Koran, as well as a richer curtain for the door. The aspect thus given to the Kaʿba is seen in the woodcut; there are openings to show the two sacred stones.[2] The door of two leaves, with its posts and lintel, is of silver gilt.

The interior of the Kaʿba is now opened but a few times every year; there is a great scramble for admission—the portable staircase being seldom brought forward—and a great clamour for backshish; thus the modern descriptions, from observations made under difficulties, are not very complete. Little change, however, seems to have been made since the time of Ibn Jubair, who describes the floor and walls as overlaid with richly variegated marbles, and the upper half of the walls as plated with silver thickly gilt, while the roof was vailed with coloured silk. Modern writers describe the place as windowless, but Ibn Jubair mentions five windows of rich stained glass from ʿIráḳ. Between the three pillars of teak hung thirteen silver lamps. A chest in the corner to the left of one entering contained Korans, and at the ʿIráḳ corner a space was cut off enclosing the stair that leads to the roof. The door to this stair (called the door of mercy—Báb el-Raḥma) was plated with silver by the caliph Mutawakkil. Here, in the time of Ibn Jubair, the Maḳám or standing-stone of Abraham was usually placed for better security, but brought out on great occasions (pp. 131, 161).[3]

The houses of ancient Mecca pressed close upon the Kaʿba, the noblest families, who traced their descent from Ḳoṣay, the reputed founder of the city, having their dwellings immediately round the sanctuary. To the north of the Kaʿba was the Dár el-Nadwa, or place of assembly of the Koreysh, where all matters of public interest were discussed. The multiplication of pilgrims after Islám soon made it necessary to clear away the nearest dwellings and enlarge the place of prayer around the Ancient House. ʿOmar, ʿOthmán, and Ibn Zubeyr had all a share in this work, but the great founder of the mosque in its present form, with its spacious area and deep colonnades, was the caliph El-Mahdí, who spent enormous sums in bringing costly pillars from Egypt and Syria. The work was still incomplete at his death in 785 A.D., and was finished in less sumptuous style by his successor. Subsequent repairs and additions, extending down to Turkish times, have left little of El-Mahdí's work untouched, though a few of the pillars probably date from his days. There are more than five hundred pillars in all, of very various style and workmanship, and the enclosure—250 paces in length and 200 in breadth, according to Burckhardt's measurement—is entered by nineteen archways irregularly disposed.

After the Kaʿba the principal points of interest in the mosque are the well Zamzam and the Maḳám Ibráhím. The former is a deep shaft enclosed in a massive vaulted building paved with marble, and, according to Mohammedan tradition, is the source (corresponding to the Beer-lahai-roi of Gen. xvi. 14) from which Hagar drew water for her son Ishmael. This of course is pure invention, and indeed the legend tells that the well was long covered up and rediscovered by ʿAbd el-Muṭṭalib, the grandfather of the Prophet. Sacred wells are familiar features of Semitic sanctuaries, and Islám, retaining the well, made a quasi-Biblical story for it, and endowed its tepid waters with miraculous curative virtues. They are eagerly drunk by the pilgrims, or when poured over the body are held to give a miraculous refreshment after the fatigues of religious exercise, and the manufacture of bottles or jars for carrying the water to distant countries is quite a trade. Ibn Jubair (p. 139) mentions a curious superstition of the Meccans, who believed that the water rose in the shaft at the full moon of the month Shaʿbán. On this occasion a great crowd, especially of young people, thronged round the well with shouts of religious enthusiasm, while the servants of the well dashed buckets of water over their heads. The Maḳám or standing place of Abraham is also connected with a relic of heathenism, the ancient holy stone which once stood on the Maʿjan, and is said to bear the prints of the patriarch's

[1] See Ibn Hishám, i. 54; Azraḳí, p. 80 (ʿUzzá in Batn Marr); Yáḳút, iii. 705 (Otheydá); Bar Hebræus on Psalm xii. 9. Stones worshipped by circling round them bore the name *dawár* or *duwár* (Krehl, *Rel. d. Araber*, p. 69). The later Arabs not unnaturally viewed such cultus as imitated from that of Mecca (Yáḳút, iv. 622; comp. Dozy, *Israeliten te Mekka*, p. 125, who draws very perverse inferences).

[2] The old *kiswa* is removed on the 25th day of the month before the pilgrimage, and fragments of it are bought by the pilgrims as charms. Till the 10th day of the pilgrimage month the Kaʿba is bare.

[3] Before Islám the Kaʿba was opened every Monday and Thursday; in the time of Ibn Jubair it was opened with considerable ceremony every Monday and Friday, and daily in the month Rajab. But, though prayer within the building is favoured by the example of the Prophet, it is not compulsory on the Moslem, and even in the time of Ibn Batúta the opportunities of entrance were reduced to Friday and the birthday of the Prophet.

feet. The whole legend of this stone, which is full of miraculous incidents, seems to have arisen from a misconception, the Maḳám Ibráhím in the Korán meaning the sanctuary itself; but the stone, which is a block about 3 spans in height and 2 in breadth, and in shape "like a potter's furnace" (Ibn Jubair), is certainly very ancient. It is now covered up, and no one is allowed to see it, though the box in which it lies can be seen or touched through a grating in the little chapel that surrounds it. In the Middle Ages it was sometimes shown, and Ibn Jubair describes the pious enthusiasm with which he drank Zamzam water poured on the footprints. It was covered with inscriptions in an unknown character, one of which was copied by Fákihí in his history of Mecca. To judge by the facsimile in Dozy's *Israeliten te Mekka*, the character is probably essentially one with that of the Syrian Ṣafá inscriptions, which we now know to have extended through the Nejd and into the Ḥijáz.[1]

The general aspect of the great mosque will be best understood by reference to the woodcut, which is taken from a photograph. The photographer has taken his stand on a lofty building facing the black stone corner of the Ka'ba, so that house tops, with high parapets serving to protect the privacy of the women, who spend much of their time on these terraces, form too prominent a feature in the foreground, and obstruct the view of part of the cloistered area. The background is the Red Mountain; the fort which is seen above the town is not the great castle but a building of the sherif Ghálib, dating from about the beginning of this century. It will be observed that at two places there are smaller cloistered courts annexed to the main colonnade. That to the right, with a polygonal minaret, corresponds to the ancient Dár el-Nadwá, which was included in the mosque by the caliph Mo'taḍid. The other minor court is at the Báb Ibráhím. Of the two walls of the Ka'ba concealed from view, that to the right is the one adjoining the Ḥijr. The two-storied pagoda-like building facing this wall is the Maḳám or station for prayer of orthodox Moslems of the Ḥanafí rite, to which the Turks belong. The similar stations of the other orthodox sects have but one story; that of the Málikí rite is seen to the left of the Ka'ba; the roof of the Ḥanbalí station is just visible in the foreground a little to the left of the "black" corner; the Sháfi'í station, which stands on the roof of the Zamzam building, is more prominent a little to the right. Between this and the Maḳám Ḥanafí rises the slender gilt spire of the white marble pulpit from which sermons are preached on Fridays and high days. Between the pulpit and the Zamzam is the small chapel of Abraham's stone. It does not rise high enough to be seen in the cut. The two small and ugly domes to the right of the Zamzam are the dome of 'Abbás and the dome of the Jewess. They are used as storerooms, but the former, which has its name from the uncle of the Prophet, was formerly the drinking-place of the pilgrims. In the time of Ibn Jubair it was still used for cooling the Zamzam water. The oval part of the court next to the Ka'ba within the railing is paved with marble; parts of the area beyond are also paved, part being strewn with gravel. Around the railing a number of glass lamps are lighted at night.

Ṣafá and Merwa.—In religious importance these two points or "hills," connected, as we have seen, by the Mas'á, stand second only to the Ka'ba. Ṣafá is an elevated platform surmounted by a triple arch, and approached by a flight of steps.[2] It lies south-east of the Ka'ba, facing the black corner, and 76 paces from the "Gate of Ṣafá," which is architecturally the chief gate of the mosque. Merwa is a similar platform, formerly covered with a single arch, on the opposite side of the valley. It stands on a spur of the Red Mountain called J. Ḳu'ayḳi'án. The course between these two sacred points is 493 paces long, and the religious ceremony called the "sa'y" consists in traversing it seven times, beginning and ending at Ṣafá. The lowest part of the course, between the so-called green milestones, is done at a run. This ceremony, which, as we shall presently see, is part of the 'omra, is generally said to be performed in memory of Hagar, who ran to and fro between the two eminences vainly seeking water for her son. The observance, however, is certainly of pagan origin; and at one time there were idols on both the so-called hills (see especially Azraḳí, pp. 74, 78).

Mecca—the Great Mosque.

The Ceremonies and the Pilgrimage.—Before Islám the Ka'ba was the local sanctuary of the Meccans, where they prayed and did sacrifice, where oaths were administered and hard cases submitted to divine sentence according to the immemorial custom of Semitic shrines. But besides this, as we have seen, Mecca was already a place of pilgrimage. Pilgrimage with the ancient Arabs was the fulfilment of a vow, which appears to have generally terminated—at least on the part of the well-to-do—in a sacrificial feast. A vow of pilgrimage might be directed to other sanctuaries than Mecca—the technical word for it (ihlál) is applied for example to the pilgrimage to Manát (Bekrí, p. 519). He who was under such a vow was bound by ceremonial observances of abstinence from certain acts (*e.g.*, hunting) and sensual pleasures, and in particular was forbidden to shear or comb his hair till the fulfilment of the vow. This old Semitic usage has its close parallel in the vow of the Nazarite. It was not peculiarly connected with Mecca; at Ṭáif, for example, it was customary on return to the city after an absence to present oneself at the sanctuary, and there shear the hair (*Muh. in Med.*, p. 381). Pilgrimages to Mecca were not tied to a single time, but they were naturally associated with festive occasions, and especially with the great annual feast and market already spoken of, when by extensive hospitality the citizens did all in their power to attract the worshippers who were at the same time their customers. The pilgrimage was so intimately connected with the wellbeing of Mecca, and had already such a hold on the Arabs round about, that the politic Mohammed could not afford to sacrifice it to an abstract purity of religion, and thus the old usages were transplanted into Islám in the double form of the 'omra or vow of pilgrimage to Mecca, which can be discharged at any time, and the ḥajj or pilgrimage at the great annual feast. The latter closes with a visit to the Ka'ba, but its essential ceremonies lie outside Mecca, at the neighbouring shrines where the old Arabs gathered before the Meccan fair.

The 'omra begins at some point outside the Ḥaram or holy territory, generally at Tan'ím described above, both for convenience sake and because 'Áisha began the 'omra there in the year 10 of the Flight. The pilgrim enters the Ḥaram in the antique and scanty pilgrimage dress (iḥrám), consisting of two cloths wound round his person in a way prescribed by ritual. His devotion is expressed in

[1] See De Vogüé, *Syrie Centrale: Inscr. Sem.*; Lady Anne Blunt, *Pilgrimage to Nejd*, vol. ii.; and W. R. Smith, in the *Athenæum*, March 20, 1880.

[2] Ibn Jubair speaks of fourteen steps, Aly Bey of four, Burckhardt of three. The surrounding ground no doubt has risen so that the old name "hill of Ṣafá" is now inapplicable.

shouts of Labbeyka (a word of obscure origin and meaning); he enters the great mosque, performs the ṭawáf and the sa'y[1] with circumstances and prayers which it is unnecessary to detail, and then has his head shaved and resumes his common dress. This ceremony is now generally combined with the ḥajj, or is performed by every stranger or traveller when he enters Mecca, and the iḥrám (which involves the acts of abstinence already referred to) is assumed at a considerable distance from the city. But it is also proper during one's residence in the holy city to perform at least one 'omra from Tan'ím in connexion with a visit to the mosque of 'Áisha there. The absurd triviality of these rites is ill concealed by the legends of the sa'y of Hagar and of the ṭawáf being first performed by Adam in imitation of the circuit of the angels about the throne of God; but in truth the meaning of their ceremonies seems to have been almost a blank to the Arabs before Islám, whose religion had become a mere formal tradition. We do not even know to what deity the worship expressed in the ṭawáf was properly addressed. There is a tradition that the Ka'ba was a temple of Saturn (Shahrastání, p. 431); perhaps the most distinctive feature of the shrine may be sought in the sacred doves which still enjoy the protection of the sanctuary. These recall the sacred doves of Ascalon (Philo, vi. 200 of Richter's ed.), and suggest Venus-worship as at least one element (comp. Herod., i. 131; iii. 8; Ephr. Syr., *Op. Syr.*, ii. 457).

To the ordinary pilgrim the 'omra has become so much an episode of the ḥajj that it is often described as a mere visit to the mosque of 'Áisha; a better conception of its original significance is got from the Meccan feast of the seventh month (Rajab) graphically described by Ibn Jubair from his observations in 1184 A.D. Rajab was one of the ancient sacred months, and the feast, which extended through the whole month, and was a joyful season of hospitality and thanksgiving, no doubt represents the ancient feasts of Mecca more exactly than the ceremonies of the ḥajj, in which old usage has been overlaid by traditions and glosses of Islám. The 'omra was performed by crowds from day to day, especially at new and full moon.[2] The new moon celebration was nocturnal; the road to Tan'ím, the Mas'á, and the mosque were brilliantly illuminated; and the appearing of the moon was greeted with noisy music. A genuine old Arab market was held, for the wild Bedouins of the Yemen mountains came in thousands to barter their cattle and fruits for clothing, and deemed that to absent themselves would bring drought and cattle plague in their homes. Though ignorant of the legal ritual and prayers, they performed the ṭawáf with enthusiasm, throwing themselves against the Ka'ba and clinging to its curtains as a child clings to its mother. They also made a point of entering the Ka'ba. The 29th of the month was the feast day of the Meccan women, when they and their little ones had the Ka'ba to themselves without the presence even of the Sheybís.

The central and essential ceremonies of the ḥajj or greater pilgrimage are those of the day of 'Arafa, the 9th of the "pilgrimage month" (Dhu'l Ḥijja), the last of the Arab year; and every Moslem who is his own master, and can command the necessary means, is bound to join in these once in his life. By them the pilgrim becomes as pure from sin as when he was born, and gains for the rest of his life the honourable title of ḥájj. Neglect of other parts of the pilgrim ceremonial may be compensated by offerings, but to miss the "stand" (wokúf) at 'Arafa is to miss the pilgrimage. 'Arafa or 'Arafát is a space artificially limited, round a small isolated hill called the Hill of Mercy, a little way outside the holy territory, on the road from Mecca to Ṭáif. One leaving Mecca after midday can easily reach the place on foot the same evening. The road is first northwards along the Mecca valley and then turns eastward. It leads through the straggling village of Miná, occupying a long narrow valley (W. Miná), two to three hours from Mecca, and thence by the mosque of Muzdalifa over a narrow pass opening out into the plain of 'Arafa, which is an expansion of the great W. Na'mán, through which the Ṭáif road descends from Mount Kara. The lofty and rugged mountains of the Hodheyl tower over the plain on the north side and overshadow the little Hill of Mercy, which is one of those bosses of weathered granite so common in the Ḥijáz. 'Arafa, as we have already seen, lay quite near Dhu'l-Maják, where, according to Arabian tradition, a great fair was held from the 1st to the 8th of the pilgrimage month; and the ceremonies from which the ḥajj was derived were originally an appendix to this fair. Now on the contrary the pilgrim is expected to follow as closely as may be the movements of the Prophet at his "farewell pilgrimage" in the year 10 of the Flight (632 A.D.). He therefore leaves Mecca in pilgrim garb on the 8th of Dhú'l Ḥijja, called the day of tarwíya (an obscure and pre-Islamic name), and strictly speaking should spend the night at Miná. It is now, however, customary to go right on and encamp at once at 'Arafa. The night should be spent in devotion, but the coffee booths do a lively trade, and songs are as common as prayers. Next forenoon the pilgrim is free to move about, and towards midday he may if he please hear a sermon. In the afternoon the essential ceremony begins; it consists simply in "standing" on 'Arafa shouting Labbeyka and reciting prayers and texts till sunset. After the sun is down the vast assemblage breaks up, and a rush (technically *ifáda*, *daf'*, *nafr*) is made in the utmost confusion to Muzdalifa, where the night prayer is said and the night spent. Before sunrise next morning (the 10th) a second "stand" like that on 'Arafa is made for a short time by torchlight round the mosque of Muzdalifa, but before the sun is fairly up all must be in motion in the second *ifáda* towards Miná. The day thus commenced is the "day of sacrifice," and has four ceremonies—(1) to pelt with seven stones a cairn (*jamrat el 'akaba*) at the eastern end of W. Miná, (2) to slay a victim at Miná and hold a sacrificial meal, part of the flesh being also dried and so preserved, or given to the poor,[3] (3) to be shaved and so terminate the *iḥrám*, (4) to make the third *ifáda*, *i.e.*, go to Mecca and perform the ṭawáf and sa'y (*'omrat el-ifáda*), returning thereafter to Miná. The sacrifice and visit to Mecca may, however, be delayed till the 11th, 12th, or 13th. These are the days of Miná, a fair and a joyous feast, with no special ceremony except that each day the pilgrim is expected to throw seven stones at the *jamrat el 'akaba*, and also at each of two similar cairns in the valley. The stones are thrown in the name of Alláh, and are generally thought to be directed at the devil. This is, however, a custom older than Islám, and a tradition in Azrakí, p. 412, represents it as an act of worship to idols at Miná. As the stones are thrown on the days of the fair, it is not unlikely that they have something to do with the old Arab mode of closing a sale by the purchaser throwing a stone (Bírúní, p. 328).[4] The pilgrims leave Miná on the 12th or 13th, and the ḥajj is then over.

The colourless character of these ceremonies is plainly due to the fact that they are nothing more than expurgated heathen rites. In Islám proper they have no *raison d'être*; the legends about Adam and Eve on 'Arafa, about Abraham's sacrifice of the ram at Thabír by Miná, imitated in the sacrifices of the pilgrimage, are mere clumsy afterthoughts, as appears from their variations and only partial acceptance. It is not so easy to get at the nature of the original rites, which Islám was careful to suppress. But old usages were not quickly eradicated, and we find mention of practices condemned by the orthodox, or forming no part of the Moslem ritual, which may be regarded as traces of an older ceremonial. Such are nocturnal illuminations at Miná (Ibn Baṭúta, i. 396), 'Arafa, and Muzdalifa (Ibn Jubair, p. 179), and ṭawáfs performed by the ignorant at holy spots at 'Arafa not recognized by law (Snouck-Hurgronje, p. 149 *sq.*). We know that the rites at Muzdalifa were originally connected with a holy hill bearing the name of the god Kuzaḥ (the Edomite Kozé) whose bow is the rainbow, and there is reason to think that the *ifádas* from 'Arafa and Kuzaḥ, which were not made as now after sunset and before sunrise, but when the sun rested on the tops of the mountains, were ceremonies of farewell and salutation to the sun-god.

The statistics of the pilgrimage cannot be given with certainty and vary much from year to year. The quarantine office keeps a record of arrivals by sea at Jiddah (30,271 for the year 1878 A.D., or 1295 A.H.); but to these must be added the great overland caravans from Cairo, Damascus, and 'Irak, the pilgrims who reach Medina from Yanbu' and go on to Mecca, and those from all parts of the peninsula. Burckhardt in 1814 estimated the crowd at 'Arafa at 70,000, Burton in 1853 at 50,000, 'Abd el-Razzák in 1858 at 60,000. This great assemblage is always a dangerous centre of infection, and the days of Miná especially, spent under circumstances originally adapted only for a Bedouin fair, with no provisions for proper cleanliness, and with the air full of the smell of putrefying offal and flesh drying in the sun, produce much sickness.

Literature.—Besides the Arabic geographers and cosmographers, many of whom have been already cited, we have Ibn 'Abd Rabbih's description of the mosque, early in the 10th century (*'Iḳd Faríd*, Cairo edition, iii. 362 *sq.*), but above all the admirable record of Ibn Jubair (1184 A.D.), by far the best account extant of Mecca and the pilgrimage. It has been much pillaged by Ibn Baṭúṭa. The Arabic historians are largely occupied with fabulous matter as to Mecca before Islam; for these legends the reader may refer to C. de Perceval's *Essai*. How little confidence can be placed in the pre-Islamic history appears very clearly from the distorted accounts of Abraha's excursion against the Ḥijáz, which fell but a few years before the birth of the Prophet, and is the first event in Meccan history which has confirmation from other sources. See Nöldeke's version of Ṭabarí, p. 204 *sq.* For the period of the Prophet Ibn Hishám and Wáḳidí are valuable sources in topography as well as history. Of the special histories and descriptions of Mecca published by Wüstenfeld (*Chroniken der Stadt Mekka*, 3 vols., 1857–59, with an abstract in German 1861), the most valuable is that of Azraḳí. It has passed through the hands of several editors, but the oldest part goes back to the beginning of the 9th Christian century. Ḳuṭb el-Dín's history (vol. iii. of the *Chroniken*) goes down with the additions of his nephew to 1592 A.D.

Of European descriptions of Mecca from personal observation the best is Burckhardt's *Travels in Arabia* (cited above from the 8vo ed., 1829). *The Travels of Aly Bey* (Badia), London, 1816, describe a visit in 1807; Burton's *Pilgrimage* (3d ed., 1879) often supplements Burckhardt; Von Maltzan's *Wallfahrt nach Mekka*, 1865, is lively but very slight. 'Abd el-Razzák's report to the Government of India on the pilgrimage of 1858 is specially directed to sanitary questions. For the pilgrimage see particularly Snouck-Hurgronje, *Het Mekkaansche Feest*, Leyden, 1880. (W. R. S.)

[1] The latter perhaps was no part of the ancient 'omra; see Snouck-Hurgronje, *Het Mekkaansche Feest*, 1880, p. 115 *sq.*

[2] The 27th was also a great day, but this day was in commemoration of the rebuilding of the Ka'ba by Ibn Zubeyr.

[3] The sacrifice is not indispensable except for those who can afford it and are combining the ḥajj with the 'omra.

[4] On the similar pelting of the supposed graves of Abú Lahab and his wife (Ibn Jubair, p. 110) and of Abú Righál at Mughammas, see Nöldeke's translation of Ṭabarí, p. 208.

MECHANICS

STRICTLY speaking, the derivation of this word should have prevented the use of it as the designation of a pure science. It has been, however, employed for a long period in English speech in the identical sense that the French attach to *Mécanique pure* or the Germans to *Reine Mechanik*. These terms are all employed to denote what we should much prefer to call *Abstract Dynamics*,—the pure science which (as the derivation implies) treats of the action of Force upon Matter, but which is, correctly, the *Science of Matter and Motion*, or *of Matter and Energy*.

With the view of making clear from the outset the reason for the arrangement adopted in this article, we commence by stating in Newton's own words (accompanied by a paraphrase) the *Axiomata, sive Leges Motus*, which form the entire basis of our subject. These laws will at once indicate the order in which the subject may most logically be treated. We defer to the end of the article the more close consideration of the idea introduced by the word "force," as well as general remarks on "energy," &c. For the present we are content to regard force as defined for us by Newton's Laws.

Newton's Laws of Motion.

Newton's first law.

§ 1. Lex I. Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus illud a viribus impressis cogitur statum suum mutare.

Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by force to change that state.

Second law.

Lex II. Mutationem motus proportionalem esse vi motrici impressæ, et fieri secundum lineam rectam qua vis illa imprimitur.

Change of (quantity of) motion is proportional to force, and takes place in the straight line in which the force acts.

Third law.

Lex III. Actioni contrariam semper et æqualem esse reactionem; sive corporum duorum actiones in se mutuo semper esse æquales et in partes contrarias dirigi.

To every action there is always an equal and contrary reaction; or the mutual actions of any two bodies are always equal and oppositely directed.

Scholium.

§ 2. In 1863 Thomson and Tait (upon whose *Treatise on Natural Philosophy* much of what follows is based) called attention to the fact that, as regards Lex III., Newton gives in a scholium a second sense in which the words may be interpreted. In the first sense the action and reaction are mere forces, in the second they are *the rates at which forces do work*. Hence, and for another reason which will appear later, the word "activity" has been introduced as the English equivalent of the word *actio* in Newton's second sense. Here is the passage:—

Si æstimetur agentis actio ex ejus vi et velocitate conjunctim; et similiter resistentis reactio æstimetur conjunctim ex ejus partium singularum velocitatibus et viribus resistendi ab earum attritione, cohæsione, pondere, et acceleratione oriundis; erunt actio et reactio, in omni instrumentorum usu, sibi invicem semper æquales.

If the activity of an agent be measured by its amount and its velocity conjointly; and if, similarly, the counter-activity of the resistance be measured by the velocities of its several parts and their several amounts conjointly, whether these arise from friction, molecular forces, weight, or acceleration;—activity and counter-activity, in all combinations of machines, will be equal and opposite.

This may be looked upon as a Fourth Law. But, in strict logic, the First Law is superfluous, because its consequences are all implied (by negation) in the statement of the Second. (See § 8 below.) Hence there are, virtually, only three laws, so far as Newton's system is concerned.

Basis of Newton's laws.

§ 3. These laws are to be considered as deductions from observation and experiment, and in no sense as having an *a priori* foundation. Their proof, so far as rigorous proof is attainable in physical matters, is commonly looked on as being furnished in the most conclusive form by observational astronomy. The *Nautical Almanac*, published usually about four years in advance, contains the predicted places of the sun, moon, and principal planets from day to day, in some cases from hour to hour, throughout the year. The predictions are entirely based upon the laws of motion (along with the law of gravitation), and could not possibly be accurate unless these laws are true. So thoroughly satisfactory has hitherto been the coincidence between prediction and observation that, when a deviation occurs, no one dreams of a defect in the principles of the reasoning. On the contrary, such deviations are utilized for the purpose of correcting our knowledge of the "elements" of the orbits of the moon and planets, or our estimates of the masses of these bodies; and, as in the brilliant investigations of Adams and Leverrier, they sometimes enable us to discover the existence and even assign the position of a planet never before seen.

Newton's predecessors.

§ 4. It is not clear in what order, or by whom, these laws were first discovered. Galileo was undoubtedly acquainted with the first two; and Huygens, Wren, Hooke, and others were acquainted with the Third Law in some of its many applications. But they were first systematized and, as we have seen, extended in a most important manner by Newton. Though they were sadly disfigured in Britain during the fifty years which elapsed after the revival of mathematics in the early part of this century, they have of late been restored to the form in which Newton gave them. This readoption of Newton's simple but comprehensive system has of itself aided in no small degree the recent rapid advance of science.

Anthropomorphisms.

One peculiarity of Newton's language must be noticed here, though very briefly, as we will return to the subject towards the end of the article. A force is said to "compel" a change of state in a body; bodies are said mutually to "act" on one another, &c. Such language is, of course, in its literal acceptation, of an anthropomorphic character; but, if one thinks of the habitual use even in scientific books of such expressions as "the sun rises," "the wind blows," &c., it cannot be construed into an assertion that force has real objective existence.

Comments on the Laws of Motion.

Definition of force.

§ 5. Law I. First of all this law tells us what happens to a piece of matter which is left to itself, *i.e.*, not acted on by forces. It preserves its "state," whether of rest or of uniform motion in a straight line. This property (which, as we shall presently show, § 7, is considerably extended by Newton himself) is commonly called the "inertia" of matter, in virtue of which it is incapable of varying in any way its state of rest or motion. It may be the sport of forces for any length of time, but so soon as they cease to act it remains in the state in which it was left until they recommence their action on it. Hence, whenever we find the state of a piece of matter changing, we conclude that it is under the action of a force or forces. Thus, for the present, we have the definition of "force" as part of this First Law:—

Inertia.

Force is whatever changes the state of rest or uniform motion of a body.

When a body, originally at rest, begins to move, we conclude that force is acting on it. And when a moving body is seen to change *either* the speed *or* the direction of its motion, we conclude that this is due to force.[1]

ıbsolute nd elative.

§ 6. But there is much more than this, even in the First Law. What is "rest"? The answer must be that the term is relative. Absolute rest and absolute motion are terms to which we find it impossible to assign a meaning. Maxwell has well said (in his *Matter and Motion*):—

> "All our knowledge, both of time and place, is essentially relative. When a man has acquired the habit of putting words together, without troubling himself to form the thoughts which ought to correspond to them, it is easy for him to frame an antithesis between this relative knowledge and a so-called absolute knowledge, and to point out our ignorance of the absolute position of a point as an instance of the limitation of our faculties. Any one, however, who will try to imagine the state of a mind conscious of knowing the absolute position of a point will ever after be content with our relative knowledge."

As will be seen later, the First Law gives us also a physical definition of "time," and physical modes of measuring it.

ʼewton's om-ıents on ıe first ıw.

§ 7. Newton's own comment on this law is as follows:—

Projectilia perseverant in motibus suis, nisi quatenus a resistentia aeris retardantur, et vi gravitatis impelluntur deorsum. Trochus, cujus partes cohærendo perpetuo retrahunt sese a motibus rectilineis, non cessat rotari, nisi quatenus ab aere retardatur. Majora autem planetarum et cometarum corpora motus suos et progressivos et circulares, in spatiis minus resistentibus factos, conservant diutius.

It is particularly worthy of notice that we have here the undisturbed rotation of a body about an axis introduced as another of those "states" in which it will continue, in virtue of the First Law, until force acts to compel it to change that state. Also it is to be noticed that Newton adduces a hoop, whose axis is fixed in direction both in the body and in space, as an example of this new form of state maintained in virtue of inertia. Later, it will be seen that the same thing is true of a body free in space and rotating about the principal axis of greatest or of least moment of inertia through its centre of mass.[2]

ʼonse-ıuences f second aw.

§ 8. Law II. What Newton designates by the word *motus* is, as he has clearly pointed out, the same as is expressed by *quantitas motus*, that for which we now usually employ the term "momentum." Its numerical value depends not only on the rate of motion, but also on the amount of matter, or "mass," of the moving body, and is directly proportional to either of these when the other is unaltered. But it is regarded by Newton as having direction as well as magnitude. It is, in fact, what in the language of quaternions is called a "vector." The change of such a quantity may be either in numerical magnitude, or in direction, alone, or simultaneously in both. We now see what this Second Law enables us to do. For

(*a*) Given the mass of a body, the force acting on it, and the time during which it acts, we can calculate the change of motion. This is the *direct* problem of dynamics of a particle.

(*b*) Given the mass, and the change of velocity, we can calculate the magnitude and direction of the force acting. This is the *inverse* problem.

(*c*) We can compare, and so measure, forces by the changes of motion they produce in one and the same body.

(*d*) We can compare the masses of different bodies by finding what changes of velocity one and the same force produces in them.

(*e*) We can find the *one* force which is equivalent, in its action, to any given set of forces. For, however many changes of motion may be produced by the separate forces, they must obviously be capable of being compounded into a single change, and we can calculate what force would produce that.[3]

Necessity for a third law.

§ 9. Hitherto, we have spoken of *the* motion of a body,—thus implying (except, of course, in the case of Newton's hoop or that of the earth) that all its parts are moving in exactly the same way. From this point of view every body, however large, may be treated as if it were a single particle. But when the parts of a body have different velocities, as when a rigid body is rotating, or as when a non-rigid body is suffering a change of form, the question becomes much more complex. We cannot at this stage enter into a full explanation, but will take a couple of very simple cases to show the nature of the new difficulties, and thence the necessity for an additional law.

Suppose a bullet to be thrown in any direction. If we know with what force the earth attracts it, the calculation of the path it will pursue depends on the Second Law, which gives all the necessary preliminary information. But let two bullets be tied together by a string: we know by trial that each moves, in general, in a manner very different from that in which it would move if free. The path of each is now, usually, a tortuous curve, while its free path would be plane. It is no longer subject to gravity alone but also to what is called the "tension" of the string. If we knew the amount of this tension on either of the bullets and its direction, we could calculate, by the help of the Second Law alone, all the circumstances of the motion of that bullet. But how are we to find this tension? Is it even the same for each bullet? This, if answered in the affirmative, would simplify matters considerably, but we should still require to know the amount and direction of the tension. It is clear that, without a further axiom, we cannot advance to a solution of the question.

Consequences of third law.

Rigid constraint.

§ 10. Law III. Furnished with this, in addition to our previous information, we can attack the question with more hope. We see by this law that, whatever force be exerted by the string on one of the bullets, an equal and opposite force, which must therefore be in the direction of the string, is exerted on the other. Still, the magnitude of these equal forces remains to be found. But the string in no way interferes with the motion of either bullet *unless it is tight*, *i.e.*, unless the distance between the bullets is equal to the length of the string. Hence, whenever the unknown force comes into play, at the same time there comes in a geometrical relation of relative position between the two bullets. *This supplies the additional equation necessary for the determination of the new unknown quantity.*

Variable constraint.

§ 11. As an additional illustration, suppose the string to be made of india-rubber. The Third Law tells us that the tensions it exerts on the bullets are still equal and opposite. But we no longer have the geometrical condition we had before. We have, however, what is quite sufficient, a

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[1] The words we have italicized will be seen to have very important bearings on certain old errors which even now crop up, and which have introduced one of the most inappropriate and apparently ineradicable of terms ("centrifugal force") into the usual vocabulary of our subject.

[2] It is also, in a partial sense, true of a free body of which two principal axes through the centre of mass have equal moments of inertia. In that case, as we will show later, even when couples act upon the body, provided they be in planes passing through the third axis, the rate of rotation about that axis remains unaltered, *though its direction in space changes.* This is approximately the case of the earth. The attractions of the sun and moon on the protuberant parts about the equator produce "precession" and "nutation," but do not influence the length of the day.

[3] It is to be observed here that Newton's silence is as expressive as his speech. When he says "change of motion" we understand that it does not matter what the original motion was; and, when he mentions only one force, he implies that the effect of any one force is the same whether others are also at work or not. In fact, with Newton there can be no balancing of forces, though there may be balancing of the effects of forces, a very different thing.

knowledge of *how the tension of the string depends on its length.* Thus the tension can be calculated from the relative position of the bullets.

Transference of energy.

§ 12. Scholium to Law III. On this we will, for the present, remark only that it furnishes us with the means of studying directly the transference of energy from one body or system to another. Experiment, however, was required to complete the application of this part of Newton's systematic treatment of the subject. What was wanted, and how it has been obtainéd, will be treated of later. The first words of the scholium, however, claim for Newton the discovery of the clause we have extracted from it. For they run thus :—Hactenus principia tradidi a mathematicis recepta, et experientia multiplici confirmata.

Division of the subject.

§ 13. What has now been said enables us to see the order in which the fundamental ideas should be taken up, so that the necessities of each should be provided for before its turn comes. An indispensable preliminary is the study of motion in the abstract, *i.e.*, without any reference to *what is moving.* This is demanded in order that we may be able to apply the Second Law. The science of pure motion, without reference to matter or force, is an extension of geometry by the introduction of the idea of time and the consequent idea of velocity. Ampère suggested for it the term *Cinematique*, or, as we shall write it, *Kinematics.* We include under it all changes of form and grouping which can occur in geometrical figures or in groups of points.

We shall then be prepared to deal with the action of force on a single particle of matter, or on a body which may be treated as if it were a mere particle. Thus we have the Dynamics of a Particle. This, again, splits into two heads, Statics and Kinetics of a Particle. But all this requires the Second Law only. When we have two or more connected particles, or two particles attracting one another or impinging on one another, the Third Law is required. Next in order of simplicity come the Statics and Kinetics of a Rigid Solid. Then we have to deal with bodies whose form, &c., are altered by forces—flexible bodies, elastic solids, fluids, &c. Finally, we must briefly consider the general principles, such as "conservation of energy," "least action," &c., which are deducible by proper mathematical methods from Newton's Laws, and of which some at least, if we could more clearly realize their intrinsic nature, would probably be found to express even more simply than do Newton's Laws the true fundamental principles of abstract dynamics.

We will not restrict ourselves to one uniform course in the application of mathematical methods. Rather, as considerations of space require to be attended to, we will vary our methods from one part of the subject to another, so as to exhibit, each at least once, all the more usual processes. And we will endeavour to make the large-type portions of the article, in which only the most elementary mathematics will be introduced, a self-contained treatise which may be read by students of very moderate mathematical knowledge.

KINEMATICS.

Position and the Means of Assigning it.

Position.

§ 14. Motion (or displacement) consists simply in "change of position." Hence, to describe motion, we must have the means of assigning position. This is, of course, a question of GEOMETRY (*q.v.*). See also QUATERNIONS.

From these articles it appears that the position of one free point with reference to another (all these space relations are relative, as we have already said) depends on *three numbers*, of which one at least must involve the unit of length. In Cartesian rectangular coordinates, we denote these by x, y, z, which indicate respectively the distance of the point from each of three planes at right angles to each other, and all passing through the origin (or reference point). From another point of view they may be called "degrees of freedom." When the value of one is assigned, say by

Degrees of freedom,

$$x=a,$$

the point is said to have lost one degree of freedom, or to have had imposed upon it one "degree of constraint." It must now lie in a plane parallel to the first of the reference planes, and at a distance a from it. When a second degree of constraint is applied, say by

of constraint

$$y=b,$$

another degree of freedom is lost. The point's position is limited to lie in a second plane in a given position at right angles to the first. It must therefore lie somewhere on the straight line which consists of the series of points common to the two planes. A third degree of constraint

$$z=c$$

takes away its one remaining degree of freedom; and its position is now definitely assigned as the single point of intersection of three given planes.

§ 15. But constraint may be applied in other ways. Thus if we assign the condition

$$x^2+y^2+z^2=a^2,$$

we deprive the point of one degree of freedom by compelling it to remain at a distance a from the origin. It is now limited to the surface of a sphere, but its latitude and longitude on that sphere may be any whatever. Here again the imposition of one degree of constraint has taken away one degree of freedom.

Example of constraint.

§ 16 In general, one degree of constraint may be expressed as

$$f(x, y, z)=\xi.$$

This, when ξ has an assigned value, is the equation of a definite surface on which the point must lie. Three such conditions determine the position of the point, and may therefore be looked upon as introducing ξ, η, ζ, another set of coordinates, which may be used in place of x, y, z. The number of such systems is, of course, unlimited; but it is often possible to choose one in which the conditions of a problem are much more simply expressed than they were when expressed in x, y, z. The whole question belongs to what is called "change of variables." To give an elementary instance of its use,—suppose we take the ordinary simple pendulum, a pellet supported by a fine thread or wire, and oscillating in a vertical plane. If the origin be placed at the point of suspension, and the axis of z be vertical, we have two conditions :—

$$x^2+y^2+z^2=a^2,$$

where a is the length of the thread; and

$$y/x=\tan\alpha,$$

where α denotes the azimuth of the plane of oscillation. There is but one degree of freedom left, because two degrees of constraint have been imposed. We may choose for this either x, y, or z; but we should in each case be led to complex expressions. If, however, we consider that all the freedom left to the pendulum is to oscillate in a given plane, we may denote its sole remaining degree of freedom by θ, the angle which the string makes with the vertical; and form our dynamical equation in terms of this. When θ is found by dynamical considerations, we have

$$x=a\sin\theta\cos\alpha\,,\ \ y=a\sin\theta\sin\alpha\,,\ \ z=a\cos\theta\,.$$

Generalized coordinate.

Here θ comes in as what is called a "generalized coordinate."

If the pendulum be not limited to one plane, the azimuth, as well as the angle, of the displacement from the vertical may be any whatever. Hence there are two degrees of freedom, which are indicated by the generalized coordinates α and θ.

§ 17. In general, in any system originally with any number m of degrees of freedom, and subjected to a number n of degrees of constraint, the whole motion can be fully characterized by $m-n$ independent quantities, called generalized coordinates, and corresponding to the degrees of freedom which remain. The elegance and simplicity of a solution often depend in a marked manner upon the choice of these; and the transformation of the general equations from Cartesian to generalized coordinates forms one of the most powerful and elegant contributions to abstract dynamics which Lagrange made in the *Mécanique Analytique.*

eedom a gid stem.

§ 18. A rigid system has only *six* degrees of freedom:—three translations for any one of its points, and three independent rotations about axes passing through that point.

When one point is fixed, it loses the three translations, and has only three degrees of freedom. When a second point is fixed, it loses other two; in fact it can no longer move except by turning round the line joining the fixed points. When a third point, not in line with the other two, is fixed, there is no degree of freedom left; the system is fixed.

inear lations nong nall splace- ents.

§ 19. It may be well to notice here that, in all cases which we shall require to consider, whatever be the relations among two different sets of variables which we employ alternatively to determine the relative positions of the parts of any system, the equations which give the relations between corresponding small increments of these variables are always *linear* so far as these increments are concerned. Thus, for instance, if we have as above a condition of the form

$$f(x,\ y,\ z)=\xi\ ,$$

we deduce from it at once

$$\left(\frac{df}{dx}\right)\delta x+\left(\frac{df}{dy}\right)\delta y+\left(\frac{df}{dz}\right)\delta z=\delta\xi\ .$$

Here the differential coefficients are partial.

In such cases, any homogeneous function of the second order in δx, δy, δz, &c., will be represented by a homogeneous function, also of the second order, in $\delta\xi$, $\delta\eta$, &c., however many be the coordinates in the separate systems. When, however, one or more of the equations of condition involves the element of *time* explicitly, the relations among corresponding small increments of the alternative sets of coordinates, though still linear, will not be *homogeneous.* Thus a homogeneous function of the second order in one set will be a function of the second order in the other set, but not homogeneous, unless the increments are produced instantaneously.

To give a single instance, suppose that the string of a simple pendulum (not necessarily oscillating in one plane) *contracts* uniformly. We shall now have

$$x^2+y^2+z^2=(a-ct)^2$$

instead of the equation in the example § 15, and one of our equations among increments is

$$x\delta x+y\delta y+z\delta z=-c(a-ct)\delta t\ ,$$

which, though still linear, is no longer homogeneous in the increments of *coordinates.*

Kinematics of a Point.

ontinu- y of ath of oint.

§ 20. The one necessary characteristic of the path described by a moving point is its *continuity.* There can be no break or gap in it. But, as we study kinematics, at present, solely for its physical applications, we impose a restriction on such complete generality. The path of a moving *particle* must be one of *continuous curvature*, unless either (1) the motion ceases and commences again in a different direction (in which case we have two separate and successive states of motion to consider), or (2) an infinite force is applied to the particle (a case which we need not consider). A similar remark, we may say in passing, applies to velocity also. So that, for our purpose, we may confine ourselves to the geometrical properties of the motion of a point whose rate and direction of motion change continuously, if at all, and not by fits and starts.

)irec- ion of notion.

§ 21. If the point describe a straight line, that line gives the direction of its motion at every instant. If it describe a curve, the direction of its motion is at every instant that of the corresponding tangent to the curve.

Change of direction.

Let A, B, C, D represent four points on the path taken in close succession, in the order in which the moving point reaches them. From A the point moves to B, so that the line joining A and B (the tangent) is the direction of motion at A. Similarly the line joining B and C gives the direction of motion at B. The points A, B, C of course lie in one plane. This is the plane in which, for two successive elements of its path, the point is moving. It is therefore that in which the change of direction of motion takes place, and is called the "osculating plane." And, just as the straight line through A and B gives the direction of motion at A, so the circle passing through the points A, B, C determines the "curvature" of the path at A. If we apply the same reasoning to the three successive points B, C, D, we see the difference between a "plane" and a "tortuous" curve. For, if D lie in the plane ABC, the osculating plane is the same at A and at B; and if the same holds for other successive points the whole bending takes place in one plane. But if D be not in the plane ABC, BCD is the osculating plane at B, and we thus see that successive positions of the osculating plane of a tortuous curve are produced by its rotation about the tangent BC to the path; for BC is in both planes ABC and BCD. We shall not have space here to deal in detail with cases of tortuosity; but it was necessary to point out their essential nature.

Osculating plane.

Tortuous path.

Curvature.

§ 22. The curvature of ABC obviously depends upon the change of direction from AB to BC, and is directly proportional to it. But it is obviously greater, for the same amount of change of direction, as ABC is less. In a circle the curvature is the same at all points, and, as the radius is everywhere perpendicular to the tangent, the change of its direction is the same as that of the tangent. Hence the curvature, being the change of direction *per unit length of the arc*, is measured simply by the reciprocal of the radius.

Generally, if ϕ be the angle between the tangent at A and any fixed line in the osculating plane, and if s represent the length of the curve measured from any fixed point on it to A, we have, by the fundamental property of infinitesimals,

$$\mathrm{L}\frac{\delta\phi}{\delta s}=\frac{d\phi}{ds}=\text{curvature.}$$

(We will use, as above, the letter L for a limit, in the sense in which that term was introduced by Newton.)

In a circle we have always (a being the radius)

$$s=a\phi\ ,$$

and hence the curvature

$$\frac{d\phi}{ds}=\frac{1}{a}\ ;$$

so that in general the measure of curvature is the reciprocal of the radius of the circle passing through three consecutive points of the path. For other analytical expressions for curvature see vol. xiii. p. 26.

For a curve in space (whether tortuous or not) we have

$$\text{Curvature}=\frac{1}{\rho}=\sqrt{\left(\frac{d^2x}{ds^2}\right)^2+\left(\frac{d^2y}{ds^2}\right)^2+\left(\frac{d^2z}{ds^2}\right)^2}\ ,$$

while the direction cosines of the radius of curvature are

$$\rho\frac{d^2x}{ds^2}\ ,\quad \rho\frac{d^2y}{ds^2}\ ,\quad \rho\frac{d^2z}{ds^2}\ .$$

Evolute and involute.

§ 23. The chief properties connected with the curvature of a plane curve are made very clear by the artifice of regarding it as an "involute." This idea introduces us to the kinematics of a flexible and inextensible line. Suppose such a line, held tight, to be wrapped round a cylinder of any form, in a plane perpendicular to its axis, each point of it, when it is unwound in its own plane, will describe a curve whose form depends upon that of the transverse section of the cylinder. Let $P_0M'M$ (fig. 1) be such a section of the cylinder; MP, M′P′, two positions of the free part of the cord; P, P′, the corresponding positions of

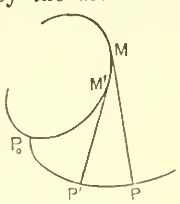

Fig. 1.

a definite point of the cord; $PP'P_0$ the path described by that point. Then $PP'P_0$ is one of the involutes of $MM'P_0$; the others are the curves traced by other points of the string. But, with reference to $PP'P_0$, the curve $MM'P_0$ is *the* "evolute." The evolute of such a curve is, in fact, unique; for it is obvious that the line MP, in any of its positions, is revolving about the point of contact M with the evolute; so that P describes an infinitesimal arc of a circle of which M is the centre. Thus the evolute of a plane curve is the locus of its centre of curvature. And it is clear from the genesis of the involute that

$$PM = P'M' + M'M = P_0M'M.$$

For the analytical discussion of evolutes, see vol. xiii. p. 26.

The subject of evolutes is of importance in various branches of physics, especially in optics. In mechanics its chief use is connected with the theory of the pendulum, as it shows how to cause the bob to move in a cycloid, the only path in which the time of oscillation is the same whatever be the extent of the oscillations.

Speed. § 24. When the line, curved or straight, in which the motion takes place is given, the position of the moving point is at once assigned in terms of a single numerical quantity. In fact it has only one degree of freedom, and its position is known by the length of the arc of the curve from any fixed point to the given position. In such a case as this we are not concerned with the direction of the motion, for that is already assigned at every point of the path. We are concerned only with what we may call the "speed" of the motion. (We purposely avoid the use of the term "velocity" here, because it properly includes direction as well as speed, as will be seen later.)

Average speed. § 25. Suppose an observer to be watching the motion (as, for instance, a traveller by rail notes the telegraph posts which he passes, referring at each to his watch), and to find that at any time t_1 the moving point was at s_1, while at time t_2 it was at s_2.

Then it is clear that the *average* speed during this part of the motion is to be found by dividing the number of units of space passed over by the number of units of time employed. For it must be greater as the former is greater and less as the latter is greater. Hence the average speed is $\frac{s_2 - s_1}{t_2 - t_1}$. If the speed has been *uniform* during the motion observed, this average value has coincided with the actual value all through; and, if the measures of space and time are accurate, we shall get exactly the same value of this ratio whether the interval of time is small or large. Hence, if v be the speed of a uniformly moving point, the space it describes in time t is vt. But if the speed has been *variable*, it must at some parts of the interval have been greater, at others less, than this average. And the shorter we take the interval the less will be the difference between the greatest and least speeds during its lapse, so that the average speed will coincide more and more nearly with the actual speed. In the language of "fluxions" (which was invented for the sake of this subject) the measure of the speed at any time t_1 is

Measurement of uniform and of variable speed.

$$\dot{s} = L\frac{s_2 - s_1}{t_2 - t_1},$$

when the interval $t_2 - t_1$ is shortened indefinitely. The accuracy of the preceding process depends entirely upon the limitations we have introduced for the purpose of confining ourselves to cases which can occur in ordinary physical problems. For the general reasoning on which it is based is obviously inapplicable to cases in which the speed alters by jerks—at least during the interval considered, small as it may be. But we are fortunately not required to discuss here the very delicate questions to which this may give rise. Considerable difficulty is sometimes felt by a student when he is told that at a certain part of its course a point has a speed say of 10 miles an hour, while the whole course may be only a few inches. But this arises from the novelty of the conception. It is not meant, when we speak of a speed of 10 miles per hour, that the motion necessarily lasts for an hour, or even for a second, but only that, *if the then speed were to be maintained constant for an hour, the moving point's path, of whatever form, would be exactly* 10 *miles long*. In actual experience in a railway train we can judge the speed (roughly at least), and we find nothing strange in saying "Now we are going at twenty miles an hour," "Now at six," and so on. And it is clear that, after the steam is put on, the train, however short its run, must go through all rates of speed from zero to its maximum, and then through all of them to zero again, when the steam is cut off and the brake applied.

In the language of the differential calculus this becomes

$$\dot{s} = L\frac{\delta s}{\delta t} = \frac{ds}{dt}.$$

The fluxional notation of Newton, in which the dot over a quantity expresses the rate of its increase, *i.e.*, its differential coefficient with regard to time considered as the independent variable, is still very convenient in abstract dynamics, and is, in fact, indispensable when we come to the higher generalizations. We shall, therefore, freely employ it when it is specially useful.

Dimensions of speed. § 26. Whether uniform or variable, speed depends for its numerical value upon the units chosen for linear space and for time. Its dimensions are $[LT^{-1}]$, and consequently its numerical expression is increased in proportion as the unit of time is increased, and diminished in proportion as that of length is increased. Thus the speed represented by 10 in feet per second becomes

$$\frac{3600}{5280} \cdot 10 = \frac{75}{11}$$

when expressed in miles per hour.

Rate of change of speed. § 27. The rate at which the speed (when not uniform) changes is found by a process precisely similar to that employed for the speed itself. Let the speed

at time t_1 be observed to be v_1,
" t_2 " " v_2;

then the average rate of increase of speed during the interval is

$$\frac{v_2 - v_1}{t_2 - t_1}.$$

The dimensions of this quantity are obviously $[LT^{-2}]$. Thus its numerical value is diminished, like that of speed, in proportion as the unit of length is increased. But it is increased in the duplicate of the proportion in which the unit of time is increased. For instance a rate of increase of speed of 32·2 feet per second per second (the mere *statement* is enough to show the double dependence on the time unit) becomes

$$32{\cdot}2\frac{(3600)^2}{5280} = 79{,}036 \text{ nearly},$$

when expressed in terms of miles and hours.

Uniform change of speed. § 28. When the rate of increase of speed is uniform, the above average value is its actual value throughout the interval. Hence with uniform rate of increase $= a$, a speed V becomes in time t

$$v = V + at.$$

Also, as it increases uniformly, its average value during time t is half way between its values at the beginning and end of that time; *i.e.*, it is

$$V + \tfrac{1}{2}at.$$

The space described during the interval is at once found (§ 25) as the product of the interval and the average speed during its lapse;—*i.e.*, it is

$$s = Vt + \tfrac{1}{2}at^2.$$

And it is easy to see from these expressions that

$$v^2 = V^2 + 2as,$$

which gives the speed acquired in terms of the space traversed.

[Stone moving vertically.] § 29. This is the only case in which the result can be reached without formally using the methods of the integral calculus. These expressions enable us at once to solve a great number of simple questions connected with the motion of a stone or bullet, under the action of gravity, in a vertical line. For it is found by experiment that gravity impresses, in every second, a downward speed of 32·2 feet per second on an unsupported body; and, by the Second Law, this is independent of the body's previous motion.

Hence, if a stone be let fall, its speed after t seconds is $32{\cdot}2t$, and the space fallen through is $16{\cdot}1t^2$. Also, if it fall through s feet, it will acquire a speed whose square is $v^2 = 64{\cdot}4s$.

Again, if a stone be thrown upwards with a speed of 300 feet per second, after t seconds its speed will be $300 - 32{\cdot}2t$, and the height to which it has then ascended is $300t - 16{\cdot}1t^2$. Thus it stops, and turns, after $\frac{300}{32{\cdot}2}$ seconds; and the greatest height it reaches is $\frac{300^2}{64{\cdot}4}$ feet.

From the statement above, putting $\dot{s} = v$, we find

$$\ddot{s} = \dot{v} = L\frac{v_2 - v_1}{t_2 - t_1} = \frac{dv}{dt}.$$

From this expression the preceding results may be at once obtained. Thus, assuming

$$\ddot{s} = a,$$

we have by integration

$$\dot{s} = V + at,$$

and again $$s = s_0 + Vt + \tfrac{1}{2}at^2.$$

As an instance of the indirect problem—*i.e.*, to find the speed, and its rate of increase, when the law of the motion is given:—suppose

$$s = a\cos\omega t.$$

(This equation describes the simplest form of vibratory motion, and will be fully treated later.) We have, by taking the fluxion,

$$\dot{s} = -a\omega\sin\omega t,$$

and again $$\ddot{s} = -a\omega^2\cos\omega t = -\omega^2 s.$$

[Velocity.] § 30. Velocity, as we have already said, involves the ideas of speed and of direction of motion conjointly.[1] To compound two velocities (as is required in the application of Newton's Second Law), we have the following obvious construction. From any fixed point O (fig. 2), draw a line OA representing, in magnitude and direction, one of the two velocities. From its extremity A draw AB representing in the same way, and on the same scale, the other. Complete the triangle OAB. Then OB represents, in magnitude and direction (still on the same scale), the resultant velocity. We have called the construction obvious because one has only to think of *how* a point can be said to have simultaneous velocities, in order to see its truth. Thus, if OA represents the velocity of a railway train, AB that of a passenger walking in a saloon carriage, O may be looked upon as the position of the point of the carriage at which he began his walk, at the moment when he did begin it; while B represents the position of the point of the carriage which he has reached at the end of his walk, just at the moment when he did reach it. Here OA is the velocity of the carriage relative to the earth, AB that of the passenger relative to the carriage. This proposition may be called the triangle of velocities. Another obvious mode of stating it is to complete the parallelogram of which OB is a diagonal (fig. 3); and then we have the same construction in the form:—If the two velocities to be compounded, represented by OA and OC, be taken as contiguous sides of a parallelogram, the conterminous diagonal OB represents their resultant.

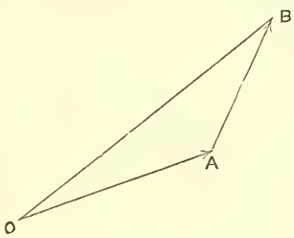

Fig. 2.

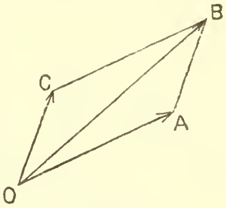

Fig. 3.

[Composition of velocities.] § 31. From the triangle of velocities we may pass at once to the polygon of velocities, which gives us the resultant of any number of simultaneous velocities. Thus, beginning as above at any point O (fig. 4), lay off OA, AB, BC (however many there may be) as successive sides of a polygon *all taken in the same direction round.* The separate velocities may be in one plane or not. When this is done, the final point C is easily seen to be independent of the *order* in which the separate velocities were taken, and is thus a perfectly definite point. OC, completing the polygon, represents the resultant velocity. But it is taken *in the opposite direction round.* If C coincide with O, there is no resultant;—*i.e.*, a point which has, simultaneously, velocities represented by the successive sides of any polygon, all taken the same way round, is at rest.

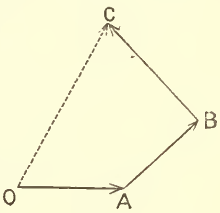

Fig. 4.

In what precedes, we have denoted the position of the moving point in its known path by the single quantity s. But if we think of its Cartesian coordinates x, y, z, we see that in general each of these must vary during the motion. And just as we represented the whole speed by $\dot{s}$ so we may speak of $\dot{x}$ as the speed in the direction of the axis of x, &c. And now we have a hint of a most important character. For, by the ordinary laws of the differential calculus, we have three equations of the form

$$\frac{\dot{x}}{\dot{s}} = \frac{dx}{ds} \text{ or } \dot{x} = \frac{dx}{ds}\dot{s}.$$

Now $\frac{dx}{ds}$ is the cosine of the inclination of the tangent at s to the axis of x. And so with $\dot{y}$ and $\dot{z}$. These give us

$$\dot{x}^2 + \dot{y}^2 + \dot{z}^2 = \dot{s}^2\left(\left(\frac{dx}{ds}\right)^2 + \left(\frac{dy}{ds}\right)^2 + \left(\frac{dz}{ds}\right)^2\right) = \dot{s}^2.$$

Hence we see that a speed in any direction may be resolved into three in any assigned directions at right angles to one another; that the speed in any one of these is determined by multiplying the whole speed by the cosine of the angle between its direction and that of its resolved part; and that the square of the whole speed is the sum of the squares of the speeds in the resolved motions. These results, however, can be obtained more directly, and in a more instructive manner, by the consideration of "velocities," and not of mere "speeds." But, before we take this step, let us take the second fluxions of the coordinates, and see to what they lead us.

From $$\dot{x} = \frac{dx}{ds}\dot{s}$$

we obtain at once $$\ddot{x} = \frac{dx}{ds}\ddot{s} + \frac{d^2x}{ds^2}\dot{s}^2;$$

or, introducing in the last term, both as a multiplier and as a divisor, the radius of curvature of the path,

$$\ddot{x} = \frac{dx}{ds}\ddot{s} + \rho\frac{d^2x}{ds^2}\cdot\frac{\dot{s}^2}{\rho},$$

with similar expressions for $\ddot{y}$ and $\ddot{z}$. These show that the rates of increase of speed, parallel to the three axes respectively, may be considered as made up of the resolved parts of the two directed quantities $\ddot{s}$ and $\dot{s}^2/\rho$. The first is in the direction of the tangent to the path, the second in the direction of the radius of curvature; and the law of resolution is, for each, multiplication by the cosine of the angle between the two directions concerned. We shall presently recognize these as the components of the acceleration.

[1] It is, in fact, in the language of quaternions, a "vector," of which the speed is the "tensor" or length, and of which the "versor" assigns the direction. And the laws of composition of velocities are in all respects the same as those of vectors.

Resolution of velocity.

§ 32 To resolve a velocity is of course a perfectly indefinite problem, unless the number of conditions requisite for definiteness be imposed. For, in general, it may be taken as one side of any complete polygon, whether in one plane or not; and the other sides, all taken in the opposite order round, represent its components.

The only cases which we need consider, in which the conditions are such as to ensure one definite solution, are—(1) when a velocity is to be resolved into components parallel and perpendicular to a given line; and (2) an extension of the same case to components parallel respectively to three lines at right angles to one another. In case (1) the given velocity is to be taken as the hypotenuse of a right-angled triangle of which one of the sides is parallel to the given line. In case (2) it is to be taken as the diagonal of a rectangular parallelepiped of which the edges are parallel to the three lines respectively. In either case the magnitude of each component is found by multiplying the amount of the velocity by the cosine of the angle between its direction and that of the component; and the square of the whole velocity is equal to the sum of the squares of the components. We are now prepared to take up the requisite preliminaries for the application of the Second Law. What, in fact, is "change of velocity"? The preceding statements at once enable us to give the answer. For let OA (fig. 5) be the velocity of a point at one instant, OB at a succeeding instant. To convert OA into OB, we must compound with it a velocity represented by AB. AB represents the change. Hence if, during any motion *whatever* of a point, a line OA be constantly drawn from a fixed point O, so as to represent at every instant the magnitude and direction of the velocity of the moving point, the extremity of OA will describe a curve (plane if the original path be plane, but not otherwise, except in certain special cases) which possesses the following important but obvious properties:—(1) the tangent at A is the direction of the change of velocity in the original path; (2) the rate of motion of A is the rate of change of velocity in the original path. Hence in this auxiliary curve, called the HODOGRAPH (*q.v.*), the velocity represents, in magnitude and direction, what is called "acceleration" in the original path. And, because the acceleration can thus be represented as a velocity, the laws of composition and resolution of velocities hold good for accelerations also.

Change of velocity.

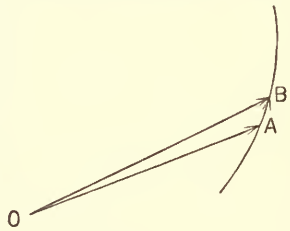

Fig. 5.

Hodograph.

Acceleration.

§ 33. Hence, if we desire to know the whole acceleration in any case of motion of a point, we need only find its components in, and perpendicular to, the tangent to the path. That in the tangent has already been found; it is $\dot{v}$ or $\ddot{s}$ as in § 29. For that perpendicular to the path we may study the simple case of uniform motion in a circle.

Acceleration in uniform circular motion.

§ 34. If a point move with uniform speed V in a circle, the hodograph is evidently a circle of radius V, and is described uniformly in the same time as the orbit (see fig. 6). Hence the speeds in the two circles are as their radii. Let R be the radius of the orbit. Then the magnitude of the acceleration in the orbit (the speed in the hodograph) is found from

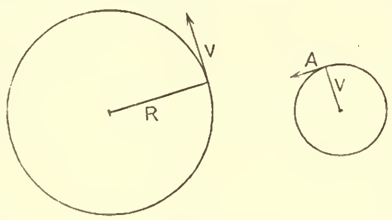

Fig. 6.

$$A : V :: V : R;$$

that is,

$$A = V^2/R.$$

The direction of this acceleration, being that of the tangent to the hodograph, is perpendicular to the corresponding radius of the hodograph, *i.e.*, to the tangent to the orbit. Hence it is *along the radius of the orbit and directed inwards to its centre.*

The so-called centrifugal force.

§ 35. In other words, to *compel* a mass to describe an *unnatural* (because curved) path, it must be acted on by a force directed towards the centre of curvature of the path. We anticipate so far as to introduce here mass and force, although, strictly, we are dealing with kinematics. But the student cannot be too early warned of the dangerous error into which so many have fallen, who have supposed that a mass has a tendency to fly *outwards* from a centre about which it is revolving, and therefore exerts a "centrifugal force," which requires to be balanced by a "centripetal force." The centripetal force is required if the path is to be curved; it is required for the purpose of *producing the curvature*, and not because there is any tendency to fly out from the centre.

Components of acceleration.

§ 36. Thus, in any motion of a point, the whole acceleration is the resultant of two parts—the first in the direction of motion and of magnitude equal to the rate of increase of speed, the second directed towards the centre of curvature and of magnitude as the curvature and the square of the speed conjointly. The sole effect of the first component is to alter the *speed*, of the second to alter the *direction*, of the motion. There is no acceleration perpendicular to the osculating plane, because two successive values of the velocity, and therefore also the corresponding *change of velocity*, are in that plane.

Angular velocity.

§ 37. A very convenient expression for acceleration which changes the direction of motion is furnished in terms of what is called the "angular velocity," *i.e.*, the rate at which direction changes. This also is properly a vector, or directed line, perpendicular to the plane in which the change of direction takes place, and of length proportional to the rate at which the angle assigning the direction changes.

§ 38. In the case of uniform motion in a circle of radius R, with speed V, the time of describing the complete circumference $(2\pi R)$ is $2\pi R/V$. Hence the angular velocity is V/R, usually denoted by ω. Thus the above expression for the acceleration in a direction perpendicular to the path of a point (§ 34) may be written in the form $\rho\omega^2$, where ρ is the radius of curvature of the orbit and ω the angular velocity of that radius. The direction of this acceleration, as we have seen, is always towards the centre of curvature.

§ 39. The general difficulty of any question concerning acceleration is usually a purely mathematical one, involving only such physical considerations as are required for the formation of the differential equations, and for the determination of the so-called arbitrary constants or arbitrary functions involved in the integrals. We will not now discuss the various forms in which the difficulty may present itself, because in the course of the article many of the more important of these will be fully treated in connexion with motions actually observed among terrestrial or cosmical bodies.

Uniform acceleration parallel to a fixed line.

§ 40. We have sufficiently considered (§§ 27–29) uniform acceleration in the line of motion. Let us now consider uniform acceleration in a fixed direction, whether the motion of the point be in that direction or not. This is the most general case of the motion of an *unresisted* projectile, on the supposition that its path is confined to a region throughout which gravity is sensibly constant alike in direction and in intensity. Two well-known properties of the parabola lead to an immediate solution of our problem.

Let fig. 7 represent a parabola, defined completely by its focus S and its directrix MN. We suppose it to be placed with its axis vertical, and vertex upwards. Take any point P, join PS, and draw PM perpendicular to the directrix. Then

(*a*) If PQ bisect the angle SPM, it is the tangent to the parabola at P.

Let Q be any point in the tangent, and let QR, drawn parallel to MP, meet the curve in R. Then we have

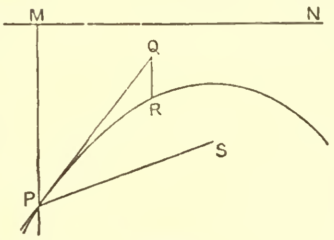

Fig. 7.

(*b*) $$PQ^2 = 4SP.QR.$$

.th of unre- .ted o- tile.

§ 41. Now suppose a point, originally moving along PQ with uniform speed V, to have its motion accelerated in a direction parallel to MP, the acceleration being α, a constant. Then, after t seconds it would have moved along PQ through a space Vt, and parallel to MP through a space $\frac{1}{2}\alpha t^2$. Hence, if R be its position at that time,

$$PQ = Vt, \qquad QR = \tfrac{1}{2}\alpha t^2.$$

From these equations we find at once

$$PQ^2 = \frac{2V^2}{\alpha}QR.$$

This relation is of the same form as that already written for a parabola, and (as it does not involve t) it holds for every point of the path. Hence the point moves in a parabola whose axis is vertical, which touches PQ (the direction of projection) in P, and in which $SP = V^2/2\alpha$. But these three data determine the parabola. For we have only to draw PM vertical, make the angle QPS = QPM, and measure off the lengths PM and PS each equal to $V^2/2\alpha$. M is a point in the (horizontal) directrix, and S is the focus. Hence the path is completely determined.

It is well to notice that, as $V^2 = 2\alpha PM$, M is the point which the projectile would just reach if it were projected vertically upwards (§ 29).

amples motion pro- tile.

§ 42. If the speed of projection be kept constant, while the direction of PQ alters in a vertical plane, S describes a circle about P as centre. This consideration enables us easily to *find the direction of projection that a given object may be struck.* Let O (fig. 8) be the object. Join PO, and let it cut in B the circle MBS (whose centre is P). Draw ON perpendicular to the common directrix, and with radius ON describe a circle about O. This will (in general) cut MBS in two points F and F′. *These are the foci of the two paths by either of which the projectile can reach O.* For by construction FO = ON, so that O lies on the path whose focus is F. Similarly for F′.

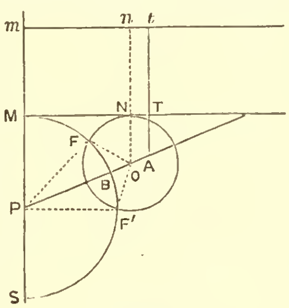

Fig. 8.

To find the most distant point along PO which can be reached, with the given speed of projection from P, we have merely to note that, as O is taken farther and farther from P, F and F′ approach B, and finally coincide with it. If O be then at A, we have AT = AB, where AT is perpendicular to the directrix. Hence, if we produce AT to t so that Tt = BP, we have At = AP. Draw through t a line tm parallel to TM. Then A lies on the parabola whose focus is P and directrix mt. This parabola is the envelop of all the possible paths from P. Any point within it can be reached by two different paths. These become coincident when the point lies on the curve; and no point outside it can be reached.

§ 43. Many of the most important cases of motion of a point involve acceleration whose direction is always towards a definite "centre" as it is called. In such cases the motion is obviously confined to the plane which, at any instant, contains the centre and the line of motion of the point. Acceleration to fixed centre.

Also the "moment" of the point's velocity about the centre remains constant. Here a slight digression is necessary.

Def.—*Given a directed quantity (a velocity, force, &c.) in a line AB* (fig. 9). *If a perpendicular OP be drawn to AB from any point O, the "moment" of the directed quantity about O is the product of its amount by the length of the perpendicular.* Moment.

If the directed quantity be reversed, the *sign* of the moment is changed. The moment is, in fact, properly a directed quantity (or vector) perpendicular to the plane OAB. And its numerical magnitude is double the area of the triangle OAB.

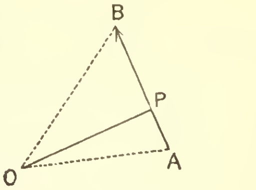

Fig. 9.

[§ 44. The convention usually made as to the sign of rotation about an axis is to regard it as positive when it is in the same sense as that in which the earth turns about its axis, as seen by a spectator above the north pole. This is in the opposite direction to that of the hands of a watch. Hence the plane angle AOP (fig. 10), representing the change of direction of a line originally coincident with OA, is positive, and is looked on as due to rotation about an axis drawn from O *upwards* from the plane of the figure. Thus the rotation of the sun and the orbital motions of the planets take place in the positive direction about axes drawn on the whole northwards from the plane of the ecliptic; or we may put it thus:—seizing an axis by the positive end, we must *un*screw—by the negative end, we must screw—to give positive rotation. And when, later, we consider rotations about three rectangular axes, Ox, Oy, Oz, we shall suppose them so drawn that rotation through a positive right angle Convention as to sign of angle, angular velocity, &c.

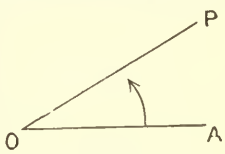

Fig. 10.

about Ox changes Oy into Oz,
,, Oy ,, Oz ,, Ox,
,, Oz ,, Ox ,, Oy,

the three letters being throughout arranged in cyclical order, xyz, yzx, &c.]

§ 45. Here we must introduce a simple geometrical proposition:— Geometrical proposition.

If any point be taken in the plane of a parallelogram, and triangles be formed with the point as vertex and with contiguous sides and the conterminous diagonal as their respective bases, the sum of the areas of the first two triangles is equal to the area of the third.

Thus, in areas (fig. 11),

$$OAB + OAC = OAD.$$

If O lie within the angle BAC, as in fig. 12, the proposition becomes

$$OAC - OAB = OAD.$$

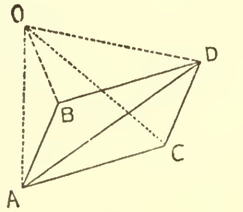

Fig. 11.

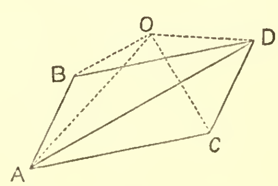

Fig. 12.

§ 46. Remembering that these areas represent half the moments of the bases of the respective triangles about the point O (that of OAB being *negative* in the second case above), we see that

The moment of a diagonal of a parallelogram about any point in the plane of the figure is the (algebraic) sum of the moments of two conterminous sides.

Now, suppose the sides of the parallelogram to represent a velocity and its change. If the direction of the change pass through O, its moment is *nil*. Hence, *for acceleration directed towards a fixed point the moment of the velocity about that point is constant.*

Equable description of areas.

This is commonly expressed by saying that *the radius-vector describes equal areas in equal times about the point to which the acceleration is directed.* For the moment of the velocity is double the area so traced in unit of time.

Another way of expressing the same thing is to say that the angular velocity of the radius-vector is inversely as the square of its length. For the product of the square of the radius-vector and its angular velocity is double the area described by it in unit of time.

The converse of this proposition is also evidently true; *i.e., when a point moves so that the moment of the velocity about a point in the plane of its motion is constant, its acceleration relative to that point (if any) is directed towards or from that point.*

Analytical treatment of central acceleration.

§ 47. Analytically: if P be the acceleration, directed towards a fixed point which we choose as origin, we have

$$\ddot{x} = -P\cos\theta = -Px/r,$$
$$\ddot{y} = -P\sin\theta = -Py/r,$$

(r and θ being the polar coordinates of the moving point; we have already seen that the path is necessarily plane). Eliminating P, we have

$$0 = x\ddot{y} - y\ddot{x} = \frac{d}{dt}(r^2\dot{\theta}).$$

Thus $$x\dot{y} - y\dot{x} = r^2\dot{\theta} = \text{const.} = h.$$

This may be transformed, at once, by the methods of the differential calculus, into

$$p\dot{s} = pv = h,$$

where p is the length of the perpendicular from the origin to the tangent to the path. Conversely, if equal areas be described by the radius-vector in equal times, we have

$$r^2\dot{\theta} = x\dot{y} - y\dot{x} = h.$$

Whence $$x\ddot{y} - y\ddot{x} = 0,$$

or $$\ddot{x} = Qx,\ \ \ddot{y} = Qy.$$

Hence the whole acceleration is Qr, and is directed towards or from the origin.

Polar coordinates.

While we are dealing with these formulæ we may investigate the general expressions for velocity and acceleration in terms of polar coordinates for a point moving in a plane.

We have $$x = r\cos\theta,\ \ y = r\sin\theta.$$

From these

$$\dot{x} = \dot{r}\cos\theta - r\dot{\theta}\sin\theta,$$
$$\dot{y} = \dot{r}\sin\theta + r\dot{\theta}\cos\theta.$$

Hence the speed along the radius-vector is

$$\dot{x}\cos\theta + \dot{y}\sin\theta = \dot{r};$$

and that perpendicular to the radius-vector (in the direction in which θ increases) is

$$\dot{y}\cos\theta - \dot{x}\sin\theta = r\dot{\theta}.$$

These expressions might have been written down at once, if we note that δr and $r\delta\theta$ are the resolved parts of δs along, and perpendicular to, r. But we must be careful how we carry this species of reasoning one step further. Taking the second fluxions of x and y, we have

$$\ddot{x} = (\ddot{r} - r\dot{\theta}^2)\cos\theta - (2\dot{r}\dot{\theta} + r\ddot{\theta})\sin\theta,$$
$$\ddot{y} = (\ddot{r} - r\dot{\theta}^2)\sin\theta + (2\dot{r}\dot{\theta} + r\ddot{\theta})\cos\theta.$$

Hence the acceleration along the radius-vector is

$$\ddot{x}\cos\theta + \ddot{y}\sin\theta = \ddot{r} - r\dot{\theta}^2,$$

and that perpendicular to it (positive when in the direction in which θ increases) is

$$\ddot{y}\cos\theta - \ddot{x}\sin\theta = 2\dot{r}\dot{\theta} + r\ddot{\theta} = \frac{1}{r}\frac{d}{dt}(r^2\dot{\theta}).$$

Thus, although $\dot{r}$ represents truly the speed along r, $\ddot{r}$ does not represent the acceleration in that direction. It represents, in fact, only the *acceleration of speed* along r. But we have seen that there is acceleration along r, if its direction changes, even when its length is constant, *i.e.*, when the path is circular; and in that case $r\dot{\theta}^2$ is the quantity which we designated as $\rho\omega^2$ in § 38.

As a verification of these formulæ, let us consider uniform motion in a straight line.

Here $$r\cos\theta = a,$$

the equation of the straight line, and

$$a\tan\theta = Vt,$$

the condition of uniform motion. We have

$$\dot{r} = a\sec\theta\tan\theta.\dot{\theta},$$
$$V = a\sec^2\theta.\dot{\theta} = r^2\dot{\theta}/a;$$
$$\dot{r} = V\sin\theta,$$
$$\ddot{r} = V\cos\theta.\dot{\theta} = \frac{aV}{r}\dot{\theta} = \frac{a^2V^2}{r^3}.$$

Here, although there is no acceleration, $\ddot{r}$ has a definite value. But

$$\ddot{r} - r\dot{\theta}^2 = a^2V^2/r^3 - a^2V^2/r^3 = 0.$$

From the expressions for the acceleration along and perpendicular to the radius-vector we at once obtain the result above (§ 46). For, if there be no acceleration perpendicular to the radius-vector,

we have $$\frac{1}{r}\frac{d}{dt}(r^2\dot{\theta}) = 0,$$

from which $$r^2\dot{\theta} = \text{const.} = h.$$

We have, in addition to this, the expression for the acceleration towards the origin,

$$\ddot{r} - r\dot{\theta}^2 = -P.$$

Eliminating $\dot{\theta}$, we have

$$\ddot{r} - h^2/r^3 = -P.$$

This gives r in terms of t, and thus reduces (if we please) any case of a central orbit to a corresponding case of rectilinear motion. The difference between the accelerations in the revolving radius-vector and in the fixed line is a term depending on the inverse cube of the radius-vector. But the usual mode of proceeding is as follows.

Reduction to case of recti-linear motion.

Multiply by $\dot{r}dt$ and integrate, then

$$\dot{r}^2 + \frac{h^2}{r^2} = C - 2\int P dr;$$

or $$\left(\frac{dr}{d\theta}\right)^2\frac{h^2}{r^4} + \frac{h^2}{r^2} = C - 2\int P dr.$$

The left-hand member obviously represents the square of the velocity, as it is the sum of the squares of $\dot{r}$ and $r\dot{\theta}$. For we have

$$\dot{r} = \frac{dr}{d\theta}\dot{\theta} = \frac{dr}{d\theta}\frac{h}{r^2}.$$

This gives a relation between r and θ, which is therefore the polar equation of the path described. It is usual to employ, instead of r, its reciprocal $1/r = u$. With this the equation becomes

$$h^2\left(\left(\frac{du}{d\theta}\right)^2 + u^2\right) = C + 2\int\frac{P du}{u^2}.$$

Differentiating with regard to θ, and dividing by $2h^2\frac{du}{d\theta}$, we obtain finally

$$\frac{d^2u}{d\theta^2} + u = \frac{P}{h^2u^2},$$

Polar equation of path.

an equation of very great importance.

When there is acceleration T perpendicular to the radius-vector, as well as $-P$ along it, this equation takes the form

$$\frac{d^2u}{d\theta^2} + u = \frac{\dfrac{P}{u^2} - \dfrac{T}{u^3}\dfrac{du}{d\theta}}{h^2 + 2\displaystyle\int\frac{T}{u^3}d\theta}.$$

§ 48. There are two specially important cases of central acceleration. The first is that of the gravitation law, the other that of Hooke's law. We will take these in order, but by very different methods.

Special cases.

§ 49. *Planetary Motion.*—With the gravitation law the acceleration varies inversely as the square of the distance from the point to which it is directed. But, as we have just seen, the angular velocity of the radius-vector, *i.e.*, of the direction of acceleration, varies according to the same law. Hence in the hodograph, the linear velocity (whose *magnitude* is that of the acceleration in the path) is pro-

Planetary motion.

portional to the angular velocity of the tangent (whose direction is parallel to the acceleration).

rcular lo- ph.

Thus, in the hodograph, the angle between successive tangents is proportional to the arc between their points of contact; and therefore the curvature is constant;—*i.e.*, *the hodograph is a circle.*

rm of ne- y bit.

Let A (fig. 13) be the centre of this circle, O the pole of the hodograph, P any position of the tracing point. Then OP is, in magnitude and direction, the velocity in the orbit. But it may be looked on as consisting of two parts, OA and AP. Of these both are constant in magnitude; but OA is constant in direction, while AP is perpendicular to the direction of acceleration in the orbit. Hence the velocity in the orbit is the resultant of two constant parts,—one always in a fixed direction, the other always perpendicular to the radius-vector.

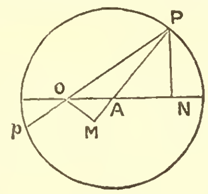

Fig. 13.

This gives the form of the orbit as follows:—

$$\dot{x}=a(e-y/r),\ \dot{y}=ax/r\ ;$$

so that $r\dot{r}=x\dot{x}+y\dot{y}=cr\dot{y}$,

or $r=c\ (y+b)$;

where the meanings of the quantities are obvious.

But if PO cut the circle again in p, Op is proportional to the perpendicular on the tangent to the orbit from the centre of acceleration (because PO.Op is constant) and is at right angles to it (because it is in the direction of the velocity). Hence the path is such that the locus of the foot of the perpendicular from the centre of acceleration on the tangent is a circle. This property belongs exclusively to conic sections, one focus being the point from which the perpendiculars are drawn.

A third and even simpler mode of treating this most important problem is as follows. Draw OM perpendicular to PA (produced if necessary) and PN perpendicular to OA. Then OM is the resolved part of OP parallel to the tangent at P, *i.e.*, it is the speed with which the length of the radius-vector changes. Also PN is the resolved part of OP perpendicular to the fixed line OA, *i.e.*, it is the speed with which the moving point travels in a fixed direction. But by similar triangles OAM, PAN, we have

$$\text{OM} : \text{PN} :: \text{OA} : \text{AP} = \text{a constant ratio}.$$

Hence the increment of the radius-vector bears a constant ratio to the simultaneous increment of the distance of the moving point from a fixed line in the plane of motion. This is only a slightly altered form of statement of the focus and directrix property of conic sections.

When O is within the circle, the constant ratio is less than unity, and the conic is an ellipse; when without, the ratio is greater than unity, and we have an hyperbola. When O is on the circumference of the hodograph, the path is a parabola; for the ratio is unity.

In a subsequent section we will return to this question, and treat it from the point of view of Kepler's Laws of Planetary Motion.

Analy- ical proof.

Simple as are the geometrical methods above, the direct analytical one is still simpler. For we have

$$\text{P}=-\frac{\mu}{r^2}\ ,$$

so that $\ddot{x}=-\frac{\mu}{r^2}\cos\theta\ ,\ \ \ddot{y}=-\frac{\mu}{r^2}\sin\theta\ .$

Hence, as before (§ 47),

$$x\dot{y}-y\dot{x}=r^2\dot{\theta}=h\ ;$$

and therefore, by eliminating r^2, we have

$$\ddot{x}=-\frac{\mu}{h}\cos\theta\ .\ \dot{\theta}\ ,\ \ \ddot{y}=-\frac{\mu}{h}\sin\theta\ .\ \dot{\theta}\ ,$$

so that $\dot{x}-a=-\frac{\mu}{h}\sin\theta\ ,\ \ \dot{y}-\beta=+\frac{\mu}{h}\cos\theta\ .$

These give at once, by squaring and adding,

$$(\dot{x}-a)^2+(\dot{y}-\beta)^2=\mu^2/h^2\ ,$$

the equation of the circular hodograph. Also, by multiplying the first by y, and subtracting it from the second multiplied by x, we have

$$h-\beta x+ay=r\mu/h\ ,$$

the equation of the orbit. This is evidently a conic section of which the origin is a focus. The directrix corresponding is the line

$$ay-\beta x+h=0\ ,$$

and the excentricity is

$$h\sqrt{a^2+\beta^2}/\mu\ .$$

From these the major axis can be calculated.

§ 50. *Elliptic Motion about the Centre.*—When a point moves uniformly in a circle, the motion presents very different appearances according to the spectator's point of view. If we suppose him to be situated at a distance very great compared with the radius of the circle, he sees what is practically an orthographic projection of the orbit on a plane perpendicular to the line of sight. In general, an orthographic projection of a circle is an ellipse—whose centre is the projection of that of the circle. As equal areas are projected orthographically into equal areas, the appearance is therefore elliptic motion, in which the radius-vector from the centre describes equal areas in equal times. Hence (§ 46) the acceleration is directed towards the centre. But accelerations are projected like velocities, and like lines. Hence, as the acceleration in uniform circular motion is constant, and directed towards the centre, so in elliptic motion, with equable description of areas about the centre, the acceleration is towards the centre, and is *proportional to the length of the radius-vector.*[1] But this projected orbit may again be projected orthographically, as often as we please, on different planes. It will always remain elliptical, and with the radius-vector from the centre describing equal areas in equal times. And the acceleration will always be in the same proportion as before to the radius-vector. However different in size and shape these elliptic orbits may be, they have one common property, *the time of describing them is the same.*

Central acceleration proportional to radius-vector.

Thus we see that when the orbit is an ellipse described about its centre of figure the acceleration is central, and proportional to the radius-vector. The time of describing such an ellipse depends only upon the *ratio* of the acceleration to the length of the radius-vector; or, if we choose, upon the magnitude of the acceleration at unit distance. And the converse of this proposition is also evidently true. When we look edgewise at the uniformly-described circular path with which we commenced, it is seen projected into a straight line, in which the moving point appears to *oscillate.* This is the case, for instance, very approximately, with the satellites of Jupiter as seen from the earth. Sun-spots, the red-spot on Jupiter, &c., all appear to move approximately in this way. But the extreme importance of this species of motion is that it is the simplest type of oscillation of a particle of matter displaced from a position of stable equilibrium. The vibrations of the ether when homogeneous plane-polarized light is passing through it, of the air when a pure musical note is sounded, the oscillations of a pendulum (through small arcs), the simplest vibrations of a pianoforte wire or a tuning-fork, the indications of a tide-gauge when the sea is calm,—all are instances of it. Hence the special necessity for studying it in detail.

§ 51. Def.—*Simple harmonic motion is the resolved part, parallel to a diameter, of uniform circular motion.*

Simple harmonic motion.

[1] The elastic force called into play by displacement is, by Hooke's law, proportional to the displacement, and tends to restore the displaced particle to its equilibrium position. We mention this, in passing, to show the importance of the present investigation.

Let a point P (fig. 14) move uniformly in the circle APA′. Then, drawing any diameter AOA′, and PM perpendicular to it, the motion of M is simple harmonic.

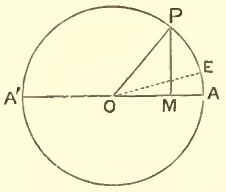

Fig. 14.

The speed and acceleration of M are obviously the resolved parts, along AA′, of the speed and acceleration of P. Hence if V be the speed of P we have

$$\text{speed of } M = \frac{PM}{PO}V,$$

$$\text{acceleration of } M = \frac{MO}{PO} \times \text{acceleration of } P$$

$$= \frac{MO}{PO} \cdot \frac{V^2}{PO} = \frac{V^2}{PO^2} MO.$$

From these expressions we see that, if we call ω the angular velocity of OP, so that $\omega = V/PO$, we have

$$\text{speed of } M = PM.\omega,$$

$$\text{acceleration of } M = MO.\omega^2.$$

Thus the speed of M increases from A to O,—being zero at A, and V at O; then it falls off to zero at A′, and goes through the same numerical values in the opposite order, when the direction of motion is reversed at A′.

The acceleration of M is always directed *towards* O. It has its greatest value at A and again at A′, and is always *proportional to the distance from O*. If T be the *period* of the simple harmonic motion, *i.e.*, the period of rotation of P in the circle, we have

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{V}a,$$

Amplitude.

where a is the radius of the circle, or, as it is also called, the "amplitude" of the simple harmonic motion. We may now write as the characteristic of this species of motion

$$\text{acceleration} = \frac{4\pi^2}{T^2} \times \text{displacement};$$

or

$$T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}}.$$

Phase and epoch.

§ 52. In our further remarks about simple harmonic motion the following terms will be found convenient. P is the position at time t of the point moving in the circle. Let E be its position at the zero of reckoning, when $t=0$. Then the angle AOP may be called the "phase" of the simple harmonic motion, and AOE the "epoch." In time units the values of the phase and epoch are found from their circular measure by dividing by ω.

If the position of the point moving with simple harmonic motion be denoted by x, we obviously have

$$x = OM = OP\cos POA,$$
$$= OP\cos(POE + EOA),$$
$$= a\cos(\omega t + \epsilon).$$

This expression is to be found, perhaps more frequently than any other, in all branches of mathematical physics. It is in terms, or series of terms, of this form that *every* periodic phenomenon can be described mathematically, as will be seen later. From the expressions for the longitude and radius-vector of a planet or a satellite to those of the most complex undulations whether in water, in air, or in the luminiferous medium, all are alike dependent upon it.

The results obtained geometrically above are easily reproduced from this form:—

thus $\quad \dot{x} = -a\omega\sin(\omega t + \epsilon);$

and $\quad \ddot{x} = -a\omega^2\cos(\omega t + \epsilon) = -x\omega^2.$

Graphic representation.

§ 53. The simplest graphical method of exhibiting the nature of any kind of rectilineal motion is to compound it with a uniform velocity in a direction perpendicular to the line in which it is executed. This is, in fact, what is done in the majority of *self-registering* instruments, where a slip of paper is drawn by clock-work uniformly past the moving point, in a direction perpendicular to its line of motion, and a record is made by mechanical means, by a pencil, by an electric spark, or (best of all) by photographic processes. When this process is applied to a simple harmonic motion the record is of the general form of the curve in fig. 15. This curve has long been known as


Fig. 15.

the "curve of sines," or the "harmonic" curve. All its forms can be deduced from any one of them by mere extension or foreshortening in the vertical or horizontal directions in the figure. It represents the simplest forms into which a vibrating string can be thrown, as well as the instantaneous form of a section of the surface of water along which a simple series of oscillatory waves or ripples is passing. In this case the *form* of the section remains the same as time goes on, but the whole figure moves steadily onwards in the direction in which the waves are travelling.

Analy- cal ex- pressi for a wave.

This is expressed analytically by the form

$$y = a\cos(nt - mx),$$

where x and y are horizontal and vertical coordinates of a point at the surface of the water, y being measured from the level of the undisturbed surface. When x is constant we study, for all time, the simple harmonic rise and fall at a particular *place*. When t is constant we have the above-figured instantaneous glance of a section of the whole water-surface.

The rate at which the wave travels is obviously n/m; for, if we increase t by any quantity τ, and x by the corresponding quantity $n\tau/m$, the value of y is unaltered.

Comp- sition simple harmo- nic mo- tions i one li

§ 54. We have next to consider the result of superposing or compounding two simple harmonic motions which take place in the same line. The geometrical method amply suffices for this purpose provided the *periods* of the two are equal, however different may be their amplitudes and their phases. For, if we suppose PQ (fig. 16) to turn about P in the same plane and with the same angular velocity as OP about O, the angle OPQ will remain unaltered, and therefore the triangle OPQ will remain of constant size and form while turning about O. Thus Q describes a circle about O in the given period. The resolved parts of OP, PQ, along any diameter OA, together make up the resolved part of OQ along the same line. Hence *two simple harmonic motions, of the same period and in the same line, are equivalent to a single simple harmonic motion of the common period.* The amplitude of the resultant simple harmonic motion is OQ, and depends only upon OP, PQ, and the angle OPQ,—the amplitudes of the two component simple harmonic motions and *the supplement of the difference of their phases.*

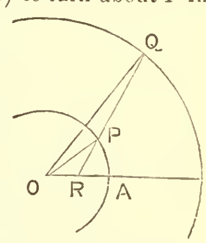

Fig. 16.

Ampli- tude, &c., o result- ant.

§ 55. When the difference of phase is *nil*, or any whole number of circumferences, the resultant amplitude is the sum of the amplitudes of the components, which is its greatest value. When the difference of phase is an odd number of semi-circumferences, the amplitude of the resultant is the difference of those of the components.

If we produce QP to meet OA in R, we see that QOA, the phase of the resultant simple harmonic motion, is intermediate in value to the phases of the components, which are POA and QRA respectively. Its excess over the one, and its defect from the other, are the angles at O and Q in the triangle OPQ; and their sines are to one another as the separate amplitudes QP, PO. Hence, when these amplitudes differ, the phase of the resultant coincides more nearly with that of the component whose amplitude is the greater.

ıalyti- ıl treat- ıent.

Analytically the resultant motion is expressed by

$$x = a\cos(\omega t+\epsilon) + a'\cos(\omega t+\epsilon'),$$
$$= (a\cos\epsilon + a'\cos\epsilon')\cos\omega t - (a\sin\epsilon + a'\sin\epsilon')\sin\omega t,$$
$$= \mathrm{P}\cos(\omega t + \mathrm{Q}),$$

provided that

$$\mathrm{P}\cos\mathrm{Q} = a\cos\epsilon + a'\cos\epsilon',$$

and

$$\mathrm{P}\sin\mathrm{Q} = a\sin\epsilon + a'\sin\epsilon'.$$

These expressions give for the amplitude of the resultant

$$\mathrm{P} = \sqrt{(a\cos\epsilon + a'\cos\epsilon')^2 + (a\sin\epsilon + a'\sin\epsilon')^2},$$
$$= \sqrt{a^2 + 2aa'\cos(\epsilon - \epsilon') + a'^2}.$$

This may be put in either of the forms

$$\sqrt{(a+a')^2 - 4aa'\sin^2\tfrac{1}{2}(\epsilon-\epsilon')} \text{ or } \sqrt{(a-a')^2 + 4aa'\cos^2\tfrac{1}{2}(\epsilon-\epsilon')},$$

from which the above conclusions follow at once.

Also, for the epoch of the resultant, we have

$$\tan\mathrm{Q} = \frac{a\sin\epsilon + a'\sin\epsilon'}{a\cos\epsilon + a'\cos\epsilon'}.$$

'eriods early ıqual.

When ϵ and ϵ' are both positive and less than $\frac{1}{2}\pi$, this is obviously intermediate in value to $\tan\epsilon$ and $\tan\epsilon'$.

When the periods of the components are not exactly equal, the simple artifice which follows enables us still to apply the same method of composition. We have now

$$x = a\cos(\omega t+\epsilon) + a'\cos(\omega' t+\epsilon'),$$
$$= a\cos(\omega t+\epsilon) + a'\cos(\omega t+\epsilon'+(\omega'-\omega)t).$$

Hence the above values of P and Q will still satisfy the conditions if we write $\epsilon' + (\omega'-\omega)t$ instead of ϵ'. Thus we may treat the two components as being of the same period, but make the epoch of one of them steadily increase with an angular velocity equal to the difference of the angular velocities in the generating circles of the components.

The triangle OPQ will no longer preserve its form; it will pass *continuously* through all the various forms which we have seen would be given to it by various differences of phase in the component simple harmonic motions. The time in which it returns to a former value is evidently $2\pi/(\omega'-\omega)$, which is greater the more nearly equal are the periods of the components.

ˣxam- ıle. ıolar ınd ıunar ides.

§ 56. One of the best examples of the principles we have just discussed is furnished by the tides. If there were but one tide-producing body, we should have (approximately) a simple harmonic rise and fall of the sea-level at any given place twice over in the course of about twenty-four hours, and the phase would depend simply upon the distance of the tide-producing body from the meridian (whether above or below the pole). The joint effect of the sun and moon is practically the resultant of the effects which they would separately produce. Hence, when these bodies are in conjunction or in opposition (*i.e.*, at new or at full moon), the whole rise of the tide is the sum of the solar and lunar tides; and we have what are called "spring tides." When the moon is in quadrature, the amplitude of the tidal rise or fall is the excess of the lunar over the solar tide, for it is low water as regards the sun when it is high water as regards the moon. In intermediate positions the effect lies between these extremes, but the joint high-tide lies nearer to the crest of the lunar than to that of the solar tide. In the first and third quarters of the moon, high tide is *earlier* than the high tide due to the moon alone; in the second and fourth *later*. This is what is called "priming" and "lagging" of the tides, and is seen at once to follow from the construction given above. Had the lunar and solar tides been of equal amplitude, spring tides would have been of double the altitude of either, and there would have been no tide at all at the time of neap.

Spring and neap tides.

Priming and lagging.

The mode in which we have treated this special case is an illustration of the general method (above described) of combining simple harmonic motions in which the periods are slightly different.

Composition of two wave motions generally.

§ 57. What we have said of the tide-waves holds of course of all waves in which the separate disturbances are so small that the joint effect is found by superposing the separate effects. Thus when, at sea, two series of waves of equal length meet at any place, the resultant is still a set of waves of the same length, but the altitudes and phases of the components determine those of the resultant. When crest meets crest, we have waves of the sum of the original amplitudes; when crest meets trough, the difference. In the latter case we have still water when the amplitudes of the components are equal. What is called a "jabble,"—where, for a short time, a portion of a stormy sea is almost calm, and after a little it is violently agitated,—is the result of a number of "cross seas."

Common phenomena.

§ 58. If we now consider the instantaneous form of a section of the surface, instead of the successive displacements of one portion of it, we can easily account for a striking phenomenon which is very frequently observed on a shelving beach. We often notice that every ninth or tenth wave or so is higher than those immediately before or after it. This is the result of superposition of two or more sets of waves in which the distance from crest to crest is different in the different sets. In the joint system we have, represented as in § 53, phenomena akin to the spring and neap tides, and the priming and lagging of the tides.

Fig. 17 shows part of the result when the amplitudes are equal, and the wave-lengths as 15 to 17. It gives also a rough approximation to the whole result when the lengths are as 7 to 8 or as 8 to 9

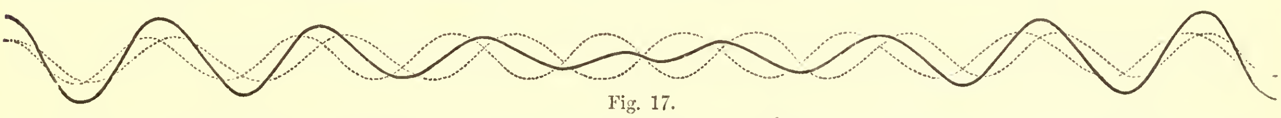

Fig. 17.

Compo- sition of more than two simple harmo- nic mo- tions of one period.

§ 59. To compound any number of simple harmonic motions, of equal periods, in one line, we may obviously take them two by two, and apply the preceding process over and over again till we have as final resultant another simple harmonic motion of the common period.

Or thus:—

$$x = \Sigma a\cos(\omega t+\epsilon) = \cos\omega t\,\Sigma(a\cos\epsilon) - \sin\omega t\,\Sigma(a\sin\epsilon) = \mathrm{P}\cos(\omega t+\mathrm{Q}),$$

where $\mathrm{P}\cos\mathrm{Q} = \Sigma(a\cos\epsilon)$, $\mathrm{P}\sin\mathrm{Q} = \Sigma(a\sin\epsilon)$.

When the separate periods are not equal, and not even *nearly* equal, it is only in special cases that any simplification can be effected by analytical processes. But this is not much to be regretted, because for most purposes a graphic method is sufficiently accurate, and it can always be easily carried out.

Two simple harmo- nic mo- tions at right angles.

§ 60. We must now consider the composition of simple harmonic motions in directions at right angles to each other;—but for the present we confine ourselves to the case in which their periods are equal. In this case we know that the acceleration is in the *same* ratio to the displacement in each of the two rectangular directions. Hence by the general theorem of § 50 the motion is elliptic, with uniform description of areas about the centre.

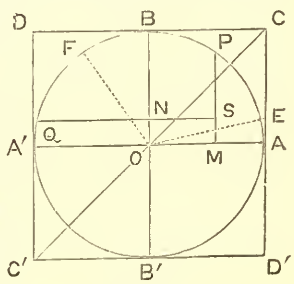

Fig. 18.

To analyse this, suppose, at starting, that their amplitudes also are equal. Let OA, OB (fig. 18) represent the two rectangular directions. With centre O, and radius equal to the common amplitude, describe a circle. Let AOE, BOF represent the epochs of the two components (the corresponding circular motion being supposed positive for each), then obviously EOF exceeds by a right angle the difference between the

Simple harmonic motions at right angles.

phases of the motions in OB and OA. Then if P, Q represent at time t the corresponding positions in the common circle, we have arc FQ = arc EP; and if perpendiculars be drawn, PM to OA, and QN to OB, their intersection S is the position at time t in the resultant motion. The locus of S is, by what has been proved above, an ellipse which touches the sides of the square CDC′D′.

When EOF is a right angle, *i.e.*, when the phases are alike, this ellipse becomes the diagonal CC′ of the square touching the circle at the extremities of AA′ and BB′. When EOF is three right angles, the ellipse becomes the diagonal DD′. When it is two right angles, or four, *i.e.*, when OB is one quarter, or three quarters, of a period in advance of OA, the ellipse becomes the circle ABA′B′. To find in any case whether it is described positively or negatively (§ 44), we have only to notice how OS turns. Now while P is near A, MS remains closely coincident with AC. If, then, Q be anywhere in the semicircle BA′B′, N moves in the direction BB′ and the angle AOS *diminishes.* Hence the ellipse is described negatively (or in the direction of the hands of a watch) if the epoch of the motion in OB exceeds that of the motion in OA by anything up to two right angles. And similar reasoning shows that, if the excess be from two to four right angles, the ellipse is described positively.

If the amplitudes be not equal, we have only to extend or foreshorten the figure parallel to OA or to OB. The square CDC′D′ becomes a rectangle, in which the orbits (all of which, with the exception of the diagonals, are now ellipses) are inscribed. Everything else is as before.

Periods nearly equal.

§ 61. When the periods in the two component motions are nearly, but not quite, equal, the phase of one gains gradually on the other, and the path passes continuously through the forms of all the possible ellipses, but remains possessed of the one property common to them all. It becomes a species of spiral, but in every convolution it touches, in succession, each side of the square or rectangle above discussed.

Simple harmonic motions of one period, in any directions.

§ 62. Similar reasoning shows that the superposition of any number of simple harmonic motions in any directions and with any amplitudes and differences of phase, provided the period is the same for all, gives rise to motion in an ellipse about the centre. But this follows more easily from analysis.

Take, first, two simple harmonic motions of the same period parallel to the axes of x and y. We have

$$x = a\cos(\omega t + \epsilon),$$
$$y = a'\cos(\omega t + \epsilon').$$

Eliminating t between these equations, we have at once

$$\frac{x^2}{a^2} - 2\frac{xy}{aa'}\cos(\epsilon' - \epsilon) + \frac{y^2}{a'^2} = \sin^2(\epsilon' - \epsilon),$$

the equation of an ellipse.

It becomes a circle when and only when

$$a = a', \qquad \cos(\epsilon' - \epsilon) = 0,$$

i.e., when the amplitudes are equal, and the phases differ by an odd number of right angles.

It becomes the straight line

$$x/a - y/a' = 0,$$

when $\epsilon' - \epsilon$ is zero; and

$$x/a + y/a' = 0,$$

when $\epsilon' - \epsilon$ is two right angles.

If SOA be called θ, we have

$$\tan\theta = \frac{y}{x} = \frac{a'\cos(\omega t + \epsilon')}{a\cos(\omega t + \epsilon)}$$
$$= \frac{a'}{a}\left(\cos(\epsilon' - \epsilon) - \sin(\epsilon' - \epsilon)\tan(\omega t + \epsilon)\right).$$

Hence, taking the fluxion of each side,

$$\sec^2\theta\,.\,\dot\theta = -\frac{a'}{a}\omega\sin(\epsilon' - \epsilon)\sec^2(\omega t + \epsilon).$$

Thus, as before, $\dot\theta$ is essentially negative, *i.e.*, the rotation in the ellipse is right-handed if $\epsilon' - \epsilon$ lie between 0 and π, left-handed if it lie between π and 2π.

For a simple harmonic motion, denoted by

$$\xi = a\cos(\omega t + \epsilon),$$

in a line whose direction cosines are l, m, n, we have the components $l\xi$, $m\xi$, $n\xi$ parallel to the three axes respectively. Hence for the resultant of any number of such, *all having the same period*, we have

$$x = \Sigma\,.\,al\cos(\omega t + \epsilon) = \cos\omega t\,\Sigma(al\cos\epsilon) - \sin\omega t\,\Sigma(al\sin\epsilon).$$

Thus we have three equations of the form

$$x = \mathrm{A}\cos\omega t - \mathrm{A}'\sin\omega t,$$
$$y = \mathrm{B}\cos\omega t - \mathrm{B}'\sin\omega t,$$
$$z = \mathrm{C}\cos\omega t - \mathrm{C}'\sin\omega t.$$

If we take three quantities λ, μ, ν, such that

$$\lambda\mathrm{A} + \mu\mathrm{B} + \nu\mathrm{C} = 0,$$
$$\lambda\mathrm{A}' + \mu\mathrm{B}' + \nu\mathrm{C}' = 0,$$

we have also

$$\lambda x + \mu y + \nu z = 0.$$

The first two equations determine without ambiguity the ratios of μ and ν to λ. Hence the third is the equation of a definite *plane* in which the path lies. We may now choose this plane as that of x, y. The value of z above becomes identically zero; and the elimination of t between the equations for x and y gives the ellipse as before.

Period not equal.

§ 63. When the periods of the simple harmonic motions are not equal we have

$$x = a\cos(\omega t + e), \qquad y = a'\cos(\omega' t + e').$$

It is easy to trace the corresponding curve by points; but, except when there is a simple numerical ratio between ω and ω', the equation cannot be presented as an algebraic one between x and y. If $2\omega' = \omega$, we may shift the epoch so that the equations may be written

$$x = a\cos(2\omega' t + a), \qquad y = a'\cos\omega' t.$$

Eliminating t from the first, by the help of the second, we have

$$\frac{x}{a} = \left(\frac{2y^2}{a'^2} - 1\right)\cos a - \frac{2y}{a'}\sqrt{1 - \frac{y^2}{a'^2}}\sin a.$$

This denotes, in general, a curve of the fourth order, of a figure-of-8 form, as in fig. 19. When $a = n\pi$ the curve is a portion of a

Fig. 19.

parabola, its vertex being to the right or left as n is odd or even. This parabola corresponds, in the present case, to the straight lines in the case of § 62. When the periods differ slightly from the ratio 2 : 1, the path passes in succession through the forms traced, forward and backward alternately; and, each time that it opens out from the parabolic form, the tracing-point describes it in the opposite direction to that in which it described it before the path collapsed into the parabola.

Composition of uniform circular motions.

§ 64. The principles already illustrated are sufficient for the examination of every case of this kind. But one or two particular cases merit special notice. The case of two uniform circular motions of equal periods, in one plane, we have already noticed (§ 54). Q describes its circle about P, P its circle about O, and the result is uniform circular motion of Q about O. The radius of this circle may be equal to the sum or difference of the radii of the separate circles, or may have any intermediate value, according to the difference of phase. If the periods be not exactly equal, the motion takes place virtually in a circle whose radius continuously oscillates between the above limits. The path is a species of spiral, which lies between two concentric circles of these radii.

§ 65. When the component circular motions are in opposite directions, we have an extremely interesting and important case. It is obvious that there must now be positions in which OP and PQ are in the same straight line. Let OA, AB (fig. 20) be one of these. Then, in any other position, OP and PQ are equally inclined to OA. The path of Q is an ellipse, of which the major semi-axis OB is the sum of the radii, and the minor axis their difference. Hence when the radii are equal the result is simple harmonic motion in the line OBB′. Thus we have the proposition, of very great importance in optics, that a simple harmonic motion may be looked upon as the resultant of two equal and opposite circular motions in one plane.

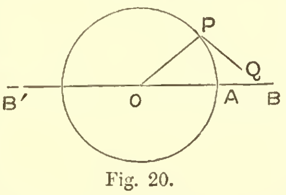

Fig. 20.

When the periods are not exactly equal, the motion may be regarded as simple harmonic motion, in a line which rotates with uniform angular velocity in a plane. This is the case of Foucault's pendulum, and of plane polarized light passing along the axis of a crystal of quartz, or through a piece of glass or other transparent substance in the magnetic field.

-cloids. § 66. Uniform circular motions, of different periods, give epicycloids, &c. A particular case is uniform circular motion superposed on uniform rectilinear motion, in which case we have cycloids, &c. But these we merely mention.

§ 67. By far the most important of the applications of simple harmonic analysis is summed up in what is called

-rier's -orem. Fourier's Theorem.—*A complex harmonic function, with a constant term added, is the proper expression for any periodic single-valued function, and, consequently, can express any single-valued function whatever between any assigned values of the variable.*

To show the importance of this in physics we need take but a single example. The one essential characteristic of a musical sound is its "periodicity." Hence it may be analysed into a series of simple harmonic disturbances. Their respective periods are the fundamental period, its half, third, fourth part, &c. The first gives the pitch of the note; the others determine its quality. The investigation which follows is not intended to prove the theorem; it is merely introduced as readily suggesting it.

The essence of periodicity of a function f is that we must have

$$f[x+\tfrac{1}{2}a]=f[x-\tfrac{1}{2}a]$$

whatever be x, provided a be the period.

We may write this as

$$\varepsilon^{\frac{a}{2}\frac{d}{dx}}f(x)=\varepsilon^{-\frac{a}{2}\frac{d}{dx}}f(x),$$

or

$$\left(\varepsilon^{\frac{a}{2}\frac{d}{dx}}-\varepsilon^{-\frac{a}{2}\frac{d}{dx}}\right)f(x)=0.$$

Now the equation

$$\varepsilon^{\frac{1}{2}\xi}-\varepsilon^{-\frac{1}{2}\xi}=0$$

has the real root

$$\xi=0,$$

and the infinite series of pairs of imaginary roots

$$\tfrac{1}{2}\xi=\pm i\pi\sqrt{-1},$$

where i is any integer. Hence

$$\varepsilon^{\frac{1}{2}\xi}-\varepsilon^{-\frac{1}{2}\xi}=\xi(1+\xi^2/2^2\pi^2)(1+\xi^2/4^2\pi^2)(1+\xi^2/6^2\pi^2)\ \ldots$$

so that the differential equation for $f(x)$ gives, besides a constant term, the infinite series of terms due to solutions of equations of the second order of which the type is

$$\left(\frac{a^2}{2^2i^2\pi^2}\left(\frac{d}{dx}\right)^2+1\right)f(x)=0.$$

The solution of this representative equation gives the following particular integral of the complete equation,

$$f(x)=\mathrm{P}_i\cos(2i\pi xa^{-1}+\mathrm{Q}_i).$$

Hence the general solution is

$$f(x)=\mathrm{A}_0+\Sigma_1^\infty \mathrm{P}_i\cos(2i\pi xa^{-1}+\mathrm{Q}_i)$$
$$=\mathrm{A}_0+\Sigma_1^\infty \mathrm{A}_i\cos 2i\pi xa^{-1}+\Sigma_1^\infty \mathrm{B}_i\sin 2i\pi xa^{-1},$$

where the constants are to be determined by special integration, according to the process already described in the article Harmonic Analysis (*q.v.*).

As a single example, suppose that the value of $f(x)$ is unity from $x=0$ to $x=a$, and zero from $x=a$ to $x=2a$. This has many applications, as, for instance, to alternate heating and cooling of one surface of a solid, alternate "make and break" with a battery and a telegraph wire, &c. In this case we have

$$f(x)=\frac{1}{2}+\frac{2}{\pi}\Sigma_1^\infty\frac{1}{2i+1}\sin\frac{(2i+1)\pi x}{a}.$$

§ 68. *A point describes a logarithmic spiral with constant angular velocity about the pole; find the acceleration.*[1] Resisted harmonic motion.

Since the angular velocity of SP (fig. 21) and the inclination of this line to the tangent are each constant, the linear velocity of P is as SP. Take a length PT, equal to e.SP, to represent it. Then the hodograph, the locus of p, where Sp is parallel and equal to PT, is evidently another logarithmic spiral, similar to the former, and described with the same constant angular velocity. Hence pt, the acceleration required, is equal to e.Sp, and makes with Sp an angle equal to SPT. Hence, if Pu be drawn parallel and equal to pt, and uv parallel to PT, the whole

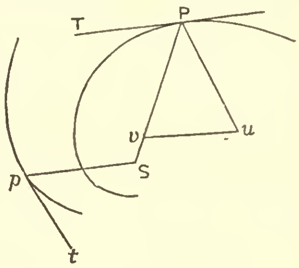

Fig. 21.

acceleration Pu may be resolved into Pv and vu; and Pvu is an isosceles triangle, whose base angles are each equal to the angle of the spiral. Hence Pv and vu bear constant ratios to Pu, and therefore also to SP or PT.

The acceleration, therefore, is composed of a central acceleration proportional to the distance, and a tangential retardation proportional to the velocity. And, if the resolved part of P's motion parallel to any line in the plane of the spiral be considered, it is obvious that in it also the acceleration will consist of two parts—one directed towards a point in the line (the projection of the pole of the spiral) and proportional to the distance from it, the other proportional to the velocity but retarding the motion. Hence a particle which, unresisted, would have a simple harmonic motion has when subject to resistance proportional to its velocity a motion represented by the resolved part of the spiral motion just described.

If α be the angle of the spiral, ω the angular velocity of SP, we have evidently PT. $\sin\alpha=\mathrm{SP}.\omega$.

Hence

$$\mathrm{P}v=\mathrm{P}u=pt=\frac{\mathrm{PT}^2}{\mathrm{SP}}=\frac{\omega}{\sin\alpha}\,\mathrm{PT}=\frac{\omega^2}{\sin^2\alpha}\,\mathrm{SP}=n^2.\,\mathrm{SP}\ \text{(suppose)};$$

and $$vu=2\mathrm{P}v\,.\,\cos\alpha=\frac{2\omega\cos\alpha}{\sin\alpha}\mathrm{PT}=2k\,.\,\mathrm{PT}\ \text{(suppose)}.$$

Thus the central acceleration at unit distance is $n^2=\omega^2/\sin^2\alpha$, and the coefficient of resistance is $2k=2\omega\cos\alpha/\sin\alpha$.

The time of oscillation is evidently $2\pi/\omega$; but, if there had been no resistance, the properties of simple harmonic motion show that it would have been $2\pi/n$; so that it is increased by the resistance in the ratio $\operatorname{cosec}\alpha : 1$, or $n:\sqrt{n^2-k^2}$.

The rate of diminution of SP is evidently

$$\mathrm{PT}\,.\,\cos\alpha=\frac{\omega\cos\alpha}{\sin\alpha}\,\mathrm{SP}=k\mathrm{SP};$$

that is, SP diminishes in geometrical progression as time increases, the rate being k per unit of time per unit of length. By an ordinary result of arithmetic (compound interest payable every instant) the diminution of log SP in unit of time is k.

[1] The physical application of this problem to pendulum motion, taking place in a medium in which there is *resistance* proportional to the velocity, will be afterwards discussed analytically.

Hence, in the resolved part of the motion, the logarithm of the amplitude is diminished, every half vibration, by $k\pi/\omega$.

This process of solution is only applicable to resistance of harmonic vibrations when n is greater than k. When n is not greater than k the auxiliary curve can no longer be a logarithmic spiral, for the moving particle never describes more than a finite angle about the pole; and then the geometrical method ceases to be simpler than the analytical one.

Relative motion.

§ 69. What we have said about composition of motions is merely a particular case of the general question of relative motion, which in its main principles is exceedingly simple. It is entirely comprehended in the following propositions,—which may be regarded as almost self-evident.

Given the motion of A with regard to a point O, and that of B with regard to A, to find that of B with regard to O.

By compounding the vectors of relative position OA, AB, we have at once the required vector OB. Thus it is obvious that we have only to add the separate components of the velocity of A with regard to O, and those of B with regard to A, to obtain those of B with regard to O. And, of course, the same rule applies to the accelerations.

If x, y, z be the coordinates of A (referred to O) at time t; x', y', z' those of B referred to parallel axes from A; ξ, η, ζ those of B referred to O; we have at once

$$\xi=x+x',\quad \eta=y+y',\quad \zeta=z+z'.$$

They give, by differentiation with regard to t,

$$\dot\xi=\dot x+\dot x',\ \&c.,\quad \ddot\xi=\ddot x+\ddot x',\ \&c.,$$

which constitute the analytical proof of the statement above.

§ 70. Hence we have the solution of the further question: *Given the motions of A and B with regard to O, to find the relative motion of B with regard to A.* In this case, of course, before compounding, the vector of A must have its sign changed.

Another very important case is that in which the motion is referred to axes which are themselves moving. So long as their *directions* remain unchanged, this reduces itself to the former investigation as a mere question of changed origin; so that we need consider only the effect of the change of direction of the axes. And this is at once deducible from the results of last section. For we have only to consider, instead of the moving point, its projections on the moving axes, and find *their* velocities and accelerations relative to fixed axes.

Revolving axes.

Thus, if the rectangular axes of x and y be fixed, and those of ξ and η be rotating in the same plane, we have a datum of the form,

$$\theta=\text{angle }\xi Ox=f(t),$$

giving the position of the moving axes in terms of the time. Let P be the moving point, and PM perpendicular to $O\xi$ (fig. 22). Then, as the polar coordinates of M are ξ, θ, we have, for its velocity,

$$\dot\xi \text{ along } O\xi,\quad \xi\dot\theta \text{ along MP}.$$

But these must be combined with the velocity of P relative to M, which consists of

$$\dot\eta \text{ along MP and } \eta\dot\theta \text{ parallel to } \xi O.$$

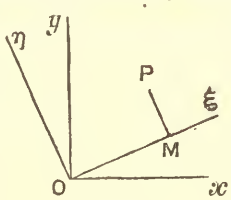

Fig. 22.

Thus the velocities parallel to fixed lines corresponding to the instantaneous positions of $O\xi$ and $O\eta$ are, respectively,

$$\dot\xi-\eta\dot\theta \text{ and } \dot\eta+\xi\dot\theta.$$

In the same way it is easy to see, by § 47, that the corresponding components of the acceleration are

$$\ddot\xi-\xi\dot\theta^2-\frac{1}{\eta}\frac{d}{dt}(\eta^2\dot\theta) \text{ and } \ddot\eta-\eta\dot\theta^2+\frac{1}{\xi}\frac{d}{dt}(\xi^2\dot\theta).$$

Kinematics of a Rigid Plane Figure, displaced in its own Plane.

§ 71. When a rigid plane figure is displaced anyhow in its own plane, the displacement may always be regarded as the result of a definite rotation about a definite axis perpendicular to the plane.

Motion of a plane figure in its plane.

The proof of this follows at once from the fact that, under the assigned conditions, the figure has only three degrees of freedom; and consequently its position is determinate whenever the positions of *any two* of its points are given. Also, a single rotation can, in general, be found which will transfer these two points from one pair of assigned positions to another.

Let A, B, A′, B′ (fig. 23) be successive positions of two points of the figure. Bisect AA′ by the line Oa perpendicular to it, and let Ob do the same for BB′. Let these perpendiculars meet in O. Then it is clear that the two triangles OAB, OA′B′ are similar and equal. Hence AB may be regarded as having passed to the position A′B′ by rotation about an axis through O perpendicular to the plane of the paper. The angle of rotation is AOA′ or BOB′.

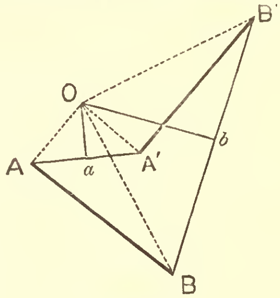

Fig. 23.

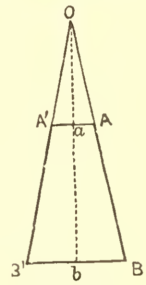

Fig. 24.

The construction fails when Oa and Ob coincide, but in this case it is evident that the required point O is the point of intersection of BA and B′A′ (fig. 24). It also fails when the bisecting perpendiculars are parallel (fig. 25). But then AA′ and BB′ are equal and parallel, and the displacement is a pure translation, the same for every point of the plane figure, which may be regarded as an infinitely small rotation about an infinitely distant axis.

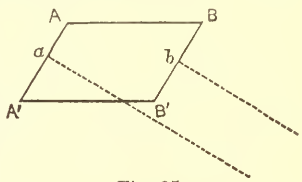

Fig. 25.

Composition of rotations about parallel axes.

§ 72. Since any displacement in one plane corresponds in general to a rotation, any two or more rotations about parallel axes can always be compounded into a single one. Of two equal and opposite rotations the resultant is simple translation. This is evident from fig. 26. In both cases A and B are the initial positions, A′ and B′ the final positions of the two axes. In the first we begin with the rotation about A, in the second with that about B.

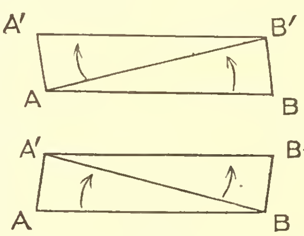

Fig. 26.

§ 73. When these equal rotations are *simultaneous* instead of *successive*, the figure becomes a rectangle; —*i.e.*, the translation is perpendicular to the line joining the axes. For in this case we may suppose the two rotations to be each broken up into successive equal but infinitesimal instalments. And the principles of infinitesimals show that two such instalments, either about the same or about different axes, produce the same ultimate effects whether they be applied simultaneously or successively. The general principle of which this is a particular case is called the "*principle of superposition of small motions.*" It is merely an application of the fact that infinitesimals of the second order may be neglected in comparison with those of the first order.

Superposition of small motions.

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The consideration of simultaneous rotations is very important. Suppose a plane figure to rotate in its own plane, with angular velocity ω, about the origin. Then it is obvious that $r\omega$, in a direction perpendicular to r, is the velocity of a point whose distance from the origin is r. The components are, therefore,

$$\dot{x} = -y\omega,\ \dot{y} = x\omega .$$

If the rotation be about the point a, b, these become

$$\dot{x} = -(y-b)\omega,\ \dot{y} = (x-a)\omega .$$

Hence, when there is any number of simultaneous rotations about parallel axes, we have

$$\dot{x} = -y\Sigma\omega + \Sigma(b\omega), \quad \dot{y} = x\Sigma\omega - \Sigma(a\omega).$$

If we write $\qquad \Omega = \Sigma\omega ,$

and $\qquad \alpha = \frac{\Sigma(a\omega)}{\Sigma\omega}, \quad \beta = \frac{\Sigma(b\omega)}{\Sigma\omega};$

we have $\qquad \dot{x} = -(y-\beta)\Omega, \quad \dot{y} = (x-\alpha)\Omega .$

These are the component velocities which the point x, y would have if there were only a single rotation, with angular velocity Ω, about an axis passing through the point α, β.

When $\qquad \Sigma(\omega) = \Omega = 0,$

we see that $\qquad \dot{x} = \Sigma(b\omega), \quad \dot{y} = -\Sigma(a\omega),$

so that all points of the figure have equal velocities. This is the case of pure translation. Here α and β are (in general) each infinite;—*i.e.*, we have as resultant a vanishing angular velocity about an infinitely distant axis.

olling f curve n curve.

§ 74. As any displacement of a plane figure in its own plane is equivalent to a rotation, we may represent a series of displacements by a series of rotations. Also if we know the positions, in the figure itself, of the points which are successively the axes, and likewise the position which each of them occupies in space at the instant when the rotation about it takes place, we can construct the whole motion. Let them be O, A, B, C, &c., and O, a, b, c, &c., respectively (fig. 27). Then the figure turns about O till A coincides with a. Next it turns about A (or a) till B coincides with b, and so on. Hence the motion will be represented by the *rolling* of the polygon OABC, fixed in the moving figure, on the polygon Oabc fixed in the plane of the motion.

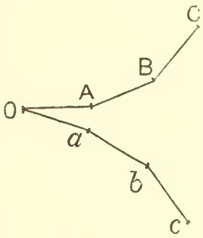


Fig. 27.

In the limit, when the axis continuously shifts its position in the figure while the rotation goes on round it, the polygons become plane curves. Thus we have the fundamental proposition that any motion of a plane figure in its own plane can be represented by the rolling of a curve attached to it, on a curve fixed in space. Both curves are situated at an infinite distance when the motion is one of pure translation.

Kinematics of a Rigid Figure.

isplacement of phere bout its entre.

§ 75. When a spherical cap, or skin, moves on the surface of a sphere of equal radius with which it is everywhere in contact, we may make the construction of § 71 with great circles bisecting the arcs AA′ and BB′. Two great circles (unless they coincide) always intersect at the extremities of one definite diameter. The case of coincidence is met exactly as it was in § 71. Hence every motion of a spherical skin on a sphere is equivalent to a rotation about a definite axis through the centre of the sphere. Thus any number of successive or simultaneous rotations about axes passing through one point can be compounded into a single rotation about an axis passing through that point. And the construction of § 74 can be carried out with spherical polygons or curves, so that we see that any motion of a rigid figure, one point of which is fixed, can be represented by the rolling of a pyramid or cone, fixed in the figure, upon another fixed in space.

Composition of rotations about axes which intersect.

§ 76. The law of composition of simultaneous angular velocities about axes which pass through one point is precisely the same as that for simultaneous linear velocities of a moving point. The following simple geometrical process establishes the proposition for two intersecting axes; and it is easy to see that it can be extended to any number of such. Let OA and OB (fig. 28) represent the two axes, and let the lengths of these lines (both drawn in the positive direction for the rotation about them) represent the angular velocities corresponding. Then a point P, in the angle between the positive ends of the axes, is raised above the plane of the paper by rotation about OA, but depressed below it by the rotation about OB. The amounts of the elevation and depression are proportional to the distance from either axis, and to the angular velocity about it, conjointly. Hence they will annihilate one another if, perpendiculars PM, PN being drawn to the axes, we have

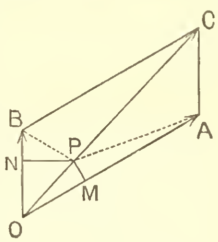


Fig. 28.

$$\text{OA . PM} = \text{OB . PN} .$$

This is equivalent to saying that the areas of the triangles OAP, OBP, are equal,—which necessitates that P should lie on the diagonal of the parallelogram of which OA, OB are conterminous sides. Let OC be the diagonal of this parallelogram. From what has been said above it is evident that the displacement of any point in the plane is necessarily proportional to the algebraic sum of the moments of OA and OB about it, and therefore (§ 46) to the moment of OC. Hence all points in the line OC remain at rest, and the figure turns about that line with an angular velocity represented by its length. This analogy to moments shows the reason for the remarkable proposition that angular velocities, about axes which intersect, are to be compounded according to the same law as linear velocities.

Analogy between linear and angular velocities.

§ 77. Any proposition regarding simultaneous linear velocities or accelerations has thus its counterpart in angular velocities and accelerations. Thus, as we have seen (§ 36) that under acceleration in one plane, always perpendicular to the direction of motion, a point moves with uniform velocity, so, if a figure be rotating about one axis, and have angular acceleration about a second axis always perpendicular to the first, the *direction* of the axis about which it rotates is changed, but not the angular velocity.

It is to be noted that in such a case the direction of the axis changes not only in space, but also in the rotating figure itself. This, however, is merely the result of § 36 in a slightly altered form.

Composition of angular velocities about intersecting axes.

If ω_z be the angular velocity of a figure about the line which, for the moment, coincides with the axis of z, the consequent displacements during time δt of a point x, y, z are (§ 73)

$$\delta x = -y\omega_z\delta t, \quad \delta y = x\omega_z\delta t .$$

Of course similar results hold for the angular velocities about lines for the moment coinciding with the axes of x and of y. The joint effect therefore is found by adding the various separate values obtained by permuting the letters x, y, z in cyclical order. Thus

$$\delta x = (z\omega_y - y\omega_z)\delta t,$$
$$\delta y = (x\omega_z - z\omega_x)\delta t,$$
$$\delta z = (y\omega_x - x\omega_y)\delta t.$$

The right hand members of these equations vanish if

$$\frac{x}{\omega_x} = \frac{y}{\omega_y} = \frac{z}{\omega_z} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

These correspond to the two equations of the instantaneous axis, and reproduce, in an analytical form, the result of § 76.

The angular velocity about this axis is

$$\Omega = \sqrt{\omega_x^2 + \omega_y^2 + \omega_z^2} .$$

For it is clear that the direction cosines of the displacement of x, y, z are proportional to

$$z\omega_y - y\omega_z ,\ x\omega_z - z\omega_x ,\ y\omega_x - x\omega_y ,$$

showing that it takes place in a line perpendicular to the plane passing through x, y, z and (1). It is therefore perpendicular to (1).

Also the whole displacement is

$$\sqrt{(\delta x)^2+(\delta y)^2+(\delta z)^2}=\delta t\sqrt{(z\omega_y-y\omega_z)^2+(x\omega_z-z\omega_x)^2+(y\omega_x-x\omega_y)^2}$$

$$=\delta t\sqrt{\omega_x^2+\omega_y^2+\omega_z^2}\sqrt{x^2+y^2+z^2-\frac{(x\omega_x+y\omega_y+z\omega_z)^2}{\omega_x^2+\omega_y^2+\omega_z^2}}\,.$$

The last factor is the distance of x, y, z from (1). Hence the second is the angular velocity about (1).

It appears at once from this result, and from the form of (1), that

$$\frac{\omega_x}{\Omega},\quad\frac{\omega_y}{\Omega},\quad\frac{\omega_z}{\Omega}$$

are the direction cosines of the instantaneous axis.

If the figure be rotating simultaneously about a number of axes,—say with angular velocity ω_1, about an axis whose direction cosines are l_1, m_1, n_1, &c.,—we have evidently

$$\omega_x=\Sigma(l\omega),\ \omega_y=\Sigma(m\omega),\ \omega_z=\Sigma(n\omega).$$

From these the single instantaneous axis is found immediately as above.

Rigid figure anyhow displaced.

§ 78. Any displacement whatever of a rigid figure may be effected by means of a screw-motion, *i.e.*, translation parallel to some definite line, accompanied by a proportionate rotation about that line. Let A and A′ be successive positions of any point in the figure, and suppose the body to be brought back by a mere translation so that A′ coincides again with A. Then we have seen (§ 75) that *one* line of the figure through A is necessarily restored to its original position. Let P be any plane section of the figure, perpendicular to this line, P′ its position after displacement. These fully determine the initial and final positions of the whole figure. Shift P into the plane of P′ by a translation perpendicular to either, and let P″ be its position. P″ can (§ 71) be brought to coincide with P′ by a rotation in its own plane. Hence the proposition. There is an exceptional case when P″ requires only translation to make it coincide with P′. But then the whole figure is merely translated.

Angular acceleration about a moving axis.

§ 79. We have seen that the straight line representing an angular velocity is to be resolved by the same process as that representing a linear velocity. If we consider a figure to be rotating about axes fixed relatively to it, accelerations of angular velocity about these will be represented by changes in the lengths of the lines representing the angular velocities, and will therefore be subject to the same conditions as the angular velocities themselves. Thus, as it is obvious that a figure is rotating at any instant with the same angular velocity about an axis fixed relatively to itself, and about another axis *fixed in space*, which at the given instant coincides with the former, it follows that the angular accelerations about these axes are equal at that instant.

This is really the same proposition as that $\dot r$ is the velocity along a fixed line coinciding with the radius-vector r (§ 47). But, just as $\ddot r$ is not the complete acceleration parallel to r, if r be rotating, so the proposition above, though true for the first fluxion of the angular velocity about a moving line, is not generally true for fluxions of higher orders.

As this subject is commonly regarded as somewhat obscure, we may give a more formal examination of it by an analytical process. Suppose ω_1, ω_2, ω_3 to be the angular velocities about rectangular axes OA, OB, OC fixed relatively to a figure, and ω the angular velocity of the figure relatively to a line OS fixed in space. Let l, m, n, be the direction cosines of the latter line with regard to the former three, then

$$\omega=l\omega_1+m\omega_2+n\omega_3\,,$$

and $$\dot\omega=l\dot\omega_1+m\dot\omega_2+n\dot\omega_3+\dot l\omega_1+\dot m\omega_2+\dot n\omega_3\,.$$

But $$l\dot l+m\dot m+n\dot n=0\,;$$

and if, at a particular instant, we have $l=1$, $m=0$, $n=0$, this gives also $\dot l=0$, so that we have

$$\dot\omega=\dot\omega_1+\dot m\omega_2+\dot n\omega_3\,.$$

Now $$m=\cos\text{BOS}=\cos\theta \text{ suppose. Hence}$$

$$\dot m=-\sin\theta\,.\,\dot\theta\,.$$

But, at the instant in question, $\theta=\frac{1}{2}\pi$ and $\dot\theta=\omega_3$,

so that $$\dot m=-\omega_3\,.$$

In the same way we see that

$$\dot n=+\omega_2\,;$$

and thus we have $$\dot\omega=\dot\omega_1\,,$$

which is the proposition above given.

Position of rigid figure in terms of rotation about axes fixed in space;

§ 80. To complete the kinematics of a rigid figure of which one point is fixed, we require to have the means of calculating its position, after the lapse of any period during which it has been rotating with given angular velocities about given axes.

If the axes about which the angular velocities are given be fixed *in space*, the formulæ of § 77 give at once, for a unit line fixed in the figure, the expressions

$$\dot l=n\omega_y-m\omega_z\,,$$
$$\dot m=l\omega_z-n\omega_x\,,$$
$$\dot n=m\omega_x-l\omega_y\,.$$

Here l, m, n are the direction cosines of the unit line at time t; and they satisfy, of course, the condition

$$l\dot l+m\dot m+n\dot n=0\,.$$

But, except in some special cases, these equations are intractable. This, however, is of little consequence, because in the applications to kinetics of a free rigid body the physical equations usually give the angular velocities about lines *fixed in the body*. Our problem, then, takes the form

fixed in the figure.

§ 81. *Given the angular velocities of a figure about each of a system of three rectangular axes which are rigidly attached to it, find at any time its position in space.*

It is clear that, if we know the positions of the revolving axes, referred to a fixed system, with which they at one instant coincided, the corresponding position of the figure is determined. The method usually employed is as follows.

About the common origin of the two sets of axes suppose a sphere of unit radius to be described. Let X, Y, Z (fig. 29) be the traces on this sphere of the fixed axes, and A, B, C those of the revolving axes. Draw a great circle ZC so as to meet in A′ the quadrant BA produced. Then it is clear that the figure can be constructed (*i.e.*, that the data are sufficient for calculation) if we know (a) the angle XZC,—this we call ψ; (b) the arc ZC, called θ; (c) the angle A′CA, or the arc A′A, called ϕ. For X, Y, Z are given. Then (a) shows how to draw the great circle ZC, whose pole is N on the great circle XY. Hence (b) gives us the points C and A′. We can next draw the great circle A′N, and A and B are found on it by (c), for A′A = NB = ϕ. We have now only to determine these angular coordinates in terms of the angular velocities of the figure about OA, OB, OC, which we denote by ω_1, ω_2, ω_3 respectively.

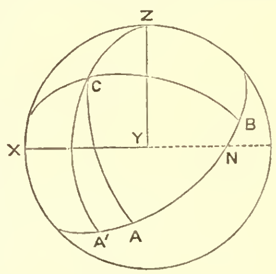


Fig. 29.

The velocity of C along ZC is $\dot\theta$. But it is produced by the rotations about A and B. Thus we have

$$\dot\theta=\omega_2\cos\phi+\omega_1\sin\phi\,.$$

The velocity of C perpendicular to ZC is $\sin\theta\,.\,\dot\psi$. This also is part of the result of the rotations about A and B, so that

$$\sin\theta\,.\,\dot\psi=\omega_2\sin\phi-\omega_1\cos\phi\,.$$

The velocity of A along AB is that of A′ together with the rate of increase of A′A. Also it is entirely due to rotation about OC. Hence

$$\cos\theta\,.\,\dot\psi+\dot\phi=\omega_3\,.$$

These three equations determine θ, ψ, ϕ when ω_1, ω_2, ω_3 are given as functions of t.

Symmetrical process.

§ 82. The process above is essentially unsymmetrical. The first suggestion of a symmetrical system is due to Euler, and depends upon the general proposition of § 75. What we must seek is the single axis, and the angle of rotation about it, which (by one operation) will bring the system or figure from its initial state determined by X, Y, Z to its state at time t, determined by A, B, C.

Let l, m, n be the direction cosines of this axis, ϖ the angle of rotation about it. Then by the elementary theorems of spherical trigonometry we find

$$\cos XA = l^2 + (1-l^2)\cos\varpi,$$
$$\cos YB = m^2 + (1-m^2)\cos\varpi,$$
$$\cos ZC = n^2 + (1-n^2)\cos\varpi.$$

Thus, as we have an independent relation among l^2, m^2, n^2, these quantities, as well as ϖ, can all be expressed in terms of the cosines of the three angles between the original and final directions of the three axes severally.

We have other six equations, of which only one need be written, viz. :—

$$\cos YA = lm(1-\cos\varpi) + n\sin\varpi.$$

Rodrigues's coordinates.

§ 83. If we put

$$w = \cos\tfrac{1}{2}\varpi,\ x = l\sin\tfrac{1}{2}\varpi,\ y = m\sin\tfrac{1}{2}\varpi,\ z = n\sin\tfrac{1}{2}\varpi,$$

which involve the equation of condition

$$w^2 + x^2 + y^2 + z^2 = 1,$$

the nine direction cosines of the new positions OA, OB, OC, referred to the fixed lines OX, OY, OZ, become

$$\begin{array}{ccc} w^2+x^2-y^2-z^2, & 2(wz+xy), & 2(xz-wy), \\ 2(yx-wz), & w^2-x^2+y^2-z^2, & 2(yz+wx), \\ 2(xz+wy), & 2(yz-wx), & w^2-x^2-y^2+z^2. \end{array}$$

These expressions, rational in terms of the four quantities w, x, y, z, are due to Rodrigues, who, however, gave them in a slightly different form.

If ω_1, ω_2, ω_3 be the angular velocities about OA, OB, OC, respectively, we have

$$\begin{aligned} 2\dot{w} &= -x\omega_1 - y\omega_2 - z\omega_3, \\ 2\dot{x} &= w\omega_1 - z\omega_2 + y\omega_3, \\ 2\dot{y} &= z\omega_1 + w\omega_2 - x\omega_3, \\ 2\dot{z} &= -y\omega_1 + x\omega_2 + w\omega_3. \end{aligned}$$

If ω_x, ω_y, ω_z be the angular velocities about OX, OY, OZ, respectively, we have

$$\begin{aligned} 2\dot{w} &= -x\omega_x - y\omega_y - z\omega_z, \\ 2\dot{x} &= w\omega_x + z\omega_y - y\omega_z, \\ 2\dot{y} &= -z\omega_x + w\omega_y + x\omega_z, \\ 2\dot{z} &= y\omega_x - x\omega_y + w\omega_z. \end{aligned}$$

Each of these sets is equivalent to three independent equations only, on account of the relation

$$w\dot{w} + x\dot{x} + y\dot{y} + z\dot{z} = 0.$$

Kinematics of a Deformable Figure. Strain.

Strain.

§ 84. So far we have considered change of position of a figure of invariable form. We must now consider changes of form and volume in the figure itself. This is required for application to physical problems, such as compression of a liquid or gas, the distortion of a piece of india-rubber, &c. Any such change of volume or form is called a "strain." The treatment of strains is entirely a kinematical question, until we come to regard them as produced in physical bodies, and consider their cause.

Stress.

The system of forces which is said to produce a strain is called a "stress." But, just as we study velocity as a preparation for the discussion of the effect of force on a free body, so we study strains as a preparation for the discussion of the effects of stress.

Heterogeneous strain.

§ 85. In order to fix the ideas, it is convenient to suppose the figure which is to undergo strain to be cut up into an infinite number of similar, equal, and similarly situated parellelepipeds. This is effected at once by supposing it to be cut by three series of planes, those of each series being parallel to one another, and equidistant. No two of these three series must be parallel, but the distance from plane to plane need not be the same in any two of the series. If the strain be *continuous* there will be no finite difference of effect upon any two neighbouring parallelepipeds;—but in general their edges, which originally formed three series of parallel straight lines, will become series of curves. No two parallelepipeds of the system will in general be altered in precisely the same manner. This is called "heterogeneous strain."

Homogeneous strain,

§ 86. We found it convenient to study uniform speed before proceeding to consider variable speed, and so we find it convenient to take up first what is called

Homogeneous Strain.—A figure is said to be homogeneously strained when all parts of it originally equal, similar, and similarly situated remain equal, similar, and similarly situated, however much they may individually have been altered in form, volume, and position.

Now recur to our set of parallelepipeds. After a homogeneous strain these remain equal, similar, and similarly situated. Hence *they must remain parallelepipeds*, for they must together still continuously make up the volume of the altered figure. Thus planes remain planes, and straight lines remain straight lines. Equal parallel straight lines remain equal and parallel. Parallel planes remain parallel, ellipses remain ellipses (as is obvious from their properties relative to conjugate diameters), ellipsoids remain ellipsoids, &c.

requires nine constants.

But we can now easily see how many conditions fully determine a homogeneous strain. For if we know how each of three conterminous edges of any one of the original parallelepipeds is altered in length and direction, we can build up the whole altered system. Hence, to fully describe a homogeneous strain, we require merely to know what changes take place in the lengths and directions of three unit lines not in one plane. Three numbers are required for the altered lengths, and two (analogous, say, to altitude and azimuth, or latitude and longitude, or R.A. and N.P.D.) for each of the altered directions. Hence, in general, a homogeneous strain depends upon, and is fully characterized by, *nine* independent numbers.

Uniform dilatation.

§ 87. The simplest form of strain is that which is due to uniform hydrostatic stress acting on a homogeneous isotropic body. Here directions remain unaltered, and the lengths of all lines are altered in the same ratio. Every portion of the original figure remains similar to itself, its linear, superficial, and volume dimensions being altered as the first, second, and third powers of that ratio.

Pure strain.

Next in order of simplicity is the case in which there are three directions, at right angles to one another, which suffer no change except as regards *length*. This state of things would be produced in a homogeneous isotropic body by three longitudinal extensions or compressions in lines at right angles to one another, or by hydrostatic pressure in a homogeneous non-isotropic solid. In this case, if the changes of length above spoken of are all different, an originally spherical figure becomes an ellipsoid, with three unequal axes parallel respectively to the lines whose directions remain unaltered. Every line in the body not originally parallel to one of these is altered in direction. If one of the principal changes of length be an extension, and another a shortening, there will be a cone formed of lines which are not altered in length. This is seen at once by describing from the centre of the ellipsoid a sphere equal to the original sphere. One axis of the ellipsoid being greater than the radius of the sphere, and another less, the ellipsoid and sphere must intersect; and all lines drawn from the common centre to the curve of intersection are unaltered in length (though all altered, as before remarked, in direction).

Pure strain.

When two only of the changes of length are equal, the ellipsoid becomes one of rotation, oblate or prolate as the case may be; and if the radius of the sphere be intermediate in value to the axes of this rotation-ellipsoid, we have a *right* cone of rays unaltered in length.

When all three changes of length are equal we have the simplest possible case,—which has been already treated.

§ 88. The essential element in these particular cases is that three lines at right angles to one another are unaltered in direction by the strain. Here there is a mere change of form, and the strain is said to be "pure," or "free from rotation." Such a strain, in its most general form, is fully characterised by *six* independent numbers. For a system of three mutually perpendicular lines is fully given in direction by *three* numbers, and three more are required for the changes of length which they severally undergo.

Rotational strain. Strain ellipsoid.

But, in general, a strain is not pure. It will be shown, however, below that the principal axes of the ellipsoid into which a sphere is changed by any strain, and which is called the "strain ellipsoid," were originally radii of the sphere at *right* angles to one another. Hence the strain may be looked upon as made up of two operations, viz., a pure strain, and a rotation through a definite angle about an axis in a definite position in space. The axes of the pure strain are lines fixed in the figure.

Conjugate of a strain.

§ 89. It is useful, in farther considering the subject, to introduce along with the original strain (thus analysed), another which is called its "conjugate." This is defined as composed of an equal pure strain with the first with an equal but opposite rotation. And the separate component operations must be taken in the opposite order in the strain and in its conjugate.

The successive application of the strain and its conjugate thus necessarily leads to the reduplication (or squaring) of the pure part of the strain, and to the annihilation of the rotation. For, call the parts, as operators, P and R. The strain and its conjugate, referred to axes fixed in space, may be either

$$RP \text{ and } PR^{-1}$$

or

$$P_1R \text{ and } R^{-1}P_1,$$

according as the pure strain or the rotation is first applied. The operations in each group are written, from right to left, in the order in which they are performed. Thus RP means the pure strain P, followed by the rotation R.

Successive application of conjugate strains.

§ 90. The final results are P^2 and P_1^2. In the first case we have the pure strain, followed by the rotation; then (by the conjugate) the rotation is undone, and the pure strain reapplied. In the second we rotate first, then apply the pure strain twice, and finally undo the rotation. Thus the student must be cautioned against the error of supposing that the results of applying PR and RP separately are generally the same. Perhaps it will be easier for the reader to consider the "reciprocal," instead of the conjugate, of a strain. For if the strain be RP, the reciprocal is obviously $P^{-1}R^{-1}$; if it be PR, the reciprocal is $R^{-1}P^{-1}$. Either pair of these, taken in either order, restores the figure to its primitive form. The one point to be noticed is that, in whatever order the direct component operations are supposed to occur in the strain, their reciprocals must be taken in the opposite order in the reciprocal strain. The reciprocal strain simply undoes the strain, and therefore differs from the conjugate by a factor, the square of the pure part of the strain.

Reciprocal strain.

From this we have at once, as will be seen later, the means of decomposing a given strain into its pure and its rotational factors. This is effected as soon as we can form the expression for the conjugate strain in terms of that for the strain itself.

Shear.

§ 91. As, in general, any strain converts a spherical portion of a figure into an ellipsoid, and as an ellipsoid has two series of parallel *circular sections*, it appears that in every strain there are two series of *planes of no distortion*.[1] The consideration of these planes leads us to a second and very different mode of analysing a strain into simpler components. Perhaps the most elementary mode of considering this subject is by thinking of the motion of water flowing slowly down a uniform channel. We know that water, at ordinary pressures, is practically incompressible; also that the upper layers of the water in a canal flow faster than those below them. Hence the definition of a "simple shear." Let one plane of a figure be fixed, and let the various planes parallel to it slide over it and over one another, all in the same direction, and with velocities proportional to their distances from the fixed plane. It is clear that this shear produces homogeneous strain in the figure, but it is mere change of form without change of volume. The fixed plane and all those parallel to it, are planes of no distortion. But we have seen that there must be two sets of such planes. To find the second set, let us suppose the plane of fig. 30 to be parallel to the common direction of sliding, and perpendicular to the fixed plane. This plane, so defined, is the plane of the shear. Let AB be the trace on it of the fixed plane, PQ that of one of the sliding planes, PP′ the amount of its sliding. Bisect PP′ in M by a perpendicular, meeting AB in A. Join AP, take AB = AP, and draw BQ parallel to AP. Consider the strain of the rhomboidal portion APQB of the figure. P moves to P′, and Q to Q′, where QQ′ = PP′. Hence the rhombus remains a rhombus, for AP′ = AP = AB. But the lengths of its diagonals have been interchanged. It has been subjected to an elongation of AQ, and a contraction of BP, each in the same ratio (so that their product, *i.e.*, double the area of the rhombus, remains unaltered), while all lines perpendicular to the plane of the figure remain unaltered. From the symmetry of the rhombus it is obvious that AQ′ and BP′ are the greatest and least axes of the strain ellipsoid, while AB and AP′ are parallel to its circular sections. Planes originally parallel to AP and perpendicular to the paper are therefore the second set of planes of no distortion. The rotational part of the shear may be measured in terms of the angle PAM, but is given directly by PBP′, and its axis is perpendicular to the plane of the figure. The most convenient measure of the shear is the ratio of PP′ to AM, or, what involves the same, the angle PAP′. Another mode of measuring it is by means of the ratio BP/AQ, = 1 + e, suppose. If e be a small quantity, as is usually the case with solids, we may write $1 \pm e$ for the measure of the shear. Here e indicates the extension per unit of length along one diagonal of the rhombus, and the contraction per unit of length along the other.

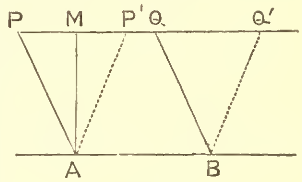


Fig. 30.

Decomposition of a strain.

§ 92. It is quite clear from what has been said that we can analyse a strain by the help of simple shears compounded with different forms of pure strain. For the shears may be taken in an infinite number of ways so as to produce the rotational part of the given strain, while also producing deformation without change of volume. The final adjustment is to be made by a pure strain, whose axes are those of the strain ellipsoid due to the shears. As a shear depends on four quantities only, two shears and a dilatation furnish the nine constants required for a homogeneous strain.

[1] We here exclude spheres and ellipsoids of rotation. The latter have only one series of circular sections, the former an infinite number.

Com- position of pure strains.

The successive application of two pure strains does not, except in special cases, give rise to a pure strain. This is, physically, a most important proposition. Thus, for instance, the instantaneous strains of each element of a perfect fluid in which there is no vortex motion are pure; and yet, if the element be followed in its motion, it will be found in general to rotate. Its motion is said to be "differentially irrotational."

To prove this proposition by the help of a particular case is simple enough. Take, for instance, a compression in one direction, followed by an equal extension in a different direction. Only when these directions are at right angles to one another is the resultant strain pure.

Analysis.

§ 93. The analytical theory of strains is, at least in its elements, an immediate application of the properties of determinants, usually of the third order. We subjoin a slight sketch of it.

We have seen that it is only necessary, for the full characterizing of a strain, that we should know what becomes of three unit lines not originally coplanar. Take these parallel to the axes (generally oblique) of x, y, z. Then if the x unit becomes a line which is the diagonal of a parallelepiped with sides a, d, g parallel to the axes, y similarly that of b, e, h, and z of c, f, i, we see at once that the coordinates of the point originally at x, y, z become

$$\left.\begin{aligned} x' &= ax+by+cz \\ y' &= dx+ey+fz \\ z' &= gx+hy+iz \end{aligned}\right\} \quad \ldots \ldots \quad (A).$$

Here it is obvious, from the premises, that the nine quantities a, b, c; d, e, f; g, h, i are all real, and altogether independent, at least so far as kinematics is concerned.[1] To obtain an idea of their nature from another point of view, let us suppose the axes to be rectangular. Let unit parallel to x become e_1, in the direction given by the cosines l_1, m_1, n_1. Similarly, let e_2, l_2, m_2, n_2 belong to a unit originally parallel to y, and e_3, l_3, m_3, n_3 to a unit parallel to z. Then the broken line x, y, z becomes x', y', z', where

$$\left.\begin{aligned} x' &= e_1l_1x + e_2l_2y + e_3l_3z \\ y' &= e_1m_1x + e_2m_2y + e_3m_3z \\ z' &= e_1n_1x + e_2n_2y + e_3n_3z \end{aligned}\right\} \quad \ldots \quad (A').$$

Though we have introduced three numbers e along with nine direction cosines, no greater generality is secured, for there are three necessary relations, one among each set of cosines.

Characteristic of pure strain.

To find the characteristic property of a pure strain, let us take it in its most general form. Thus let l_1, m_1, n_1 *now* denote a line which, without change of direction, has its length altered by the strain in the ratio $e_1 : 1$. Let l_2, m_2, n_2, e_2 and l_3, m_3, n_3, e_3 be similar data for the other two of the system of rectangular axes of the pure strain. Then to *these* axes the coordinates of x, y, z are

$$\xi = l_1x+m_1y+n_1z,$$
$$\eta = l_2x+m_2y+n_2z,$$
$$\zeta = l_3x+m_3y+n_3z.$$

The strain converts ξ into $\xi' = e_1\xi$, η into $\eta' = e_2\eta$, and ζ into $\zeta' = e_3\zeta$. Hence the final coordinates (to the original axes) of the point originally at x, y, z are

$$x' = l_1\xi' + l_2\eta' + l_3\zeta',$$
$$y' = m_1\xi' + m_2\eta' + m_3\zeta',$$
$$z' = n_1\xi' + n_2\eta' + n_3\zeta';$$

or, in terms of x, y, z,

$$\left.\begin{aligned} x' &= (e_1l_1^2+e_2l_2^2+e_3l_3^2)x + (e_1l_1m_1+e_2l_2m_2+e_3l_3m_3)y \\ &\quad + (e_1l_1n_1+e_2l_2n_2+e_3l_3n_3)z \\ y' &= (e_1m_1l_1+e_2m_2l_2+e_3m_3l_3)x + (e_1m_1^2+e_2m_2^2+e_3m_3^2)y \\ &\quad + (e_1m_1n_1+e_2m_2n_2+e_3m_3n_3)z \\ z' &= (e_1n_1l_1+e_2n_2l_2+e_3n_3l_3)x + (e_1n_1m_1+e_2n_2m_2+e_3n_3m_3)y \\ &\quad + (e_1n_1^2+e_2n_2^2+e_3n_3^2)z \end{aligned}\right\} . \quad (B).$$

If we compare this with the general expression above given for a strain, we see that the coefficient of y in the value of x' is *equal* to that of x in the value of y'. Similarly that of z in x' is equal to that of x in z'; and that of z in y' is equal to that of y in z'; or finally

$$b=d, \quad c=g, \quad f=h.$$

Conversely, when these three conditions are satisfied, and not otherwise, the strain is pure. It is to be observed that ξ, η, ζ form a rectangular system, and thus the nine direction cosines (usually involving *six* arbitrary numbers) depend here on three numbers alone. Thus there are six independent numbers, corresponding to a, e, i, b, c, f, in the general expression for the strain.

Pure strain depends on six conditions.

Change of volume by strain

It is clear, from the elements of coordinate geometry, that the determinant

$$\begin{vmatrix} a & b & c \\ d & e & f \\ g & h & i \end{vmatrix}$$

represents the ratio in which the volume is increased by the strain.[2]

Conjugate strains.

Let us now introduce, in succession to the strain

$$\begin{matrix} a & b & c \\ d & e & f \\ g & h & i \end{matrix} \quad \ldots \ldots \ldots \quad (1),$$

the connected strain

$$\begin{matrix} a & d & g \\ b & e & h \\ c & f & i \end{matrix} \quad \ldots \ldots \ldots \quad (1'),$$

which obviously produces an equal change of volume with the former.

Applying these strains in succession, we have as the final result

$$x'' = ax' + dy' + gz',$$
$$y'' = bx' + ey' + hz',$$
$$z'' = cx' + fy' + iz',$$

or, substituting for x', y', z' their values in terms of x, y, z,

$$x'' = (a^2+d^2+g^2)x + (ab+de+gh)y + (ac+df+gi)z,$$
$$y'' = (ba+ed+hg)x + (b^2+e^2+h^2)y + (bc+ef+hi)z,$$
$$z'' = (ca+fd+ig)x + (cb+fe+ih)y + (c^2+f^2+i^2)z.$$

Thus the resultant strain is

$$\begin{matrix} a^2+d^2+g^2 & ab+de+gh & ac+df+gi \\ ba+ed+hg & b^2+e^2+h^2 & bc+ef+hi \\ ca+fd+ig & cb+fe+ih & c^2+f^2+i^2 \end{matrix}$$

which, for simplicity, we will write as

$$\begin{matrix} \alpha & \delta & \gamma \\ \delta & \epsilon & \beta \\ \gamma & \beta & \iota \end{matrix} \quad \ldots \ldots \ldots \quad (2).$$

It will be observed that this group of nine numbers, if treated as a determinant, constitutes the product of the determinants formed of the two systems above.

This satisfies the criterion of a "pure strain," as given above; and we thus see that in the successive application of the strains

$$\begin{matrix} a & b & c \\ d & e & f \\ g & h & i \end{matrix} \quad \text{and} \quad \begin{matrix} a & d & g \\ b & e & h \\ c & f & i \end{matrix}$$

the rotation produced by the first is annihilated by the second.

Let A, B, C, &c., be the minors of

$$\Delta = \begin{vmatrix} a & b & c \\ d & e & f \\ g & h & i \end{vmatrix}$$

corresponding to a, b, c, &c.

Then by our original equations we have

$$\Delta x = Ax' + Dy' + Gz',$$
$$\Delta y = Bx' + Ey' + Hz',$$
$$\Delta z = Cx' + Fy' + Iz'.$$

Reciprocal of strain.

Thus the reciprocal of the strain

$$\begin{matrix} a & b & c \\ d & e & f \\ g & h & i \end{matrix} \quad \text{is} \quad \begin{matrix} A/\Delta & D/\Delta & G/\Delta \\ B/\Delta & E/\Delta & H/\Delta \\ C/\Delta & F/\Delta & I/\Delta. \end{matrix}$$

This is evident from the formulæ just written. For they express that the new strain converts x', y', z' into x, y, z.

Apply the resultant strain in succession to this reciprocal. The result is easily foreseen from separate terms like the following:—

$$A(a^2+d^2+g^2) + B(ab+de+gh) + C(ac+df+gi)$$
$$= a(Aa+Bb+Cc) + d(Ad+Be+Cf) + g(Ag+Bh+Ci)$$
$$= a\Delta; \ \&c.$$

[1] But when strain is produced in a piece of *matter*, a limitation comes in. For, to take the simplest case, the strain

$$x' = -x, \quad y' = -y, \quad z' = -z$$

implies that the figure to which it is applied has been "perverted,"— *i.e.*, changed into its image as seen in a plane mirror.

[2] When this strain is produced in a piece of *matter*, the numerical value of the determinant obviously cannot be *negative*.

Hence when we apply (2) to a figure previously strained by the reciprocal of (1) the result is the strain (1′). Hence we verify that the latter is the conjugate of (1); as it possesses the properties described in § 90, all of which are thus established.

Analysis of strain. To analyse a strain in the simplest manner, we must find the axes of the strain ellipsoid (§ 88), as well as the original radii of the unit sphere which were distorted into them. It is more direct, however, to consider the ellipsoid which becomes a unit sphere in consequence of the strain. The equation of that ellipsoid is

$$(ax+by+cz)^2+(dx+ey+fz)^2+(gx+hy+iz)^2=1\ ;$$

or, with the notation employed in (2) above,

$$\alpha x^2+\epsilon y^2+\iota z^2+2\delta xy+2\beta yz+2\gamma zx=1.$$

But the square of any radius-vector is

$$x^2+y^2+z^2=r^2, \text{ suppose.}$$

The maximum radius-vector, therefore, of the ellipsoid is found from the two equations

$$(\alpha x+\delta y+\gamma z)dx+(\delta x+\epsilon y+\beta z)dy+(\gamma x+\beta y+\iota z)dz=0,$$
$$xdx+ydy+zdz=0.$$

Hence, p being a numerical quantity to be found,

$$\begin{aligned}\alpha x+\delta y+\gamma z&=px,\\ \delta x+\epsilon y+\beta z&=py, \quad \ldots\ldots \quad (4).\\ \gamma x+\beta y+\iota z&=pz.\end{aligned}$$

Multiply respectively by x, y, z, add, and take account of the two preceding undifferentiated equations. We thus have

$$1=pr^2,$$

or p is the reciprocal of the square of the maximum semi-axis required.

But, if we eliminate x, y, and z simultaneously from the preceding linear equations, we have

$$\begin{vmatrix}\alpha-p & \delta & \gamma\\ \delta & \epsilon-p & \beta\\ \gamma & \beta & \iota-p\end{vmatrix}=0.$$

Axes of the strain ellipsoid. This equation is known to have three real positive roots, because the determinant is symmetrical. The roots are the squared reciprocals of the semi-axes of the ellipsoid, *i.e.*, they are the squares of the semi-axes of the strain ellipsoid.

When the three values of p have been found from this equation, any two of the equations (4) give in an unambiguous form the corresponding values of the ratios $x:y:z$ for each of them. Thus we know the original positions of the lines which become the axes of the strain ellipsoid. Their final positions are found from these by means of (A). And, since we thus know the original and final positions of the rectangular system, the method of Rodrigues enables us to calculate the axis and amount of the rotation.

One line, at least, unaltered in direction. In homogeneous strain, one direction at least is unchanged. This is an addition to, or extension of, the singular result of § 75. For, if x, y, z be shifted to a point on its radius-vector, we must have

$$\left.\begin{aligned}ax+by+cz&=\epsilon x\\ dx+ey+fz&=\epsilon y\\ gx+hy+iz&=\epsilon z\end{aligned}\right\}\ ;$$

so that

$$\begin{vmatrix}a-\epsilon & b & c\\ d & e-\epsilon & f\\ g & h & i-\epsilon\end{vmatrix}=0,$$

a cubic equation, which must have one real root.

Strain a mere rotation. When the figure is rigid, the strain must be a rotation only. Hence in the formulæ (A′) above we have $e_1=e_2=e_3=1$. Thus the last written equation becomes

$$\begin{vmatrix}l_1-\epsilon & l_2 & l_3\\ m_1 & m_2-\epsilon & m_3\\ n_1 & n_2 & n_3-\epsilon\end{vmatrix}=0\ ;$$

or (by the properties of the direction cosines of a set of rectangular axes)

$$1-(l_1+m_2+n_3)(\epsilon-\epsilon^2)-\epsilon^3=0.$$

This has, of course, the real root $\epsilon=1$. But we also have

$$1+\epsilon\big(1-(l_1+m_2+n_3)\big)+\epsilon^2=0.$$

This cannot have real roots if the coefficient of ϵ lie between the limits 2 or −2. But these are its greatest and its least possible values. For, first, l_1, m_2, n_3 may be each = 1 simultaneously. Here we have

$$(1-\epsilon)^2=0.$$

Or two of them may be each = −1, but then (to avoid perversion) the third must be = 1. Then we have

$$(1+\epsilon)^2=0.$$

In the first case the figure has no rotation. In the second it rotates through an angle π about the axis of $\epsilon=1$.

Composition of two pure strains. The proposition that two pure strains succeeding one another usually give a rotational strain is proved at once by analysis. Let the pure strains be such that

$$\begin{aligned}x'&=ax+dy+cz,\\ y'&=dx+ey+bz,\\ z'&=cx+by+iz;\end{aligned}$$

and

$$\begin{aligned}x''&=a'x'+d'y'+c'z',\\ y''&=d'x'+e'y'+b'z',\\ z''&=c'x'+b'y'+i'z'.\end{aligned}$$

Then, writing only the second term of x'' and the first of y'' in terms of x, y, z, we have

$$\begin{aligned}x''&=\ \ldots\ldots\ +(a'd+d'e+c'b)y+\ \ldots\\ y''&=(d'a+e'd+b'c)x+\ \ldots\ldots\ +\ \ldots\\ z''&=\ \ldots\ldots\ +\ \ldots\ldots\ +\ \ldots\end{aligned}$$

It is clear that, in general, this is *not* a pure strain. But it is also clear that a third pure strain can be found whose application in succession to the other two will give a pure strain.

For let the last equations be written

$$\begin{aligned}x''&=a''x+b''y+c''z,\\ y''&=d''x+e''y+f''z,\\ z''&=g''x+h''y+i''z;\end{aligned}$$

and let us apply further the pure strain

$$\begin{aligned}x'''&=\alpha x''+\delta y''+\gamma z'',\\ y'''&=\delta x''+\epsilon y''+\beta z'',\\ z'''&=\gamma x''+\beta y''+\iota z''.\end{aligned}$$

Then we have

$$\begin{aligned}x'''&=\ \ldots\ldots\ +(\alpha b''+\delta e''+\gamma h'')y+\ \ldots\\ y'''&=(\delta a''+\epsilon d''+\beta g'')x+\ \ldots\ldots\ +\ \ldots\\ z'''&=\ \ldots\end{aligned}$$

There are but three conditions to satisfy, that this strain may be pure. But we may accomplish this in an infinite number of ways, for we have five disposable quantities, viz., the ratios of any five of α, ϵ, ι, β, γ, δ to the remaining one. In a precisely similar manner we may show that three pure strains can be found, such that their resultant is a mere rotation. In fact, all we have to do, since two pure strains in general produce a distortion accompanied by rotation, is to apply a pure strain to annihilate the distortion, which can of course always be done.

Heterogeneous strain. § 94. In general when a figure is continuously strained, which is usually the case in physical applications, at least until cracks occur, the strain is not homogeneous. But, on account of the continuity of the strain, portions indefinitely near one another are strained indefinitely nearly alike. Hence we may treat such a case by the ordinary process for homogeneous strain, so long as we confine our attention to small regions of the figure strained. When there is discontinuity in the motion of a fluid, it is the common practice to treat the motion as continuous by the fiction of an infinitely thin vortex-sheet separating the two discontinuously moving portions. This is, in all likelihood, physically true in ordinary fluids; but, so far as the imaginary frictionless fluid of the mathematicians is concerned, it is a mere analytical artifice to enable us to carry out the investigation. See ATOM and HYDROMECHANICS, in which the mathematical theory of "vortex motion" is very fully considered.

Displacements of system of points. Suppose space to be uniformly occupied by points which are displaced in a continuous manner. Let ξ, η, ζ be the rectangular components of the displacement of a point originally situated at x, y, z. The continuity of the displacement requires merely that the differential coefficients, of all orders, of ξ, η, ζ, with respect to x, y, z (and any combination of them) shall be *finite*. That being assumed, the displacement, parallel to x, of the point whose initial coordinates were $x+\delta x$, $y+\delta y$, $z+\delta z$ (where δx, δy, δz are indefinitely small quantities of the first order) is necessarily expressed by

$$\xi+\frac{d\xi}{dx}\delta x+\frac{d\xi}{dy}\delta y+\frac{d\xi}{dz}\delta z.$$

Hence the relative coordinate of the second point with regard to the first is changed from δx to $\delta x+\frac{d\xi}{dx}\delta x+\frac{d\xi}{dy}\delta y+\frac{d\xi}{dz}\delta z$. And nstants the ise- ent ain.

similarly for the other relative coordinates. Hence the strain in the immediate vicinity of the point x, y, z is given by

$$\begin{array}{ccc} 1+\dfrac{d\xi}{dx} & \dfrac{d\xi}{dy} & \dfrac{d\xi}{dz}\,, \\ \dfrac{d\eta}{dx} & 1+\dfrac{d\eta}{dy} & \dfrac{d\eta}{dz}\,, \\ \dfrac{d\zeta}{dx} & \dfrac{d\zeta}{dy} & 1+\dfrac{d\zeta}{dz}\,. \end{array}$$

If the differential coefficients are all small quantities, whose squares and products two and two may be neglected, *i.e.*, if the strain is slight, we have for the ratio in which the volume is increased

$$1+\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}:1\,.$$

ondi- on iat olume un- tered.

Hence the condition of no change of volume is

$$\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}=0\,.$$

To examine this case more closely, let us suppose that it consists of a pure strain as in § 93 (B), superposed on a rotation ω_x, ω_y, ω_z about the axes of x, y, and z as in § 77. Let these be so small as not to interfere with one another. That compound strain would be

$$\begin{array}{lll} e_1l_1^2+e_2l_2^2+e_3^2l_3^2 & e_1l_1m_1+e_2l_2m_2+e_3l_3m_3-\omega_z & e_1l_1n_1+\ldots+\omega_y \\ e_1m_1l_1+e_2m_2l_2+e_3m_3l_3+\omega_z & e_1m_1^2+e_2m_2^2+e_3m_3^2 & e_1m_1n_1+\,..\,-\omega_x \\ e_1n_1l_1+e_2n_2l_2+e_3n_3l_3-\omega_y & e_1n_1m_1+\,\ldots\ldots\ldots\,+\omega_x & e_1n_1^2+e_2n_2^2+e_3n_3^2\,. \end{array}$$

Comparing with the above, we find

$$1+\frac{d\xi}{dx}=e_1l_1^2+e_2l_2^2+e_3l_3^2\,,$$

or, if we put ϵ for the "elongation," so that $e=1+\epsilon$,

$$\frac{d\xi}{dx}=\epsilon_1l_1^2+\epsilon_2l_2^2+\epsilon_3l_3^2\,,$$

with similar expressions for $\dfrac{d\eta}{dy}$ and $\dfrac{d\zeta}{dz}$.

These give

$$\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}=\epsilon_1+\epsilon_2+\epsilon_3\,.$$

Again we have

$$\frac{d\eta}{dx}+\frac{d\xi}{dy}=2(e_1l_1m_1+e_2l_2m_2+e_3l_3m_3)\,,$$
$$=2(\epsilon_1l_1m_1+\epsilon_2l_2m_2+\epsilon_3l_3m_3)\,,$$

with other two of the same kind.

eter- ina- on of ie rota- ons.

Also we have three equations of the form

$$\left.\begin{array}{l} 2\omega_x=\dfrac{d\zeta}{dy}-\dfrac{d\eta}{dz} \\ 2\omega_y=\dfrac{d\xi}{dz}-\dfrac{d\zeta}{dx} \\ 2\omega_z=\dfrac{d\eta}{dx}-\dfrac{d\xi}{dy} \end{array}\right\}.$$

ondition no tation.

These expressions show, simply, that when there is no elementary rotation the quantity

$$\xi dx+\eta dy+\zeta dz=d\phi$$

is the complete differential of a function of three independent variables. If we combine the condition that there shall be no change of volume with those that there shall be no rotation, we can eliminate ξ, η, ζ; and we arrive at Laplace's equation

$$\frac{d^2\phi}{dx^2}+\frac{d^2\phi}{dy^2}+\frac{d^2\phi}{dz^2}=0\,.$$

This shows at once how a graphical representation of stationary distributions of temperature, electric potential, &c., may be given by means of a strain.

If dS be an element of a surface at the point x, y, z, and l, m, n the direction cosines of its normal, the rotation about the normal is obviously

$$l\omega_x+m\omega_y+n\omega_z$$

The integral of double of this over a finite portion of surface is

$$\iint dS\left(l\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)+m\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)+n\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right)\right),$$

or

$$\iint\left\{\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)dydz+\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)dzdx+\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right)dxdy\right\}.$$

This, as seems to have been first pointed out by Stokes, can be expressed as a simple integral in the form

$$\int(\xi dx+\eta dy+\zeta dz)$$

extended round the boundary of the surface. Hence the double integral has the same value for all finite surfaces having the same boundary; and, as a consequence, it vanishes when taken over a closed simply-connected surface. Hence we see at once that it vanishes for multiply-connected surfaces also. The proof of the equality of the single and double integral has only to be established for a mere surface element. For, when that is done, the common boundary of each pair of elements gives equal portions, with opposite signs, in the single integral.

Directly connected with the displacements of a group of points, we have the question, *What is the mathematical expression of the fact that the number of points is not altered?* There are many ways of answering this; but the following, which is immediately deducible from our recent investigation, seems sufficiently simple. If l, m, n be the direction cosines of the normal to an element dS of a singly-connected closed surface, the number of points which pass through the element in the time δt in consequence of the displacement $\xi\delta t$, $\eta\delta t$, $\zeta\delta t$ at the point x, y, z is (So-called equation of continuity.)

$$(l\xi+m\eta+n\zeta)\rho dS\delta t,$$

where ρ is the number of points per unit volume at x, y, z. But at every point inside the closed surface the density is altered from ρ to $\rho+\dot\rho\delta t$. It will be noticed that ξ, η, ζ now stand for the x, y, z components of velocity.

Hence, if the excess of the number of points passing into the surface over those escaping be equated to the increase of the number of points included in the closed space, which is calculated from the change of density inside, we have

$$\delta t\iint(l\xi+m\eta+n\zeta)\rho dS=\delta t\iiint\dot\rho dxdydz.$$

If we take for S an elementary rectangular parallelepiped, with edges δx, δy, δz, this becomes at once

$$-\left(\frac{d(\rho\xi)}{dx}+\frac{d(\rho\eta)}{dy}+\frac{d(\rho\zeta)}{dz}\right)\delta x\delta y\delta z\delta t=\dot\rho\delta x\delta y\delta z\delta t$$

or

$$\frac{d\rho}{dt}+\frac{d(\rho\xi)}{dx}+\frac{d(\rho\eta)}{dy}+\frac{d(\rho\zeta)}{dz}=0\,.$$

If the arrangement is incompressible this becomes, as above,

$$\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}=0\,.$$

In any one of the last four forms the expression is called the "equation of continuity," another of the preposterously ill-chosen terms which have been introduced with only too great success into the nomenclature of our subject.

§ 95. In the strains which we have hitherto considered all parts of a figure were regarded as capable of changing their form and volume; and the strain of any element, when not identical with that of a proximate element, was supposed to differ only infinitesimally from it. But there is another class of changes of form, for which this restriction does not hold. The most important case, and the only one we can here consider, is that of "link-work." Here each finite piece is treated as incapable of change of form, and the change of form of the whole depends merely upon the relative motions of the parts. We will further restrict ourselves by the condition that the link-work is such that its form is determinate when the relative position of two of its parts is assigned. Thus, a jointed parallelogram is completely determined in form if the angle between two of its sides is assigned. Instead of an angle, we may assign the length of a diagonal; then the fact that the sum of the squares of the diagonals is equal to that of the squares of the sides determines the other diagonal. This gives us the kinematics of the more complex arrangement called "lazy-tongs." The most important applications of this branch of our subject are to what is called "Mechanism." One important practical problem in that branch was suggested by a stationary steam-engine, in which it was required to connect, by link-work of some kind, a point (of the piston-rod), which had a to-and-fro motion in a straight line, with another point (of the beam) which had a to-and-fro motion in a circular arc. Watt's original solution of the problem depends ultimately upon the near approach to rectilinearity of the motion of any point of a rod whose extremities move in two circles in the same plane. Thus, if OP, PQ, QO′ (fig. 31) be three bars jointed together at P and Q, having O and O′ fixed, and (Changes of figure of a jointed system of rigid parts.) (Lazy-tongs.) (Watt's parallel motion.)

the whole constrained to move in one plane, it is easy to see that the complete path of any point R of PQ is a species of figure of eight. A portion of that curve on each side of a point of inflexion (where the curvature vanishes) was found to be sufficiently straight for practical purposes.

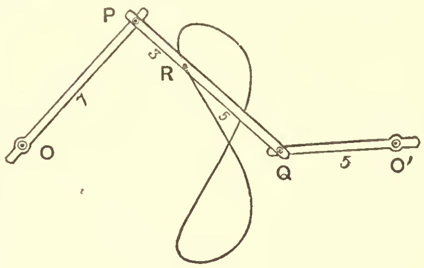


Fig. 31.

Peaucellier cell.

But the rigorous solution of this problem has only been arrived at in recent times; and the beautiful device of Peaucellier, which we will briefly explain, has led to a host of remarkable investigations and discoveries in a field regarded till lately as perfectly hopeless. A simple mode of arriving at Peaucellier's result is as follows.

Let PQ, PR (fig. 32) be *equal* links, and PO a link of a different length, all jointed together at P. Suppose O to be fixed, and Q and R constrained to move in a fixed straight line OQR, what is the relation between OQ and OR? We have, if PS be perpendicular to QR,

$$OP^2 = OS^2 + SP^2,$$
$$QP^2 = QS^2 + SP^2;$$

whence

$$OP^2 - QP^2 = OS^2 - QS^2 = OQ.OR.$$

Thus the rectangle under OQ and OR is constant; so that, if R were to describe a straight line, Q would describe a circle having O on its circumference. In practical application, to keep O, Q, R in one line, the parts of the link-work are doubled symmetrically about that line, so that it takes the form of a jointed rhombus PQP′R (fig. 33) with two equal links, PO, OP′ attached at the extremities of a diagonal. As a very curious result of this arrangement, if OQ have its length changed by any very small amount, the corresponding change of length of OR is directly as OR^2 or inversely as OQ^2. Hence, as will be seen later, a constant force (towards or from O) acting at Q will be balanced by a force (from or towards O) acting at R and varying inversely as the square of OR.

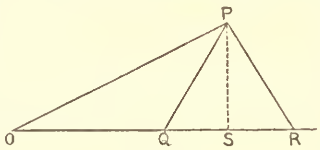


Fig. 32.

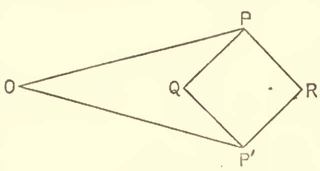


Fig. 33.

DYNAMICS.

Definitions and General Considerations.

Definition of physical particle.

§ 96. We commence with a few necessary definitions. A "physical particle" is a purely abstract conception, embodying together the ideas of inertia and of a geometrical point. It is, so to speak, a mathematical fiction, embracing only those properties which are required for our temporary purpose. Any mass, however large, can be treated as a particle, provided the forces to which it is subject are exerted in lines passing through its "centre of inertia" or "centre of mass" (this term will presently be defined), so as to be incapable of setting the mass into rotation. This is, to a first approximation, true of planetary motions, but when we look more closely into that question, so as for instance to take account of the oblate forms of the planets, we have to deal with forces which produce rotatory effects, such as "precession" and "nutation."

Mass dens

§ 97. The "quantity of matter" in a body, or the "mass," is proportional to the "volume" and the "density" conjointly. The "density" may therefore be defined as the quantity of matter in unit volume.

If M be the mass, ρ the density, and V the volume of a homogeneous body, we have at once

$$M = V\rho,$$

provided we so take our units that unit of mass is the mass of unit volume of a body of unit density. Hence the dimensions of ρ are $[ML^{-3}]$.

As will be presently explained, the most convenient unit mass is an *imperial pound*, or a *gramme*, of matter.

Mom tum.

§ 98. The "quantity of motion," or the "momentum," of a moving body is proportional to its mass and velocity conjointly. As already stated this is, like velocity, a directed quantity, or "vector." Its dimensions are, of course, $[MLT^{-1}]$.

Chan mom tum.

§ 99. "Change of quantity of motion," or "change of momentum," is proportional to the mass moving and the change of its velocity conjointly.

Change of velocity is to be understood in the general sense of § 32. Thus, with the notation of that section, if a velocity represented by OA be changed to another represented by OB, the change of velocity is represented in magnitude and direction by AB.

Rate chang mome tum.

§ 100. "Rate of change of momentum," or "acceleration of momentum," is proportional to the mass moving and the acceleration of its velocity conjointly. Thus (§ 36) the acceleration of momentum of a particle moving in a curve is $M\ddot{s}$ along the tangent, and Mv^2/ρ in the radius of absolute curvature. The dimensions of this quantity are $[MLT^{-2}]$.

Kinet energ

§ 101. The "vis viva," or "kinetic energy," of a moving body is proportional to the mass and the square of the speed conjointly. If we adopt the same units of mass and velocity as above, there is particular advantage in defining kinetic energy as *half* the product of the mass into the square of its speed. Its dimensions are $[ML^2T^{-2}]$.

Rate chang of it.

§ 102. "Rate of change of kinetic energy," thus defined, is the product of the speed into the component of acceleration of momentum in the direction of motion.

For

$$\frac{d}{dt}\left(\frac{Mv^2}{2}\right) = Mv\dot{v} = v(M\ddot{s}).$$

The dimensions are $[ML^2T^{-3}]$.

Space rate o chang of it.

§ 103. The "space-rate of change of kinetic energy" is

$$\frac{d}{ds}\left(\frac{Mv^2}{2}\right) = Mv\frac{dv}{ds} = M\frac{dv}{dt} = M\ddot{s};$$

and its dimensions are $[MLT^{-2}]$, the same as those of "force" (§ 104).

Force

§ 104. "Force," as we have already seen, is any cause which alters a body's natural state of rest, or of uniform motion in a straight line.

The three elements specifying a force, or the three elements which must be known before a clear notion of the force under consideration can be formed, are—its place of application, its direction, and its magnitude. The place of application may be a surface, as when one body presses on another; or it may be throughout the whole mass of a body, as in the case of the earth's attraction for it.

The "measure of a force" is the rate at which it produces momentum, or the momentum which it produces in unit of time, which is the same as what we have already called "rate of change of momentum." According to this method of measurement *the standard or unit force is that force which, acting on the unit of matter during the unit of* *time, generates the unit of velocity.* The dimensions of force are therefore [MLT^{-2}].

solute t ce. § 105. Hence the British absolute unit force is the force which, acting on one pound of matter for one second, generates a velocity of one foot per second.

itish stem. [According to the system followed till lately in treatises on dynamics, the unit of mass is g times the mass of the standard weight, g being the numerical value of the acceleration produced (in some particular locality) by the earth's attraction. This definition, giving a varying unit of mass, is exceedingly inconvenient. In reality, standards of weight are *masses*, not *forces*. They are employed primarily for the purpose of measuring out a definite *quantity* of matter, not an amount of matter which shall be attracted by the earth with a given force.]

§ 106. To render our standard intelligible, all that has to be done is to find how many absolute units will produce, in any particular locality, the same effect as does gravity. The way to do this is to measure the effect of gravity in producing acceleration on a body unresisted in any way. The most accurate method is indirect, by means of the pendulum. The result of pendulum experiments made at Leith Fort, by Captain Kater, is that the velocity acquired by a body falling unresisted for one second is at that place 32·207 feet per second. The variation in gravity for one degree of difference of latitude about the latitude of Leith is only ·0000832 its own amount. The average value for the whole of Great Britain differs but little from 32·2; that is, the attraction of gravity on a pound of matter in the country is 32·2 times the force which, acting on a pound for a second, would generate a velocity of one foot per second. Thus, speaking very roughly, the British absolute unit of force is equal to the weight of about half an ounce. The quantity of 32·2 feet per second per second is usually called g. Its dimensions are obviously [LT^{-2}]. And, if M be the mass . G. S. stem. of a body, its weight is Mg. In the *Centimetre-Gramme-Second* system of units, the absolute unit of force produces in one second, in a mass of one gramme, a velocity of one centimetre per second.

pre- ntation force. § 107. Forces (since they involve only direction and magnitude) may be represented, as velocities are, by vectors, that is, by straight lines drawn in their directions, and of lengths proportional to their magnitudes respectively.

Also the laws of composition and resolution of any number of forces acting at the same point are, as we shall presently show (§ 117), the same as those which we have already proved to hold for velocities; so that, with the substitution of force for velocity, § 30 is still true.

om- ponents f force. § 108. The "component" of a force in any direction is therefore found by multiplying the magnitude of the force by the cosine of the angle between the directions of the force and the component. The remaining component in this case is perpendicular to the other.

It is very generally convenient to resolve forces into components parallel to three lines at right angles to each other, each such resolution being effected by multiplying by the cosine of the angle concerned.

The magnitude of the resultant of two or of three forces in directions at right angles to each other is the square root of the sum of their squares.

entre of ass. § 109. The "centre of inertia or mass" of any system of material particles whatever (whether rigidly connected with one another, or connected in any way, or quite detached) is a point whose distance from any plane is equal to the sum of the products of each mass into its distance from the same plane, divided by the sum of the masses.

The distance from the plane yz of the centre of inertia of masses m_1, m_2, &c., whose distances from the plane are x_1, x_2, &c., is therefore

$$\bar{x} = \frac{\Sigma(mx)}{\Sigma(m)};$$

and similarly for the other coordinates.

Hence its distance from the plane

$$\delta = \lambda x + \mu y + \nu z - a = 0$$

is
$$D = \lambda\bar{x} + \mu\bar{y} + \nu\bar{z} - a = \frac{\Sigma\{m(\lambda x + \mu y + \nu z - a)\}}{\Sigma(m)} = \frac{\Sigma(m\delta)}{\Sigma(m)},$$

as stated above. And its velocity perpendicular to that plane is

$$\frac{dD}{dt} = \frac{1}{\Sigma m}\Sigma\left\{m\left(\lambda\frac{dx}{dt} + \mu\frac{dy}{dt} + \nu\frac{dz}{dt}\right)\right\} = \frac{\Sigma\left(m\frac{d\delta}{dt}\right)}{\Sigma m},$$

from which, by multiplying by Σm, and noting that δ is the distance of x, y, z from $\delta = 0$, we see that the sum of the momenta of the parts of the system in any direction is equal to the momentum in that direction of the whole mass collected at the centre of mass.

The problem of finding the centre of inertia of any given distribution of matter is a question of mere mathematics. We must confine ourselves to a few examples only. And, first, we may note that when a body is symmetrical about a plane the centre of inertia must obviously lie in that plane. Thus, as an ellipsoid and a rectangular parallelepiped have each three planes of symmetry, their centres of inertia lie at their centres of figure, where these planes meet. Again, it is obvious that, if a body can be divided into parts the centres of inertia of which lie on a straight line, the centre of inertia of the whole is in that line. Thus, as a triangular plate may be divided into strips parallel to one side, every one of which has its centre of inertia at its middle point, the centre of inertia of such a plate is the point of intersection of the bisectors of the sides. Its distance from any one side, treated as base, is therefore one-third of the height. Again, if a triangular pyramid (or tetrahedron) be divided into triangular slices by planes parallel to one face treated as base, the centres of inertia of all the slices lie in a straight line. Hence the distance of the centre of inertia from the base is one-fourth of the height. If the base be of any other form, it may be divided into triangles, and thus the whole pyramid (or cone) into tetrahedra, for each of which the same property holds. Hence the centre of inertia of a pyramid divides the line joining the vertex to the centre of inertia of the base in the ratio 3 : 1. All this is on the supposition that the solids treated of are of uniform density. When we deal either with more complex forms or with heterogeneous bodies, we must in general have recourse to integration.

For a continuous body we must take an element of mass, say $\rho\delta x\delta y\delta z$, at the point x, y, z instead of the mass m in our original formula. The sums then become integrals, and we have three expressions of the form

$$\bar{x} = \frac{\iiint \rho x dx dy dz}{\iiint \rho dx dy dz},$$

Here ρ represents the density at x, y, z; and the integration extends through the whole volume of the body.

Thus, for a homogeneous *hemisphere* of radius a we have, taking the base as the plane of yz,

$$\bar{x} = \frac{\int_0^a \pi(a^2 - x^2)x dx}{\frac{2}{3}\pi a^3} = \frac{3a}{8}.$$

The same value would be obtained for any semiellipsoid, whatever be the diametral section, provided a be the height measured perpendicular to the base; and, in general, from the position of the centre of inertia of any body we may at once find that of the same body homogeneously strained.

Recurring to the hemisphere, suppose its density to be at every point proportional to the distance from the centre. Then we have, omitting common constant factors of numerator and denominator,

$$\bar{x} = \frac{\int_0^a x dx \int_0^{\sqrt{a^2 - x^2}} r\sqrt{x^2 + r^2} dr}{\int_0^a dx \int_0^{\sqrt{a^2 - x^2}} r\sqrt{x^2 + r^2} dr} = \frac{2a}{5}.$$

A uniform hemispherical shell gives

$$\bar{x}=\tfrac{1}{2}a$$

by the well-known result due to Archimedes. From this, by taking concentric hemispherical elements, we may reproduce the preceding result for a solid hemisphere in the form

$$\bar{x}=\frac{\int_0^a 2\pi x^2 dx\,.\,x\,.\,\frac{1}{2}x}{\int_0^a 2\pi x^2 dx\,.\,x}=\frac{2a}{5}\,.$$

Here the first factor under each integral sign is the volume of the hemispherical element of radius x, and the second is proportional to its density.

If the density of a thin uniform spherical shell be everywhere proportional to the inverse cube of the distance from an internal point, that point is the centre of inertia. For, if a double cone of small angle be drawn, having that point as vertex, the volumes of the portions of the shell which it cuts out are as the squares of their distances from the vertex. Hence their masses are inversely as their distances from the vertex, which is thus their centre of inertia. The whole shell may be divided into pairs of elements for each of which this is true.

The reader may easily prove that, if the density of a solid sphere be inversely as the fifth power of the distance from an external point, the "electric image" of that point is the centre of inertia.

It may be proved in the last two examples that this point is not merely the centre of inertia of such distributions of matter, but that it is also a true "centre of gravity" in the sense that the whole attracts, and is attracted by, any other body whatever, as if its whole mass were concentrated in this point.

Moment of momentum. § 110. By introducing in the definition of moment of velocity (§ 46) the mass of the moving particle as a factor, we have an important element of dynamical science, the "moment of momentum." The laws of composition and resolution are the same as those already explained. Its dimensions are $[ML^2T^{-1}]$.

Work. § 111. A force is said to "do work" if it moves the body to which it is applied; and the work done is measured by the resistance overcome, and the space through which it is overcome, conjointly. The dimensions of work are therefore $[MLT^{-2}.\,L]$ or $[ML^2T^{-2}]$, the same as those of kinetic energy.

Thus, in lifting coals from a pit, the amount of work done is proportional to the weight of the coals lifted; that is, to the force overcome in raising them; and also to the height through which they are raised. The unit for the measurement of work, adopted in practice by British engineers, is that required to overcome the weight of a pound through the height of a foot, and is called a "foot-pound."

In purely scientific measurements, the unit of work is not the foot-pound, but the absolute unit force (§ 105) acting through unit of length.

If the weight be raised obliquely, as, for instance, along a smooth inclined plane, the distance through which the force has to be overcome is increased in the ratio of the length to the height of the plane; but the force to be overcome is not the whole weight, but only the resolved part of the weight parallel to the plane; and this is less than the weight in the ratio of the height of the plane to its length. By multiplying these two expressions together, we find, as we might expect, that the amount of work required is unchanged by the substitution of the oblique for the vertical path.

Generally, if s be an arc of the path of a particle, S the tangential component of the applied forces, the work done on the particle between any two points of its path is

$$\int S ds\,,$$

taken between limits corresponding to the initial and final positions.

Referred to rectangular coordinates, it is easy to see, by the law of resolution of forces, § 117, that this becomes

$$\int\left(X\frac{dx}{ds}+Y\frac{dy}{ds}+Z\frac{dz}{ds}\right)ds\,,$$

where X is the component force parallel to the axis of x.

§ 112. Thus it appears that, for any force, the work done during an indefinitely small displacement of the point of application is the product of the resolved part of the force in the direction of the displacement into the displacement.

From this it follows that, if the motion of a body be always perpendicular to the direction in which a force acts on it, the force does no work. Thus the mutual normal pressure between a fixed and a moving body, the tension of the cord to which a pendulum bob is attached, the attraction of the sun on a planet if the planet describe a circle with the sun in the centre, are all cases in which no work is done by the force.

In fact the geometrical condition that the resultant of X, Y, Z shall be perpendicular to ds is

$$X\frac{dx}{ds}+Y\frac{dy}{ds}+Z\frac{dz}{ds}=0\,,$$

and this makes the above expression for the work vanish.

§ 113. Work done on a body by a force is always shown by a corresponding increase of kinetic energy, if no other forces act on the body which can do work or have work done against them. If work be done against any forces, the increase of kinetic energy is less than in the former case by the amount of work so done. In virtue of this, however, the body possesses an equivalent in the form of "potential energy," if its physical conditions are such that these forces will act equally, and in the same directions, when the motion of the system is reversed. Thus there may be no change of kinetic energy produced, and the work done may be wholly stored up as potential energy. Tran mati work Pote energ

Thus a weight requires work to raise it to a height, a spring requires work to bend it, air requires work to compress it, &c.; but a raised weight, a bent spring, compressed air, &c., are *stores* of energy which can be made use of at pleasure.

As an illustration of the calculation of work, take the following question. Exam of wo

Suppose one end of an elastic string to be attached to a mass resting on the ground, what amount of work must be done, in raising the other end vertically, before the mass is lifted?

If x be at any instant the length of the string, l its original length, its tension is

$$E\frac{x-l}{l}\,.$$

Hence the value of x, when the mass is just lifted, is

$$x_1=l\left(1+\frac{W}{E}\right),$$

where W is the weight of the mass.

The whole work done is the sum of all the elementary instalments of the form

$$E\frac{x-l}{l}dx\,.$$

These must be summed up from $x=l$ to $x=x_1$, so that the result required is

$$\tfrac{1}{2}l\frac{W^2}{E}\,.$$

It is to be observed that this quantity becomes less in proportion as E is greater, *i.e.*, the less extensible is the string.

An interesting variation of the question consists in supposing the upper end of the string to be attached to the rim of a wheel, rough enough to prevent slipping. Here the various portions of the string are wound on in a more and more stretched state as the operation proceeds.

At any stage of the operation let x be the unstretched length of the part already wound on the wheel. The tension of the free part is then

$$E\frac{l-(l-x)}{l-x}\,.$$

During the next elementary step of the process a portion dx is wound on. But its stretched length is

$$\frac{ldx}{l-x}\,.$$

Hence the element of work is

$$El\frac{l-(l-x)}{(l-x)^2}dx,$$

This must be integrated between the limits 0 and W of

$$E\frac{l-(l-x)}{l-x};$$

or from $l-x=l$ to $l-x=\frac{El}{E+W}$; and the result is

$$l\left(W+E\log\frac{E}{E+W}\right);$$

which, when E is very great compared with W, gives the previous result.

Further Comments on the First Two Laws of Motion.

[Physical measurement of time.] § 114. We are now prepared to consider, more closely than we could at starting, the bearing of the various clauses of each of Newton's Laws. Thus, from the first law we may draw the following immediate consequences.

The times during which any particular body, not compelled by force to alter the speed of its motion, passes through equal distances are equal. And, again, every other body in the universe, not compelled by force to alter the speed of its motion, moves over equal distances in successive intervals, during which the particular chosen body moves over equal distances. The earth, in its rotation about its axis, presents us with a case of motion in which the condition of not being compelled by force to alter its speed is more nearly fulfilled than in any other which we can easily or accurately observe. Hence the numerical measurement of time practically rests on defining "equal intervals of time" as *times during which the earth turns through equal angles.*

§ 115. It has been objected to this statement that we begin by defining uniform motion by the description of equal spaces in equal times, and then employ this definition as a mode of measuring equal times. The objection, however, is not valid; for, if we agree to measure equal intervals by the undisturbed motion of any one physical mass, we find that in the successive intervals so determined all other absolutely free physical masses describe successive equal spaces.

[Measure of force.] § 116. Again, from the second law we see that, if we multiply the change of velocity, geometrically determined, by the mass of the body, we have the change of motion (§ 99) referred to in the law as the measure of the force which produces it. In the statement of the second law there is nothing said about the actual motion of the body before it was acted on by the force; the same force will produce precisely the same change of motion in a body whether the body be at rest or in motion with any velocity whatever. Again, nothing is said as to the body being under the action of one force only; so that we may logically put part of the second law in the following (apparently) amplified form:—

When any forces whatever act on a body, then, whether the body be originally at rest or moving with any velocity and in any direction, each force produces in the body the exact change of motion which it would have produced if it had acted singly on the body originally at rest.

[Composition of forces.] § 117. Since now forces are measured by the changes of motion they produce, and their directions assigned by the directions in which these changes are produced, and since the changes of motion of one and the same body are in the directions of and proportional to the changes of velocity, a single force, measured by the resultant change of velocity, and in its direction, will be the equivalent of any number of simultaneously acting forces. Hence

The resultant of any number of forces (applied at one point) is to be found by the same geometrical process as the resultant of any number of simultaneous velocities.

From this follows at once (§ 30) the construction of the "parallelogram of forces" for finding the resultant of two forces acting at the same point, and the "polygon of forces" for the resultant of any number of forces acting at a point. And, so far as a single particle is concerned, we have at once the whole subject of Statics.

§ 118. The second law gives us the means of measuring force, and also of measuring the mass of a body. [Measure of mass, and of force.]

For, if we consider the actions of various forces upon the same body for equal times, we evidently have changes of velocity produced which are proportional to the forces. The changes of velocity, then, give us in this case the means of comparing the magnitudes of different forces. Thus the speeds acquired in one second by the same mass (falling freely) at different parts of the earth's surface give us the relative amounts of the earth's attraction at these places.

Again, if equal forces be exerted on different bodies, the changes of velocity produced in equal times must be *inversely* as the masses of the various bodies. This is approximately the case, for instance, with trains of various lengths drawn by the same locomotive.

Again, if we find a case in which different bodies, each acted on by a force, acquire in the same time the same changes of velocity, the forces must be proportional to the masses of the bodies. This, when the resistance of the air is removed, is the case of falling bodies; and from it we conclude that the *weight of a body in any given locality, or the force with which the earth attracts it, is proportional to its mass.* This is no mere truism, but an important part of the grand *Law of Gravitation.* Gravity is not, like magnetism for instance, a force depending on the quality as well as on the quantity of matter in a particle. [Gravity.]

§ 119. It appears, lastly, from this law that every theorem of kinematics connected with acceleration has its counterpart in kinetics. Thus, for instance (§ 36), we see that the force under which a particle describes any curve may be resolved into two components, one in the tangent to the curve, the other *towards* the centre of curvature,—their magnitudes being the rate of change of momentum in the direction of motion, and the product of the momentum into the angular velocity about the centre of curvature, respectively. In the case of uniform motion, the first of these vanishes, or the whole force is perpendicular to the direction of motion. When there is no force perpendicular to the direction of motion, there is no curvature, or the path is a straight line. [Translation from kinematics into kinetics.]

Hence, if we resolve the forces acting on a particle of mass m, whose coordinates are x, y, z, into three rectangular components X, Y, Z, we have the equations originally given by Maclaurin, viz.,

$$m\frac{d^2x}{dt^2}=X,\quad m\frac{d^2y}{dt^2}=Y,\quad m\frac{d^2z}{dt^2}=Z.$$

In several of the examples which follow, these equations will be somewhat simplified by assuming unity as the mass of the moving particle. When this cannot be done, it is sometimes convenient to assume X, Y, Z as the component forces on *unit* mass, and the previous equations become

$$m\frac{d^2x}{dt^2}=mX,\ \&c.,$$

from which m may of course be omitted.

[Some confusion is often introduced by the division of forces into "accelerating" and "moving" forces; and it is even stated occasionally that the former are of *one*, and the latter of *four* linear dimensions. The fact is, however, that an equation such as

$$\frac{d^2x}{dt^2}=X$$

may be interpreted either as dynamical or as merely kinematical. If kinematical, the meanings of the terms are obvious; if dynamical, the unit of mass must be understood as a factor on the left-hand side, and in that case X is the x-component, per unit of mass, of the whole force exerted on the moving body.]

If there be no acceleration, we have of course equilibrium among the forces. Hence the equations of motion of a particle are changed into those of equilibrium by putting

$$\frac{d^2x}{dt^2}=0, \text{ \&c.}$$

Statical friction.

§ 120. We have now all that is necessary for the dynamics of a single particle, with exception of the experimental laws of friction. These, very nearly as they were established by Coulomb, we will now give.

To produce sliding of one flat-faced solid on another requires a tangential force which is directly proportional to the normal pressure between the surfaces, and whose actual magnitude is found from this pressure by means of a factor called the "coefficient of statical friction." This coefficient depends upon the nature of the solids, the roughness or smoothness of the surfaces in contact, and the amount of tallow, oil, &c., with which they have been smeared. It also depends upon the time during which they have been left in contact. It is only in extreme cases dependent on the area of the surfaces in contact.

§ 121. When the forces applied are insufficient to produce sliding, the whole amount of friction is not called into play; it is called out to an amount just sufficient to balance the other forces. Thus there are two quite distinct problems connected with the statics of friction:—the first, to determine the amount of friction called into play under given circumstances; the second, to find the limiting circumstances under which, with friction, equilibrium is possible. When motion is produced, there is

Kinetic friction.

still friction (now called "kinetic"). It follows the same laws as does statical friction, only that the coefficient, which is approximately independent of the velocity, is usually considerably less than the statical coefficient.

Statics of a Particle.

Equilibrium of a particle.

§ 122. By § 117, forces acting at the same point, or on the same material particle, are to be compounded by the same laws as velocities. Therefore the sum of their resolved parts in any direction must vanish if there is equilibrium; whence the necessary and sufficient conditions are found by resolving in three directions at right angles to one another.

They follow also directly from Newton's statement with regard to work, if we suppose the particle to have any velocity, constant in direction and magnitude (and by § 6 this is the only general supposition we can make, since absolute rest has for us no meaning). For the work done in any time is the product of the displacement during that time into the algebraic sum of the effective components of the applied forces, and there is no change of kinetic energy. Hence this sum must vanish for *every* direction. Practically, as any displacement may be resolved into three, in any three directions not coplanar, the vanishing of the work for any one such set of three suffices for the criterion. But, in general, it is convenient to assume them in directions at right angles to each other.

Hence, for the equilibrium of a material particle, it is *necessary*, and *sufficient*, that the (algebraic) sums of the applied forces, resolved in any one set of three rectangular directions, should vanish.

This statement gives at once the result that, if X_1, Y_1, Z_1, X_2, Y_2, Z_2, &c., be the components (parallel to the three axes) of the forces P_1, P_2, &c., acting on the particle, we must have

$$\Sigma(X)=0\,,\ \Sigma(Y)=0\,,\ \Sigma(Z)=0\,.$$

When these conditions are not satisfied, there is a resultant force P, with direction cosines λ, μ, ν, such that

$$P\lambda=\Sigma(X),\ P\mu=\Sigma(Y),\ P\nu=\Sigma(Z).$$

Attraction.

§ 123. By far the most extensive series of examples of the composition of forces acting on a single particle is furnished by the theory of "attraction," where each particle of the attracting mass exerts upon the attracted particle a force in the direction of the line joining them, and of magnitude depending on their masses and their mutual distance only. See Potential.

Example of particle equilibrium.

§ 124. When there are but three forces acting on the particle, their directions to give equilibrium must obviously be in one plane. For, if the third were not in the plane of the other two, it would have an uncompensated component perpendicular to that plane. Hence this case is always at once reducible to the triangle or the parallelogram of forces; and the magnitudes of each of the three forces are respectively proportional to the sines of the angles between the directions of the other two.

Thus, when a pellet is supported by two strings, as in fig. 34, we may proceed as follows to determine their tensions. Let P be the pellet, of weight W, and let AP, BP be the strings attached to points A and B respectively. Let their tensions be T and T′. The remark above shows that the strings must hang in a vertical plane, since the force W acts in a vertical line. Since A, B, and the length of the strings are given, the figure is perfectly definite. Draw $P\gamma$ vertically upwards, and make its length represent, on any assumed scale, the value of W. Draw $\gamma\beta$ parallel to AP, and let it meet BP in β. Then $\beta\gamma$ represents T, and $P\beta$ represents T′, in direction and also in magnitude, on the same scale in which γP represents W. This case leads to nothing but the determination of the tensions, since the form of the figure is definite.

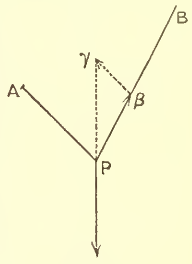


Fig. 34.

Next, let one of the tensions be given in magnitude. To effect this, we may suppose the end of PB not to be fastened at B, but to pass over a smooth pulley and support a weight Q. Let fig. 35 represent the state of equilibrium, and let the same construction as before be made. Then we must have $\gamma P : P\beta :: W : Q$; or, writing it in terms of angles,

$$\sin APB : \sin AP\gamma :: W : Q\,.$$

A and B and the direction of γP being given, this datum suffices for the drawing of the figure; *i.e.*, for the calculation of the angles. A little consideration will show that, however small Q be, provided the string supporting it be long enough, there is always *one definite* position of equilibrium. The actual calculations in such a case as this are troublesome. It was chosen mainly on that account, so as to show, in a simple case, how pure geometrical processes may occasionally save the necessity of a tedious trigonometrical investigation. But a still simpler method will be afterwards explained, viz., that, for a position of stable equilibrium, the potential energy must be a *minimum*. Now, to apply this to our example, we see that any downward displacement of Q produces an upward motion of P. But when AP is nearly vertical the vertical displacement of P is indefinitely smaller than that of Q, so that Q must go down. On the other hand if APB be nearly a straight line, a displacement of P produces an indefinitely smaller displacement of Q. Hence P must go down. And these results are in character independent of the relative magnitudes of P and Q, provided both be finite.

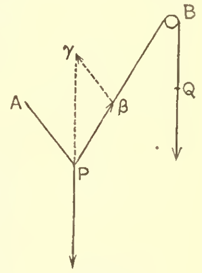


Fig. 35.

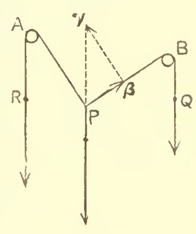


Fig. 36.

Finally, let both tensions be constant. Here we must imagine pulleys both at A and at B (fig. 36), with weights

R and Q attached to the ends of the strings. But now we see that we must have the limiting condition

$$R+Q>W.$$

This is merely the geometrical condition that

$$P\beta+\beta\gamma>P\gamma$$

Here the magnitudes of all three sides of $P\beta\gamma$ are given. Hence its angles are given, and the sole position of equilibrium is at once found.[1]

Particle on fixed surface. § 125. Now take the case of a particle resting on a surface. As we are concerned only with the portion of the surface immediately contiguous to the position of the particle, we may substitute for it its tangent plane at that point (except, of course, at singular points, where there may be an infinite number of tangent planes; but such cases we do not consider). Hence the problem reduces itself in all cases to that of a particle resting on an inclined plane.

If the plane be smooth, the particle cannot remain in equilibrium unless some force is present to prevent its sliding down. Let us suppose it to be supported by a force, F, acting upwards along the plane (fig. 37). Then we have three forces at work:—the weight P acting vertically downwards; the supporting pressure of the plane R, which necessarily acts perpendicularly to the surface; and the third force, just mentioned, which we see by previous considerations must be in the plane of the other two, and must therefore lie along the line of greatest slope of the plane. We might construct a triangle of forces as in the previous examples, but we will now vary the process, and resolve the forces in two directions at right angles to one another in their common (vertical) plane.

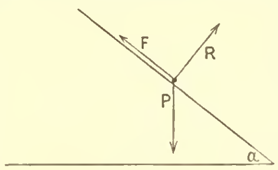


Fig. 37.

Let a be the angle of inclination of the plane to the horizon, then the algebraic sum of the components of the forces must vanish both horizontally and vertically. This gives us the two conditions

$$F\cos a-R\sin a=0\,,\quad F\sin a+R\cos a-P=0$$

From these we obtain at once

$$F=P\sin a,\quad R=P\cos a$$

Now the choice of mutually perpendicular directions in which to resolve was at our option, and we see that had we chosen to resolve *along* and *perpendicular to* the plane we should have obtained the last two equations, which are equivalent to, but simpler than, the former ones, which were obtained by resolving horizontally and vertically. Theoretically speaking, it does not matter which system we choose; in practice, however, it is well to select the directions which will give the required results in the simplest form. The full value of a proper selection will not be felt till we come to the statics of a rigid solid.

Friction. If we suppose the plane to be rough, friction alone may suffice to develop the requisite force F. But the utmost value of the friction is (§ 120) μR. Hence the particle will be on the point of sliding if

$$\mu R=F=P\sin a.$$

Divide the members of this equation by those of

$$R=P\cos a,$$

and we find

$$\mu=\tan a.$$

Hence, so long as the coefficient of friction is greater than the tangent of the inclination of the plane to the horizon, the friction will suffice to prevent sliding. More and more is called into play as the inclination of the plane increases, and finally when

Angle of repose.

$$\tan a=\mu$$

the particle is just about to slide down. This simple idea, taken along with Coulomb's results (§ 120), points to a very easy method of determining the coefficient of friction between any two substances. The limiting angle defined by

$$a=\tan^{-1}\mu$$

is called, on account of this property, the "angle of repose."

Support by elastic string. § 126. Let us now suppose the particle to be, in part, supported by an elastic string fixed at a point in the plane, and lying in the line of greatest slope. (This modification is introduced to show the nature of cases in which there are *limits* between which equilibrium is possible.) We assume "Hooke's Law," viz., that the tension of an elastic string, drawn out from its natural length l to length l', is expressed by

$$E\frac{l'-l}{l},$$

where E is a definite constant, representing theoretically the tension which would just double the length of the string.

Our equations are exactly the same as before, only that F consists now of two parts,—one due to friction, the other to the elasticity of the string. Thus

$$F=F_1+E\frac{l'-l}{l}=P\sin a\,,\qquad R=P\cos a.$$

Now, when sliding is about to commence downwards we have

$$F_1=\mu R,$$

If the particle is about to be dragged upwards,

$$F_1=-\mu R.$$

Hence for the two extreme positions of equilibrium

$$\pm\mu P\cos a+E\frac{l'-l}{l}=P\sin a.$$

Hence the limiting positions of equilibrium of the particle are given by its distance from the fixed end of the string—

$$l'=l+\frac{Pl}{E}(\sin a\mp\mu\cos a).$$

If l' be less than the smaller of these, gravity pulls the particle down; if it be greater than the larger of them, the tension of the string pulls the particle up. In intermediate positions the full available friction is not called into play.

Equilibrium with a system of equal forces tending to given points. § 127. Next, let a small ring P (fig. 38) be attached to one end of a string. Let the string pass round two smooth pulleys B, C, at different points, then be passed through the ring, then round two more pulleys D, E, and through the ring again, and so on,—the other end being either fastened to the ring or attached to a fixed point. It is required to find the position of equilibrium of the ring when the string is drawn tight, by operating on the lap of it behind two of the pulleys.

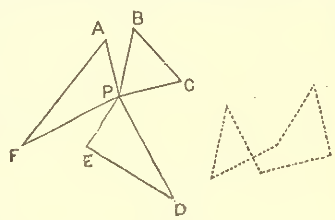


Fig. 38.

This is equivalent, from the physical point of view, to finding the position of equilibrium of a particle acted on by a number of *equal* forces each directed towards a given point. From the geometrical point of view its solution obviously answers the question, "Find the point the sum of whose distances from a number of given points is the least possible." The points need not lie all in one plane. The solution is, from the polygon of forces, that in

[1] We have assumed here, what is properly part of the results of the *third* law of motion, that the tension of a weightless string, passing over a smooth pulley, is in the direction of its length, and of the same amount at all points.

the equilibrium position the laps of the string, from the ring outwards, are parallel to the respective sides of a closed equilateral polygon, taken all in the same direction. That the solution is unique will be seen at once by considering a displacement of the ring, for the resultant of the forces obviously tends to diminish the displacement. When there are but three forces, their directions must be inclined at angles of 120° to one another (fig. 39). Thus we have immediately the solution of the celebrated geometrical problem, "Find the point the sum of whose distances from three given points is the least possible."

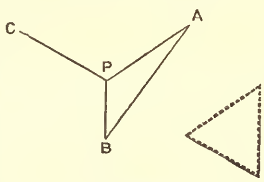


Fig. 39.

Indeterminateness of solution.

§ 128. If, in the first problem of § 124 above, the particle were supported by three strings, instead of two, each attached to a fixed point, we should first have to assure ourselves that all three are brought into play. For, if not, the problem is reduced to the former case. The obvious condition is that, when the three strings are simultaneously tight, and the points of suspension are not in one vertical plane, the particle supported shall be situated *within* the triangular prism formed by vertical planes passing through each pair of points. If this condition be satisfied, the process for determining the tensions of the strings is merely to construct a parallelepiped, three of whose edges lie along the strings, while the conterminous diagonal is vertical. This leads to an obvious geometrical construction; and, when it is carried out, the lengths of the various edges are to the diagonal as the corresponding tensions to the weight of the particle. When the three points are in one vertical plane, nothing short of infinitely perfect fitting will, in general, bring all three strings simultaneously tight; and in this case the problem, mathematically considered, is indeterminate.[1] When the strings are sufficiently extensible, all will be brought into play; and, with sufficient data, the problem is determinate.

Kinetics of a Particle with One Degree of Freedom.

§ 129. Here the motion is rectilinear, or at least takes place in some assigned curve.

The simplest case is that of a falling stone, when the effect of the resistance of the air is set aside and the acceleration due to gravity is reckoned the same at all elevations. This has already been treated with sufficient detail as a matter of pure kinematics, §§ 28, 29.

Sliding on inclined plane.

§ 130. When the particle, instead of falling freely, is constrained by a smooth inclined plane on which it slides, we see that (so long as it moves on the line of greatest slope) its weight Mg has components, $Mg\sin\alpha$ tangential to the plane and $Mg\cos\alpha$ perpendicular to it, α being the inclination of the plane to the horizon. The latter component produces the normal pressure on the plane, and is the only contributor to it, since there is no curvature. The former produces the acceleration of the motion. Thus the acceleration is now $g\sin\alpha$ only; but, with this change, the results of § 29 still hold.

Plane rough.

§ 131. If the plane be rough, with coefficient of statical friction μ, it can furnish (§ 120) a force of friction tending to prevent motion, of any amount up to

$$\mu Mg\cos\alpha\,.$$

If this be less than $Mg\sin\alpha$, motion will commence, and the force accelerating it will be

$$Mg\sin\alpha - \mu' Mg\cos\alpha\,,$$

where μ' is the coefficient of kinetic friction (§ 121). Thus the same results as in § 29 still hold, but with $g(\sin\alpha - \mu'\cos\alpha)$ instead of g. As we have seen that $\mu' < \mu$, *accelerated* motion can take place down an inclined plane in certain cases where the mass, if once at rest, would not start.

[1] Of course, physically, there is no indeterminateness, even with perfectly inextensible strings.

Body falling to earth from a great distance.

§ 132. As a slightly more complex case, let us now take again the problem of free motion in a vertical line, but allow for the diminution of gravity as the distance from the earth increases.

The weight of a particle of mass m at the earth's surface is mg. At a distance x from the centre, it is, therefore,

$$mg\frac{R^2}{x^2}\,,$$

where R is the radius of the earth, supposed spherical. This acts downwards, or in the direction opposite to that in which x increases. Hence, equating it, with its proper sign, to the rate of acceleration of momentum, we have for the equation of motion

$$m\ddot{x} = -mg\frac{R^2}{x^2}\,.$$

Here the right hand member is a function of x only.

Multiply by $\dot{x}dt$, and integrate, and we have, leaving out the extraneous factor m (the possibility of doing this showing that the motion is the same for all masses),

$$\tfrac{1}{2}\dot{x}^2 + C = \frac{R^2 g}{x}\,.$$

If V be the speed at the earth's surface (where $x = R$),

$$\tfrac{1}{2}V^2 + C = Rg\,.$$

Also if the particle turns, to come down again, at the height h above the surface,

$$C = \frac{R^2 g}{R+h}\,.$$

Hence

$$\tfrac{1}{2}V^2 = Rg\left(1 - \frac{R}{R+h}\right) = gh\frac{R}{R+h}\,.$$

This shows the amount of error in the approximate formula (§ 28) for projectiles,—

$$\tfrac{1}{2}V^2 = gh\,.$$

Meteorite.

If the particle be supposed to have been originally at rest, at a practically infinite distance from the earth (a case which may occur with a meteorite for instance), we have $\dot{x} = 0$ when $x = \infty$, and our formula becomes

$$\tfrac{1}{2}\dot{x}^2 = \frac{R^2 g}{x}\,.$$

The speed with which the mass reaches the surface (where $x = R$) is therefore $\sqrt{2gR}$, *i.e.*, that which it would acquire by falling, under constant acceleration g, through a height equal to the earth's radius.

In this special case, the second integral is

$$\tfrac{2}{3}x^{\frac{3}{2}} = \sqrt{2g}Rt + C'.$$

The second integral, in its general form, is a little complex; but we may avoid it by means of a geometrical construction, founded on the results of the investigation of planetary motion soon to be given.

Hailstone raindrop.

§ 133. Let us next take a case in which the acceleration depends upon the speed of the moving body. A sufficiently simple one is furnished by a falling raindrop, or hailstone, when the resistance of the air is taken into account. For the moderate speeds with which such bodies move, the resistance varies, at least approximately, as the square of the speed. To avoid needless complexity, we neglect here the variation of gravity due to changes of vertical height.

Suppose the particle to have been projected vertically upwards from the origin with the speed V, and let v be its speed at any time t, and x its distance from the origin at that time.

If we assume k to be the speed with which the particle must move so that the retardation due to the resistance may be equal to g, the retardation when the speed is v will be represented by $g\frac{v^2}{k^2}$.

Let the axis of x be drawn vertically upwards; then the resistance acts *with* gravity, and the equation of motion upwards is

$$\frac{dv}{dt} = -\frac{g}{k^2}(k^2 + v^2),$$

or

$$v\frac{dv}{dx} = -\frac{g}{k^2}(k^2 + v^2).$$

Integrating, and determining the constants so that, when $x=0$, $t=0$ and $v=V$, we obtain

$$\frac{gt}{k} = \tan^{-1}\frac{V}{k} - \tan^{-1}\frac{v}{k} = \tan^{-1}\frac{k(V-v)}{k^2+Vv},$$

$$\frac{2gx}{k^2} = \log\frac{k^2+V^2}{k^2+v^2}.$$

Let T be the time at which the speed becomes zero, and h the corresponding value of x, then

$$T=\frac{k}{g}\tan^{-1}\frac{V}{k}, \text{ and } h=\frac{k^2}{2g}\log\left(1+\frac{V^2}{k^2}\right).$$

After this the particle begins to return; the resistance therefore acts *against* gravity, and the equation of motion is

$$\frac{dv}{dt} = -\frac{g}{k^2}(k^2-v^2),$$

or

$$v\frac{dv}{dx} = -\frac{g}{k^2}(k^2-v^2).$$

Integrating, and determining the constants so that, when $v=0$, $x=h$ and $t=T$, we obtain

$$\frac{2g}{k}(t-T)=\log\frac{k-v}{k+v},$$

$$\frac{2g}{k^2}(h-x)=\log\frac{k^2}{k^2-v^2}.$$

(It must be remembered that v is now negative.)

Let U be the speed with which the particle returns to the point of projection; then, putting $x=0$ in the latter equation, we obtain

$$\frac{U^2}{k^2}=1-\varepsilon^{-\frac{2gh}{k^2}};$$

or, substituting for h its value,

$$\frac{U^2}{k^2}=\frac{V^2/k^2}{1+V^2/k^2},$$

whence

$$\frac{1}{U^2}-\frac{1}{V^2}=\frac{1}{k^2}.$$

rminal ocity. It is to be observed that k is the "terminal velocity," as it is called, *i.e.*, the speed to which that of a falling body continually tends, whether its original speed have been greater or less than this limit.

It is to be observed also that (strictly) we should write $g(1-a)$ for g, where a is the specific gravity of air, to take account of the apparent loss of weight of a raindrop on account of immersion in air.

When k is very large, *i.e.*, the absolute amount of resistance very small, as in the case of air, the general integrals in the second case above become, by expanding the logarithms,

$$-\frac{2g}{k}(t-T)=\frac{2v}{k}+\frac{2v^3}{3k^3}+\ldots$$

$$\frac{2g}{k^2}(h-x)=\frac{v^2}{k^2}+\frac{v^4}{2k^4}+\ldots$$

of which the terms independent of k are

$$v=-g(t-T),$$
$$v^2=2g(h-x).$$

These, if we remember that $t-T$ is the time of fall, and $h-x$ the space fallen through, are at once recognized as the ordinary formulæ of § 28. The modification due to the resistance is shown approximately by the second terms on the right-hand side of the developments above.

The necessity for this double investigation, one part for the ascent, the other for the descent, is due to the non-conservative, or "dissipative," character of the force of resistance.

mple ndu- m. § 134. As an illustration of constraint by a smooth curve, let us take the case of a simple pendulum. Let O (fig. 40) be the point of suspension, P the position of the bob at any time t. Then, if PG represent the weight of the bob, and be resolved into PH, HG respectively along, and perpendicular to, the tangent at P, we see that PH produces the acceleration of the motion, while the tension of the cord balances HG and also furnishes the acceleration perpendicular to the direction of motion which is required to produce the curvature of the path. PH is (*cæteris paribus*) proportional to the sine of PGH, that is, of POA. Hence the acceleration is proportional to the sine of the angular displacement. When that angle is small it may be used in place of its sine. Hence, for small vibrations, the acceleration is proportional to the displacement, and the motion is "simple harmonic." The time of vibration, being (§ 51) $2\pi\sqrt{\text{displacement}/\text{acceleration}}$, is here

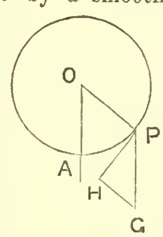


Fig. 40.

$$2\pi\sqrt{\frac{l\theta}{g\sin\theta}}=2\pi\sqrt{\frac{l}{g}}, \text{ approximately.}$$

The rigorous solution of the pendulum problem requires the use of elliptic functions.

§ 135. Some very curious properties of pendulum motion are easily proved by geometrical processes. The whole theory of the motion in a vertical plane of a particle attached by a weightless rod to a fixed point, whether it oscillate as a pendulum or perform continuous rotations, may be deduced from the two following propositions, which are easily established by geometrical processes in which corresponding indefinitely small motions are compared.

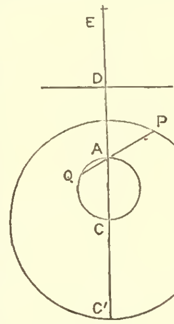


Fig. 41.

(1) To compare different cases of continuous rotation. Let DA (fig. 41) be taken equal to the tangent from D to the circle BPC′, whose centre C is vertically under D. Let PAQ be any line through A, cutting in Q the semicircle on AC. Also make DE = DA. Then, if P move under gravity with speed due to the level of D, Q moves with speed due to the level of E, the acceleration due to gravity being reduced in the ratio $AC^2 : 2BC^2$.

(2) To compare continuous rotation with oscillation. Let two circles touch one another at their lowest points O (fig. 42); compare the arcual motions of points P and p, which are always in the same horizontal line. Draw the horizontal tangent AB. Then, if P move, with speed due to g and level a, continuously in its circle, p oscillates with speed due to level AB and acceleration

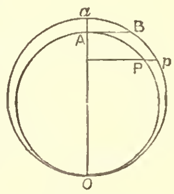


Fig. 42.

$$g\frac{aO^2}{AO^2}.$$

§ 136. Two particles are projected from the same point, in the same direction, and with the same speed, but at different instants, in a smooth circular tube of small bore whose plane is vertical, to show that the line joining them constantly touches another circle. Motion in vertical circle

Let the tube be called the circle A, and the horizontal line, to the level of which the speed is due, L. Let M, M′ (fig. 43) be simultaneous positions of the particles. Suppose that MM′ passes into its next position by turning about O, these two lines will intercept two indefinitely small arcs at M and M′ which (by a property of the circle) are in the ratio MO : OM′. Let another circle B be described touching MM′ in O, and such that L is the radical axis of A and B. Let MP, M′P′ be drawn perpendicular to L. Let M′M cut L in C. Then, by the property of the radical axis, $CO^2 = CM.CM'$; from which we have, by geometry,

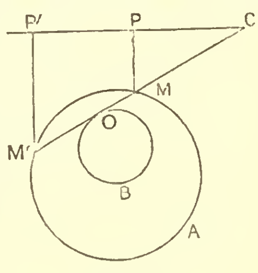


Fig. 43.

$$CM : CM' = OM^2 : OM'^2$$

or

$$OM^2 : OM'^2 = PM : P'M'.$$

But

$$(\text{speed at M})^2 : (\text{speed at M}')^2 = PM : P'M'.$$

Hence the speeds of M and M′ are as MO : OM′, and therefore, by what we have stated above about elementary arcs at M and M′, the proximate position of MM′ is also a tangent to B, which proves the proposition.

Geometrical theorem.

It is easily seen from this that, if one polygon of a given number of sides can be inscribed in one circle and circumscribed about another, an infinite number can be drawn. For this we have only to suppose a number of particles moving in A with speeds due to a fall from L, and then if they form at any time the angular points of a polygon whose sides touch B they will continue to do so throughout the motion. Fig. 44 shows two forms of a quadrilateral possessing this property.

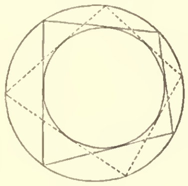


Fig. 44.

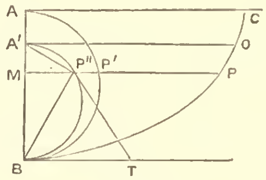


Fig. 45.

Cycloidal motion.

§ 137. *To find the time of fall from rest down any arc of an inverted cycloid.*

Let O (fig. 45) be the point from which the particle commences its motion. Draw OA′ parallel to CA, and on BA′ describe a semicircle. Let P, P′, P″ be corresponding points of the curve, the generating circle, and the circle just drawn, and let us compare the speeds of the particle at P and the point P″. Let P″T be the tangent at P″.

$$\frac{\text{Speed of P}''}{\text{Speed of P}}=\frac{\text{element at P}''}{\text{element at P}}$$

$$=\frac{\text{P}''\text{T}}{\text{BP}'}=\frac{\text{P}''\text{T}}{\text{BP}''}\sqrt{\frac{\text{A}'\text{B}}{\text{AB}}}=\frac{\text{A}'\text{B}}{2\text{A}'\text{P}''}\sqrt{\frac{\text{A}'\text{B}}{\text{AB}}}.$$

But speed of $\text{P}=\sqrt{(2g\,.\,\text{A}'\text{M})}=\sqrt{\frac{2g}{\text{A}'\text{B}}}\,.\,\text{A}'\text{P}''$.

Hence speed of $\text{P}''=\sqrt{\frac{g}{2\text{AB}}}\,.\,\text{A}'\text{B}$, a constant.

And, as the length of A′P″B is $\frac{1}{2}\pi\,.\,\text{A}'\text{B}$,

time from A′ to B in circle = time from O to B in cycloid

$$=\pi\sqrt{\frac{\text{AB}}{2g}}.$$

Tautochrone.

The time of fall to the vertex from all points of the curve is therefore the same. Hence the cycloid is called a "tautochrone."

Resisted motion of pendulum.

§ 138. As an instance of cases in which the acceleration depends upon the speed and the position jointly, take the motion of a simple pendulum in a medium whose resistance varies as the velocity directly. This is the law, at least approximately, for very small speeds, whether the pendulum oscillate in a gas or in a liquid,—and even when the resistance is due to magneto-electric induction, as when the pendulum is a magnetic needle vibrating in presence of a conducting plate or a closed coil. A synthetical solution of this problem has already been given under Kinematics in § 68.

Analytically: if l be the length of the string, θ its deflexion from the vertical at time t, m the mass of the bob, we have evidently

$$ml\ddot{\theta}=-mg\sin\theta-\kappa\dot{\theta}.$$

The ratio κ/ml may be increased (theoretically) without limit by increasing the surface which the bob exposes, without changing its mass. But it cannot be indefinitely diminished. We will write $2k$ for it. If we assume the angle of oscillation to be small, we may write the equation in the form

$$\ddot{\theta}+2k\dot{\theta}+n^2\theta=0,$$

where $n^2=g/l$, and k is essentially positive, being greater as the resistance (whether on account of the viscosity of the medium or the large surface of the bob in proportion to its mass) is greater. A particular integral of this equation is evidently

$$\theta=\varepsilon^{pt};$$

provided

$$p^2+2kp+n^2=0,$$

or

$$p=-k\pm\sqrt{k^2-n^2}.$$

Hence there are two quite distinct cases of motion, distinguished by different *forms* of solution, depending on the relative magnitudes of k and n. These are separated from one another by the unique case in which $k=n$.

(*a*) Let $k>n$, and let $k^2-n^2=n'^2<k^2$.

Then both values of p are real and negative. Thus

$$\theta=\text{A}\varepsilon^{p_1t}+\text{B}\varepsilon^{p_2t}$$

$$=\varepsilon^{-kt}(\text{A}\varepsilon^{n't}+\text{B}\varepsilon^{-n't}).$$

If A and B have the same sign, θ diminishes, without changing sign, as t increases. But if A and B have different signs, the factor in brackets may vanish for one definite value of t, and then change sign. After that the whole reaches a maximum and then diminishes without further change of sign. Examples of these cases are furnished—(1) when the pendulum is displaced from the vertical and allowed to fall back; it then approximates asymptotically to its position of equilibrium; and (2) when it is drawn aside and flung back; in this case it may pass once through the position of equilibrium and then asymptotically return to it.

(*b*) Let $n>k$ and let $n^2-k^2=n'^2<n^2$.

Here both values of p are imaginary, and we have

$$\theta=\varepsilon^{-kt}(\text{A}\varepsilon^{+n't\sqrt{-1}}+\text{B}\varepsilon^{-n't\sqrt{-1}})$$

$$=\text{P}\varepsilon^{-kt}\cos(n't+\text{Q}).$$

This may be looked upon as a "simple harmonic motion" (§ 52), of which the amplitude diminishes in a geometric ratio with the time, the decrement depending on the resistance alone, while the period is permanently lengthened in the ratio $n : n'$. This ratio depends both upon the original period and the resistance, so that for the same medium and same bob it is different for strings of different lengths. This investigation gives an approximation to the gradual dying away (by internal friction or by imperfect elasticity, &c.) of all vibratory movements. The rate of diminution of amplitude, say of torsional vibrations of a wire, is thus a valuable indication and measure of a somewhat recondite physical quantity, which, without this method, would (at present at least) be hard to measure.

(*c*) When $n=k$, *i.e.*, in the transition case, the equation becomes

$$\ddot{\theta}+2n\dot{\theta}+n^2\theta=0;$$

whose integral is known to be

$$\theta=\varepsilon^{-nt}(\text{A}+\text{B}t)=\varepsilon^{-kt}(\text{A}+\text{B}t).$$

This, also, ultimately diminishes indefinitely as t increases; but, as in case (*a*), it may either do so continuously or after having once passed through the value zero and reached a maximum, according to the relative magnitude and the signs of A and B.

§ 139. When the path is given, the determination of the motion under given forces is, as we have seen, a mere question of integration of the equation for acceleration along the tangent. But more is required if we wish to find the normal pressure on the constraining curve. This is at once supplied by compounding the resolved part of the applied forces in the direction perpendicular to the tangent, with the additional force $m\text{V}^2/\rho$ acting *from* the centre of curvature. But, strictly speaking, all such questions require the application of Law III.

Kinetics of a Particle with Two Degrees of Freedom.

§ 140. The simplest case is that of a projectile, when gravity is supposed to be uniform and to act in parallel lines throughout the whole path, and the resistance of the air is neglected. This has been sufficiently discussed in §§ 40–42. It is merely the combination of (1) the uniformly accelerated motion of a stone let fall, with (2) a uniform velocity in a definite direction. Looked at from this point of view, it gives an interesting example of the graphic method applied in § 53 to indicate the nature of simple harmonic motion.

Projectile [...] resist[...]

§ 141. We can extend these projectile results so as to take account of the alteration of direction and of intensity

Elliptic motion of projectile.

of gravity at different points of the path, by remembering that, as shown in § 49, the path of an unresisted projectile is an ellipse, one of whose foci is at the centre of the earth. The following, among many other analogous propositions, are easily proved.

(1) The locus of the second foci of the paths of all projectiles leaving a given point with a given speed, in a vertical plane, is a circle.

(2) The direction of projection, for the greatest range on a given line passing through the point of projection, bisects the angle between the vertical and the line.

(3) Any other point on the line which can be reached at all can be reached by two different paths, and the directions of projection for these are equally inclined to the direction which gives the maximum range.

(4) If a projectile meet the line at right angles, the point which it strikes is the vertex of the other path by which it may be reached.

(5) The envelop of all possible paths in a vertical plane is an ellipse, one of whose foci is the centre of the earth, and the other the point of projection.

To prove these propositions, let E (fig. 46) be the earth's centre, P the point of projection, A the point which the projectile would reach if fired vertically upwards. With centre E, and radius EA, describe a circle in the common plane of projection. This, the circle of zero velocity, corresponds to the common directrix of the parabolic paths in the ordinary theory If F be the second focus of any path, we must have EP + PF constant, because the axis major depends on the speed, not the direction, of projection. Hence (1) the locus of F is the circle AFO, centre P. Again, since, if F be the focus of the path which meets PR in Q, we must have FQ = QS, it is obvious that the greatest range Pq is to be found by the condition Oq = qs. O is therefore the second focus of this trajectory, and therefore (2) the direction of projection for the greatest range on PR bisects the angle APR. If QF = QF′ = QS, F and F′ are the second foci of the two paths by which Q may be reached; and, as ∠ F′PO = ∠ FPO, we see the truth of (3). If Q be a point reached by the projectile when moving in a direction perpendicular to PR, we must evidently have ∠ PQF′ = ∠ PQF = ∠ SQR = ∠ EQP; *i.e.*, EQ passes through F′. When this is the case, the ellipse whose second focus is F evidently meets PR at right angles; and that whose second focus is F′ has (4) its vertex at Q. The locus of q is evidently the envelop of all the trajectories. Now

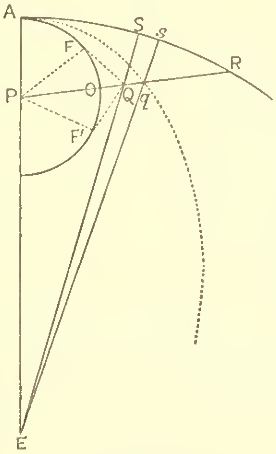


Fig. 46.

$$Pq = PO + Oq = PA + Oq ,$$
$$Eq = Es - sq = EA - Oq .$$

Hence

$$Pq + Eq = PA + AE ,$$

or (5) the envelop is an ellipse, whose foci are E and P, and which passes through A.

Planetary motion.

§ 142. One of the most important problems in this branch of our subject is that of planetary motion, which forms a good typical example of the processes to be employed in the treatment of central orbits. One or two definitions, and a general property of central orbits, must be premised.

Apse.

§ 143. *Def.* An "apse" is a point, in a central orbit, at which the path is perpendicular to the radius-vector along which the central force acts.

The length of the radius-vector is therefore, at such a point, generally a maximum or a minimum. This radius vector, drawn to an apse, is called an "apsidal line."

A central orbit is symmetrical about every apsidal line. The simplest proof of this theorem depends upon the general principle of "reversibility," which holds in all conservative systems. In fact if, at any instant, the velocity-vector of a particle, moving under the action of a conservative system of forces, be reversed, the particle will simply retrace its previous path. For if we suppose a smooth tube, in the form of the previous path, to be employed to guide it back, the speed at every point will be of the same magnitude as before. The curvature also of the path will be the same; and thus the normal component of the applied forces will balance the so-called centrifugal force,—*i.e.*, will suffice to produce the requisite curvature,—so that there will be no pressure on the tube, and it is not required. Hence since, at an apse, the velocity is perpendicular to the radius-vector, the two halves of the orbit on opposite sides of the apsidal line are similar and equal. Hence, however many apses there may be, there can be at most only two apsidal distances. For the property of symmetry about each apsidal line shows that, if there be more apses than one, the first, third, fifth, &c., must have their apsidal distances equal, as also must the second, fourth, sixth, &c. If there be one apse only, it may correspond either to a minimum or to a maximum value of the radius-vector; but, if there be more than one, they must be maxima and minima alternately.

§ 144. We now proceed to the gravitation case already promised. We will take, first, the direct problem as in § 49, where the force is assigned and the orbit is to be found.

A particle is projected from a given point in a given direction and with a given speed, and moves under the action of a central attraction varying inversely as the square of the distance; to determine the orbit. Planetary motion.

We have $P = \mu u^2$, and therefore by the last part of § 47

$$\frac{d^2u}{d\theta^2} + u - \frac{\mu}{h^2} = 0 ,$$

where h is double the constant area, or

$$\frac{d^2}{d\theta^2}\left(u - \frac{\mu}{h^2}\right) + \left(u - \frac{\mu}{h^2}\right) = 0 ,$$

the integral of which is

$$u - \frac{\mu}{h^2} = A\cos(\theta + B),$$

or, as it is usually written,

$$u = \frac{\mu}{h^2}\left\{ 1 + e\cos(\theta - \alpha)\right\} \quad . \quad . \quad . \quad . \quad . \quad (1).$$

This gives by differentiation

$$\frac{du}{d\theta} = -\frac{\mu}{h^2} e \sin(\theta - \alpha) \quad . \quad . \quad . \quad . \quad . \quad (2).$$

Let R be the distance of the point of projection from the centre, and β the angle, and V the speed, of projection; then, when $\theta = 0$,

$$u = \frac{1}{R} , \quad \cot\beta = -\left(\frac{1}{u}\frac{du}{d\theta}\right)_{\theta=0} .$$

Hence, by (1) $$\frac{h^2}{\mu R} - 1 = e\cos\alpha ,$$

and by (2) $$\frac{h^2}{\mu R}\cot\beta = -e\sin\alpha .$$

From these $$\tan\alpha = \frac{h^2\cot\beta}{\mu R - h^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3),$$

and $$e^2 = \frac{h^4}{\mu^2 R^2}\operatorname{cosec}^2\beta - \frac{2h^2}{\mu R} + 1 \quad . \quad . \quad . \quad . \quad (4),$$

But $$h^2 = V^2 R^2 \sin^2\beta ,$$

wherefore $$\tan\alpha = \frac{V^2 R \sin\beta\cos\beta}{\mu - V^2 R\sin^2\beta} \quad . \quad . \quad . \quad . \quad (3'),$$

and $$1 - e^2 = \frac{V^2R^2\sin^2\beta}{\mu}\left(\frac{2}{R} - \frac{V^2}{\mu}\right) \quad . \quad . \quad . \quad (4').$$

Now (1) is the general polar equation of a conic section, focus the pole; and, as its nature depends on the value of the excentricity e given by (4′), we see that

if $V^2 > 2\mu/R$, $e > 1$, and the orbit is an hyperbola;
if $V^2 = 2\mu/R$, $e = 1$, and the orbit is a parabola;
if $V^2 < 2\mu/R$, $e < 1$, and the orbit is an ellipse.

But the square of the speed from rest at infinity to distance R, for the law of attraction we are considering, is $2\mu/R$, and the above conditions may therefore be expressed more concisely by saying that the orbit will be an hyperbola, a parabola, or an ellipse, according as the speed of projection is greater than, equal to, or less than, the speed from infinity. Illustrations of this proposition are found in the cases of comets and of meteor swarms.

The speed of a particle moving in a circle is also often taken as the standard of comparison for estimating the velocities of bodies in their orbits. For the gravitation law of attraction the square of the speed in a circle of radius R is μ/R; and the above conditions may be expressed in another form by saying that the orbit will be an hyperbola, a parabola, or an ellipse, according as the speed of projection is greater than, equal to, or less than $\sqrt{2}$ times the speed in a circle at the same distance.

Supposing the orbit to be an ellipse, we shall obtain its major axis and latus rectum most easily by a different process of integrating the differential equation. Multiplying it by $h^2\frac{du}{d\theta}$ and integrating, we obtain

$$\frac{1}{2}h^2\left\{\left(\frac{du}{d\theta}\right)^2 + u^2\right\} = \frac{1}{2}v^2 = C + \mu u.$$

But when $u = \frac{1}{R}$, $v = V$; which gives

$$C = \frac{1}{2}V^2 - \frac{\mu}{R};$$

hence $$\frac{1}{2}h^2\left\{\left(\frac{du}{d\theta}\right)^2 + u^2\right\} = \frac{1}{2}v^2 = \frac{1}{2}V^2 - \frac{\mu}{R} + \mu u \quad . \quad . \quad (5).$$

Now to determine the apsidal distances, we must put

$$\frac{du}{d\theta} = 0;$$

and this gives us the condition

$$u^2 - \frac{2\mu}{h^2}u + \frac{2\mu}{h^2 R} - \frac{V^2}{h^2} = 0 \quad . \quad . \quad . \quad . \quad . \quad (6),$$

which is a quadratic equation whose roots are the reciprocals of the two apsidal distances. But if a be the semi-axis major, and e the excentricity, these distances are

$$a(1-e) \text{ and } a(1+e).$$

Hence, as the coefficient of the second term of (6) is the sum of the roots with their signs changed, we have

$$\frac{1}{a(1-e)} + \frac{1}{a(1+e)} = \frac{2\mu}{h^2};$$

or $$a(1-e^2) = \frac{h^2}{\mu} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7).$$

And the third term is the product of the roots, so that

$$\frac{1}{a^2(1-e^2)} = \frac{2\mu}{h^2 R} - \frac{V^2}{h^2};$$

or, by (7), $$\frac{1}{a} = \frac{2}{R} - \frac{V^2}{\mu} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8).$$

Thus $$\frac{1}{2}V^2 = \frac{\mu}{R} - \frac{\mu}{2a},$$

and therefore $$\frac{1}{2}v^2 = \frac{\mu}{r} - \frac{\mu}{2a} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9).$$

Equations (7) and (8) give the latus rectum and major axis of the orbit, and show that the major axis is independent of the direction of projection.

Equation (9) gives a useful expression for the speed at any point, and shows that the radius of the circle of zero speed is $2a$.

The time of describing any given angle is to be obtained from the formula,

$$r^2\frac{d\theta}{dt} = h = \sqrt{\{\mu a(1-e^2)\}}, \text{ by equation (7).}$$

From this, combined with the polar equation of the ellipse about the focus, we have

$$\frac{dt}{d\theta} = \frac{r^2}{\sqrt{\{\mu a(1-e^2)\}}} = \sqrt{\left(\frac{a^3(1-e^2)^3}{\mu}\right)}\frac{1}{(1+e\cos\theta)^2},$$

measuring the angle from the nearer apse.

Integrating, we find the time of describing about the focus an angle θ measured from the nearer apse, in the ellipse or hyperbola, expressed as $2/h$ of the sectorial area ASP (figure to § 147), which might have been written down from the condition of uniform moment of momentum.

In the parabola, if d be the apsidal distance, the integral becomes

$$\left[\text{since } e = 1,\ a(1-e) = d,\ a(1-e^2) = 2d\right],$$

$$t = \sqrt{\frac{2d^3}{\mu}}\left(\tan\frac{\theta}{2} + \frac{1}{3}\tan^3\frac{\theta}{2}\right).$$

From the result for the ellipse we see that the periodic time is

$$2\pi\sqrt{a^3/\mu}.$$

In the notation commonly employed for the further development of this most important question we write

$$T = 2\pi/n,$$

where n, which is called the "mean motion," is $\sqrt{\mu/a^3}$.

§ 145. By laborious calculation from an immense series of observations of the planets, and of Mars in particular, Kepler was led to enunciate the following as the kinematical laws of the planetary motions about the sun. *Kepler's laws (kinematical).*

I. The planets describe, relatively to the sun, ellipses of which the sun occupies a focus.

II. The radius vector of each planet traces out equal areas in equal times.

III. The squares of the periodic times of any two planets are as the cubes of the major axes of their orbits.

§ 146. We proceed to the *inverse* problem of § 8 (*b*), the determination of the force from the observed motions. *Consequences of Kepler's laws.*

From the second of the above laws we conclude that the planets are retained in their orbits by an attraction tending to the sun. *If the radius-vector of a particle moving in a plane describe equal areas in equal times about a point in that plane, the resultant attraction on the particle tends to that point.* For the datum is equivalent to the statement that there is no change of moment of momentum about the sun, or that the accelerations all pass through the sun viewed as a point.

From the first law it follows that the law of the intensity of the attraction is that of the inverse square of the distance.

The polar equation of an ellipse referred to its focus is

$$u = \frac{2}{l}(1 + e\cos\theta),$$

where l is the latus rectum.

Hence $$\frac{d^2u}{d\theta^2} = -\frac{2e}{l}\cos\theta,$$

and therefore the attraction to the focus requisite for the description of the ellipse is (§ 47)

$$P = h^2u^2\left(\frac{d^2u}{d\theta^2} + u\right) = \frac{2h^2}{l}u^2.$$

Hence, if the orbit be an ellipse described about a centre of attraction at the focus, the law of intensity is that of the inverse square of the distance.

From the third law it follows that the attraction of the sun (supposed fixed) which acts on unit of mass of each of the planets is the same for each planet at the same distance.

For, in the last formula in § 144, T^2 will not vary as a^3 unless μ be constant, *i.e.*, unless the strength of attraction of the sun be the same for all the planets.

We shall find afterwards that for more reasons than one Kepler's laws are only approximate, but their enunciation was sufficient to enable Newton to propound the doctrine of universal gravitation, viz., that *every particle of matter in the universe attracts every other with an attraction whose direction is that of the line joining them, and whose magnitude is as the product of the masses directly and as the square of the distance inversely*; or, according to Maxwell's formulation, *between every pair of particles there is a stress of the nature of a tension, proportional to the product of the masses of the particles divided by the square of their distance.* *Law of gravitation (physical).*

If we take into account that the sun is not absolutely fixed, then, neglecting the mutual attractions of the planets, Kepler's third law should be stated thus:—

The cubes of the major axes of the orbits are as the squares of the periodic times and the sums of the masses of the sun and the planet.

Calculation of planet's motion.

§ 147. We will now indicate, as briefly as possible, the more ordinary transformations by which the preceding formulæ are adapted (for astronomical applications) to numerical calculation.

Suppose APA′ (fig. 47) to be an elliptic orbit described about a centre of attraction in the focus S. Also suppose P to be the position of the particle at any time t. Draw PM perpendicular to the major axis ACA′, and produce it to cut the auxiliary circle in the point Q. Let C be the common centre of the curves. Join CQ.

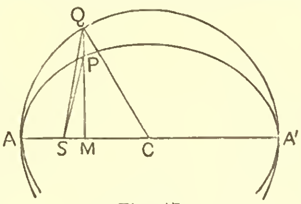


Fig. 47.

When the moving particle is at A, the nearest point of the orbit to S, it is said to be in "perihelion."

The angle ASP, or the excess of the particle's longitude over that of the perihelion, is called the "true anomaly." Let us denote it by θ.

The angle ACQ is called the "excentric anomaly," and is generally denoted by u. And, if $2\pi/n$ be the time of a complete revolution, nt is the circular measure of an imaginary angle called the "mean anomaly;" it would evidently be the true anomaly if the particle's angular velocity about S were constant.

It is easy from known properties of the ellipse to deduce the following relations between the mean and excentric, and also between the true and excentric, anomalies:—

$$nt = u - e\sin u.$$

$$\tan\frac{u}{2} = \sqrt{\left(\frac{1-e}{1+e}\right)}\tan\frac{\theta}{2}.$$

By far the most important problem is to find the values of θ and r as functions of t, so that the direction and length of a planet's radius-vector may be determined for any given time. This generally goes by the name of Kepler's Problem.

Before indicating the systematic development of u, r, and θ in terms of t from our equations, it may be useful to remark that, if e be so small that higher terms than its square may be neglected, we may easily obtain developments correct to the first three terms. Thus

$$\begin{aligned} u &= nt + e\sin u, \\ &= nt + e\sin(nt + e\sin nt) \text{ nearly}, \\ &= nt + e\sin nt + \tfrac{1}{2}e^2\sin 2nt. \end{aligned}$$

Also
$$\begin{aligned} \frac{r}{a} &= 1 - e\cos u, \\ &= 1 - e\cos(nt + e\sin nt), \\ &= 1 - e\cos nt + \tfrac{1}{2}e^2(1 - \cos 2nt). \end{aligned}$$

And
$$r^2\frac{d\theta}{dt} = \sqrt{\left\{\mu a(1-e^2)\right\}},$$

which may be written
$$\frac{a^2(1-e^2)^2}{(1+e\cos\theta)^2}\frac{d\theta}{dt} = na^2(1-e^2)^{\frac{1}{2}},$$

or
$$(1-e^2)^{\frac{3}{2}}(1+e\cos\theta)^{-2}\frac{d\theta}{dt} = n.$$

Keeping powers of e lower than the third,
$$\left(1 - 2e\cos\theta + \tfrac{3}{2}e^2\cos 2\theta\right)\frac{d\theta}{dt} = n,$$

or
$$nt = \theta - 2e\sin\theta + \tfrac{3}{4}e^2\sin 2\theta;$$

whence
$$\begin{aligned} \theta &= nt + 2e\sin\theta - \tfrac{3}{4}e^2\sin 2\theta, \\ &= nt + 2e\sin(nt + 2e\sin nt) - \tfrac{3}{4}e^2\sin 2nt, \\ &= nt + 2e\sin nt + 4e^2\cos nt\sin nt - \tfrac{3}{4}e^2\sin 2nt, \\ &= nt + 2e\sin nt + \tfrac{5}{4}e^2\sin 2nt. \end{aligned}$$

Kepler's problem.

KEPLER'S PROBLEM.—*To find r and θ as functions of t from the equations*

$$r = a(1 - e\cos u) \quad . \quad . \quad . \quad . \quad . \quad . \quad (1);$$

$$\tan\frac{\theta}{2} = \sqrt{\frac{1+e}{1-e}}\tan\frac{u}{2} \quad . \quad . \quad . \quad . \quad . \quad (2),$$

$$nt = u - e\sin u \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

These equations evidently give r, θ, and t directly for any assigned value of u, but this is of little value in practice. The method of solution which is commonly adopted is that of Lagrange, and the general principle of it is this:—

We can develop θ from equation (2) in a series ascending by powers of a small quantity, a function of e, the coefficients of these powers involving u and the sines of multiples of u. Now by Lagrange's theorem we may from equation (3) express u, $1 - e\cos u$, $\sin u$, $\sin 2u$, &c., in series ascending by powers of e, whose coefficients are sines or cosines of multiples of nt. Hence, by substituting these values in equation (1) and in the development of (2), we have r and θ expressed in series whose terms rapidly decrease, and whose coefficients are sines or cosines of multiples of nt. This is the complete practical solution of the problem. But we must refer the reader to special treatises for the full development of this subject. Compare § 52.

Stability of circular orbit.

§ 148. We may take an opportunity here of giving a sketch of a particular case of the important question of "kinetic stability." The general treatment of this subject is entirely beyond our limits. But we may investigate its conditions, in the case of a central orbit naturally circular, by a very slight modification of our equations.

Whatever be the law of central force, provided it depend on the distance alone, we can write the acceleration due to it as

$$\mu u^2 f(u),$$

where u is the now reciprocal of the radius-vector, as in § 144. The kinematics of the motion is then entirely summed up in the equations

$$\frac{d^2u}{d\theta^2} + u = \frac{\mu}{h^2}f(u), \text{ and } \frac{d\theta}{dt} = hu^2.$$

If $1/a$ be the radius of the circle, the first equation becomes simply

$$a = \frac{\mu}{h^2}f(a).$$

Now let a slight disturbance be given to the motion, such that h is unaltered, but that u becomes $a + x$. Then we have

$$\frac{d^2x}{d\theta^2} + a + x = \frac{\mu}{h^2}f(a+x).$$

Expanding to first powers of x only, and thereby assuming that x is always exceedingly small, we have

$$\frac{d^2x}{d\theta^2} + x\left(1 - \frac{\mu}{h^2}f'(a)\right) = 0,$$

the terms independent of x vanishing by the condition for a circular orbit. By eliminating the ratio μ/h^2 we have

$$\frac{d^2x}{d\theta^2} + x\left(1 - \frac{af'(a)}{f(a)}\right) = 0.$$

To secure stability, x must not be capable of increasing indefinitely. This leads to the result that the multiplier of x in the above equation must be positive; *i.e.*,

$$1 - \frac{af'(a)}{f(a)} > 0.$$

For, if the multiplier were negative, the value of x would consist of two real exponential terms, one of which would increase indefinitely with the angle θ, and would disappear from the value of x under special conditions only.

If the multiplier were zero, x would be a linear function of θ. Hence, in the only case we need consider, we have

$$x = A\cos\left(\theta\sqrt{1 - \frac{af'(a)}{f(a)}} + B\right).$$

The radius-vector is therefore a maximum and minimum (*i.e.*, apses occur) alternately as the angle θ increases by successive increments each equal to

$$\frac{\pi}{\sqrt{1 - \frac{af'(a)}{f(a)}}}.$$

Suppose the force to vary as the inverse nth power of the distance. Here $f(a) \propto a^{n-2}$, and we have $1 - \frac{af'(a)}{f(a)} = 1 - (n-2) = 3 - n$. Thus n must be less than 3; *i.e.*, a circular orbit, with the centre of force in the centre, is essentially unstable if the force vary as the inverse third, or any higher inverse power of the distance.

If $n = 2$, which is the gravitation case, the apsidal angle is evidently π.

Newton's revolving orbit.

§ 149. A very curious result, due to Newton, may be indicated here, viz., that, if any central orbit be made to revolve in its own plane with angular velocity proportional at each instant to that of the radius-vector in the fixed orbit, it will still be a central orbit; and the additional force required will be inversely as the cube of the radius-vector.

Generally, in a central orbit,

$$\ddot{r} - r\dot{\theta}^2 = P, \qquad r^2\dot{\theta} = h.$$

But suppose θ to become $c\theta_1$, where c is a constant, and we have

$$\theta = c\theta_1,$$

which is Newton's hypothesis. The above equations become

$$\ddot{r} - r\dot{\theta}_1^2 = P + (c^2-1)r\dot{\theta}_1^2, \quad r^2c\dot{\theta}_1 = h;$$

or, as they may be written,

$$\ddot{r} - r\dot{\theta}_1^2 = P + (c^2-1)h_1^2/r^3, \quad r^2\dot{\theta}_1 = h_1.$$

From these the proposition is obvious.

Other examples of central orbits will be given when we discuss general principles, such as "least action" and "varying action."

Special Problem. The Brachistochrone.

Brachistochrone. § 150. A celebrated problem in the history of dynamics is that of the "curve of swiftest descent," as it was called:—*Two points being given, which are neither in a vertical nor in a horizontal line, to find the curve joining them down which a particle sliding under gravity, and starting from rest at the higher, will reach the other in the least possible time.*

The curve must evidently lie in the vertical plane passing through the points. For suppose it not to lie in that plane, project it orthogonally on the plane, and call corresponding elements of the curve and its projection σ and σ'. Then if a particle slide down the projected curve its speed at σ' will be the same as the speed in the other at σ. But σ is *never less* than σ', and is generally greater. Hence the time through σ' is generally less than that through σ, and *never greater.* That is, the whole time of falling through the projected curve is less than that through the curve itself. Or the required curve lies in the vertical plane through the points.

Also it is easy to see that, if the time of descent through the entire curve is a minimum, that through any portion of the curve is less than if that portion were changed into any other curve.

Conditions for a maximum. And it is obvious that, *between any two contiguous equal values of a continuously varying quantity, a maximum or minimum must lie.* [This principle, though excessively simple (witness its application to the barometer or thermometer), is of very great power, and often enables us to solve problems of maxima and minima, such as require, in analysis, not merely the processes of the differential calculus but those of the calculus of variations. The present is a good example.]

Let, then, PQ, QR and PQ′, Q′R (fig. 48) be two pairs of indefinitely small sides of polygons such that the time of descending through either pair, starting from P with a given speed, may be equal. Let QQ′ be horizontal, and indefinitely small compared with PQ and QR. The brachistochrone must lie between these paths, and must possess any property which they possess in common. Hence if v be the speed down PQ (supposed uniform) and v' that down QR, drawing Qm, $Q'n$ perpendicular to RQ′, PQ, we must have

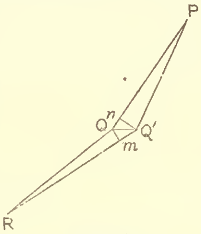


Fig. 48.

$$\frac{Qn}{v} = \frac{Q'm}{v'}.$$

Now if θ be the inclination of PQ to the horizon, θ' that of QR, $Qn = QQ'\cos\theta$, $Q'm = QQ'\cos\theta'$. Hence the above equation becomes

$$\frac{\cos\theta}{v} = \frac{\cos\theta'}{v'}.$$

This is true for any two consecutive elements of the required curve; and therefore throughout the curve

$$v \propto \cos\theta.$$

But $v^2 \propto$ vertical distance fallen through (§ 28). Hence the curve required is such that the cosine of the angle it makes with the horizontal line through the point of departure varies as the square root of the distance from that line,—which is easily seen to be a property of the cycloid, if we remember that the tangent to that curve is parallel to the corresponding chord of its generating circle. For in fig. 45, § 137,

$$\cos BP'M = \cos BAP' = \frac{AP'}{AB} = \sqrt{\frac{AM}{AB}} \propto \sqrt{AM}.$$

The brachistochrone then, under gravity, is an inverted cycloid whose cusp is at the point from which the particle descends.

§ 151. Whatever be the impressed forces, reasoning similar to that in last section would show that the osculating plane of the brachistochrone always contains the resultant force, and that

$$v'\cos\theta = v\cos\theta',$$

where θ is now the complement of the angle between the curve and the resultant of the impressed forces.

Let that resultant $= F$, and let the element $PQ = \delta s$, and $\theta' = \theta + \delta\theta$. Then

$$v'^2 - v^2 = 2F\delta s\sin\theta,$$

or

$$v\delta v = F\delta s\sin\theta.$$

But $v \propto \cos\theta$; which gives

$$\frac{\delta v}{v} = -\frac{\sin\theta}{\cos\theta}\delta\theta.$$

Hence

$$v^2\Big/\frac{\delta s}{\delta\theta} = -F\cos\theta.$$

But in the limit $\frac{\delta s}{\delta\theta} = \rho$, the radius of absolute curvature at Q; and $F\cos\theta$ is the normal component of the impressed force. Hence we obtain the result that, in any brachistochrone, the pressure on the curve is double of that due to the force acting.

§ 152. Now for the unconstrained path from P to R we have $\int v ds$ a minimum (§ 202). Hence in the same way as before, ϕ being the angle corresponding to θ, $v\cos\phi = v'\cos\phi'$ from element to element, and therefore throughout the curve, if the direction of the force be constant. Now, if the velocities in the unconstrained and brachistochrone paths be equal at any equipotential surface, they will be equal at every other. Hence, taking the angles for any equipotential surface,

$$\cos\theta\cos\phi = \text{constant}.$$

As an example, suppose a parabola with its vertex upwards to have for directrix the base of an inverted cycloid; these curves evidently satisfy the above condition, the one being the free path, the other the brachistochrone, for gravity, and the velocities being in each due to the same horizontal line. And it is seen at once that the product of the cosines of the angles which they make with any horizontal straight line which cuts both is a constant whose magnitude depends on those of the cycloid and parabola, its value being $\sqrt{l/4a}$, where l is the latus rectum of the parabola, and a the diameter of the generating circle of the cycloid.

Kinetics of a Particle Generally.

§ 153. Here we must content ourselves with a few special cases, which will be varied as much as possible. General examples.

A unit particle moves on a smooth curve, under the action of any system of forces; find the motion.

All we know directly about the pressure R on the curve is that it is perpendicular to the tangent line at any point.

Resolve then the given forces acting upon the particle into three,—one, T, along the tangent, which in all cases in nature will be a function of x, y, z and therefore of s; another, N, in the line of intersection of the normal and osculating planes (or radius of absolute curvature); and the third, P, perpendicular to the osculating plane.

Let the resolved parts of R in the directions of N and P be R_1, R_2. Now the acceleration of a point moving in any manner is compounded of two accelerations, one $\frac{d^2s}{dt^2}$ or $v\frac{dv}{ds}$ along the tangent to the path, and the other $\frac{v^2}{\rho}$ towards the centre of absolute curvature, the acceleration perpendicular to the osculating plane being zero; and therefore

$$\frac{d^2s}{dt^2} = T \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

This equation, together with the two equations of the curve, is sufficient to determine the motion completely.

Also $$\frac{v^2}{\rho}=R_1+N \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

R_1 and N being considered positive when acting towards the centre of absolute curvature; this equation determines R_1.

Now R_2 is the reaction which prevents P's withdrawing the particle from the osculating plane; and therefore

$$R_2=-P \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

(2) and (3) give the resolved parts of the pressure on the curve.

Also $R=\sqrt{(R_1^2+R_2^2)}$, and its direction makes an angle $=\tan^{-1}(R_2/R_1)$ with the osculating plane.

If the result of the investigation should show that at any time R could vanish, the particle must be treated as free until the equations of its free motion show that it is again in contact with the curve.

Particle on a smooth surface.

A particle moves, under given forces, on a given smooth surface; to determine the motion, and the pressure on the surface.

Let $$F(x, y, z)=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

be the equation of the surface, R the reaction, acting in the normal to the surface, which is the only effect of the constraint. Then, if λ, μ, ν be its direction cosines, we know that

$$\lambda=\frac{\left(\frac{dF}{dx}\right)}{\sqrt{\left\{\left(\frac{dF}{dx}\right)^2+\left(\frac{dF}{dy}\right)^2+\left(\frac{dF}{dz}\right)^2\right\}}} \quad . \quad . \quad . \quad (2),$$

with similar expressions for μ and ν, the differential coefficients being partial.

If X, Y, Z be the applied forces on unit of mass, our equations of motion are, evidently,

$$\left.\begin{aligned}\ddot{x}&=X+R\lambda\\ \ddot{y}&=Y+R\mu\\ \ddot{z}&=Z+R\nu\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Multiplying equations (3) respectively by $\dot{x}$, $\dot{y}$, $\dot{z}$, and adding, we obtain

$$\dot{x}\ddot{x}+\dot{y}\ddot{y}+\dot{z}\ddot{z}=v\dot{v}=X\dot{x}+Y\dot{y}+Z\dot{z} \quad . \quad . \quad . \quad . \quad (4).$$

R disappears from this equation, for its coefficient is

$$\lambda\dot{x}+\mu\dot{y}+\nu\dot{z}$$

and vanishes, because the line whose direction cosines are proportional to $\dot{x}$, &c., being the tangent to the path, is perpendicular to the normal to the surface.

If we suppose X, Y, Z to be a conservative system of forces, the integral of (4) will be of the form

$$\tfrac{1}{2}v^2=\phi(x, y, z)+C \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5),$$

and the velocity at any point will depend only on the initial circumstances of projection, and not on the form of the path pursued.

To find R, resolve along the normal, then

$$v^2/\rho=X\lambda+Y\mu+Z\nu+R\,,$$

which gives the reaction of the surface; ρ being the radius of curvature of the normal section of the surface through the tangent to the path, and the mass of the particle being taken as unity.

To find the curve which the particle describes on the surface.

For this purpose we must eliminate R from equations (3). By this process we obtain

$$\frac{\ddot{x}-X}{\lambda}=\frac{\ddot{y}-Y}{\mu}=\frac{\ddot{z}-Z}{\nu} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6),$$

two equations, between which if t be eliminated, the result is the differential equation of a second surface intersecting the first in the curve described.

If there be no applied forces, or if the component of the applied force in the tangent plane coincide with the direction of motion of the particle, then the osculating plane of the path of the particle, which contains the resultant of R and the applied force, will be a normal plane, and therefore the path will be a geodesic on the surface.

Thus a particle under no forces on a smooth (or rough) surface will describe a geodesic.

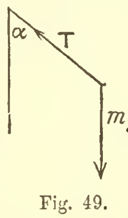


Fig. 49.

Conical pendulum.

§ 154. An excellent and important example is furnished by the simple pendulum, when its vibrations are not confined to one vertical plane. When the bob moves in a horizontal plane, the arrangement is called a "conical" pendulum, and it is a very simple matter, as follows, to find the motion. For the vertical component of the tension of the string must support the weight of the bob; *i.e.*,

$$T\cos\alpha=mg\,,$$

where α is the inclination of the string to the vertical. Also the horizontal component of the tension must supply the force mV^2/R (§ 49) requisite for the production of the curvature of the path, *i.e.*,

$$T\sin\alpha=m\frac{V^2}{l\sin\alpha}\,.$$

Eliminating m/T from these equations, we have

$$\frac{\cos\alpha}{\sin^2\alpha}=\frac{gl}{V^2}\,.$$

But, if τ be the time of revolution of the bob,

$$V\tau=2\pi l\sin\alpha\,.$$

Hence $$\frac{\cos\alpha}{\tau^2}=\frac{gl}{4\pi^2l^2}\,,$$

or $$\tau=2\pi\sqrt{\frac{l\cos\alpha}{g}}\,;$$

i.e., the conical pendulum revolves in the period of the small vibrations of a simple pendulum whose length is the vertical component of that of the conical pendulum (§ 134).

To carry the investigation to cases in which the pendulum describes a tortuous curve, we require (except for approximate results) the use of elliptic functions. We thus obtain, among others, the following results:—

The motion will be comprised between two horizontal circles. Let the depths of these circles below the centre be $b+c$ and $b-c$; then the vertical motion of the bob of the pendulum will be the same as that of a point on a simple pendulum of length l^2/c performing complete revolutions in the same periodic time as the spherical pendulum.

But for one of the most important applications the deflexion from the vertical is always very small, and it is easy to obtain a sufficiently accurate working approximation without the use of elliptic functions. If we put p and q for the semidiameters of the small elliptic orbit which will then be described by the pendulum bob, we find for the apsidal angle

$$\frac{\pi}{2}\left(1+\frac{3pq}{8a^2}+\ .\ .\ .\ \right).$$

Hence, when a pendulum is slightly disturbed in any way, the motion is to a first approximation elliptic as in § 50. But the second approximation shows that this ellipse rotates in its own plane, and in the same sense as that in which it is described, with an angular velocity proportional to its area. Hence the necessity for extreme care, in making Foucault's experiment (presently to be described), lest the path should even slightly deviate from a vertical plane.

Blackburn's pendulum.

§ 155. Another very important and useful example is furnished by Blackburn's pendulum, which is simply a pellet supported by three threads or fine wires knotted together at one point C (fig. 50). The two other ends of two of them are attached to fixed points A and B, and the third supports the pellet P. The motion of P is virtually executed on a smooth surface, whose principal curvatures near the lowest point are 1/CP in the plane of the three threads, and 1/PE in the plane perpendicular to them,—E being the intersection of the vertical through C with the line AB. Hence for small disturbances of this system, P has a simple harmonic motion in the plane of the paper whose period is $2\pi\sqrt{CP/g}$, and another at right angles to it, with period $2\pi\sqrt{PE/g}$. The amplitudes of these motions are arbitrary, and, with the difference of phase, depend entirely on the initial disturbance. Thus we have a very simple mechanical means of producing the combinations treated in § 63; for we have only to make

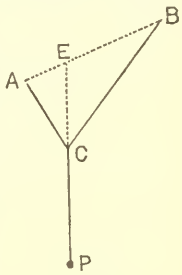


Fig. 50.

$$PE:PC::\omega^2:\omega'^2,$$

and give the bob its proper initial motion.

§ 156. When CE is very small compared with CP, we have a realization of the case of § 61, in which the orbit is (at any instant) an ellipse, but in which the ellipse gradually changes its form and position, so as to be always inscribed in a definite rectangle. This experimental arrangement is exceedingly instructive. To avoid as far as may be the effects of resistance of the air, the vibrations should be slow, *i.e.*, the wires should be as long as possible. The bob should be a ball of lead, containing a tube full of ink which slowly escapes from a fine orifice at its lower end, so as to make a permanent record of the path on a sheet of paper placed below the plane of motion of the bob, but parallel and very close to it. Or, the bob may be furnished with a spike at its lower end, from which induction sparks may be taken so as to pierce a sheet of paper laid on a copper plate below it.

By mere alterations of the point of suspension A, the ratio of ω, ω′ may be varied at pleasure, provided that AC and BC are long enough compared with CP.

Lissajoux's tuning-forks.

§ 157. Lissajoux produced similar curves by attaching plane mirrors to the legs of tuning-forks, and allowing a ray of light, after successive reflexions from two such mirrors, to fall on a screen. But it seems to have been first pointed out much earlier by Sang, and afterwards developed by Wheatstone, that the same result is obtained by fixing firmly one end of a steel rod, and setting the free end in vibration. There are two planes of greatest and least flexural rigidity (§ 274) in all wires, however carefully drawn. These are at right angles to one another; and the motion of the free end of the wire when slightly disturbed is therefore precisely that of the bob of the Blackburn pendulum. Another interesting mode of producing the same result is by causing a ray of sunlight to be reflected in succession from four mirrors, all attached, nearly at right angles, to parallel axes. One pair is made to rotate, the two in opposite directions, with one angular velocity. A ray reflected in succession from these is (§ 65) made to oscillate according to the simple harmonic law, in a plane which can be varied at pleasure by altering the relative position of the normals to the two mirrors. The other pair of mirrors supplies the other simple harmonic motion, also in any desired plane.

Foucault pendulum.

§ 158. We must next consider the effect of the earth's rotation upon the motion of a simple pendulum. Strange to say it was left for Foucault to point out, in February 1851, that the plane of vibration of a simple pendulum suspended at either pole would *appear* to turn through four right angles in twenty-four hours,—the plane, in fact, remaining constant in position while objects beneath the pendulum were carried round by the diurnal rotation. At the equator, it was pretty obvious that no such effect would occur, at least if the original plane of vibration was east and west. By some process, of which he gives no account, Foucault arrived at the result that the plane of oscillation must, in any latitude, appear to make a complete revolution in $24^h \times$ cosec latitude. This curious result has been amply verified by experiment.

The equations of motion of the pendulum, referred to rectangular axes fixed in direction in space and drawn from the earth's centre, the polar axis being that of z, are obviously

$$m\frac{d^2x}{dt^2} = -\mathrm{T}\frac{x-a}{l} + m\mathrm{X},$$

with similar expressions in y and z (a, b, c being the coordinates of the point of suspension, T the tension, l the length of the string, and X, Y, Z the components of gravity).

The equations of motion referred to a new set of axes parallel to the former, but drawn through the point of suspension, are

$$\left.\begin{array}{c} m\dfrac{d^2(x-a)}{dt^2} = -\mathrm{T}\dfrac{x-a}{l} + m\left(\mathrm{X} - \dfrac{d^2a}{dt^2}\right) \\ \text{\&c.} = \text{\&c.} \end{array}\right\} \quad . \quad . \quad . \quad (1).$$

Let us now refer the motion to axes turning with the earth, but drawn from the point of suspension. If the axis of ξ be drawn vertically, and the axes of η, ζ respectively southwards and eastwards; and if ωt be the angle at time t between the planes of xz and $\xi\eta$, λ being the co-latitude of the point of suspension, we have (assuming that ξ intersects z)

$$\cos x\xi = \sin\lambda\cos\omega t,$$
$$\cos y\xi = \sin\lambda\sin\omega t,$$
$$\cos z\xi = \cos\lambda, \text{ \&c.}$$

By means of these expressions we can at once find the values of $x-a$, $y-b$, $z-c$ in terms of ξ, η, ζ, t, as follows:

$$x - a = \xi\sin\lambda\cos\omega t + \eta\cos\lambda\cos\omega t - \zeta\sin\omega t,$$
$$y - b = \xi\sin\lambda\sin\omega t + \eta\cos\lambda\sin\omega t + \zeta\cos\omega t,$$
$$z - c = \xi\cos\lambda \qquad - \eta\sin\lambda.$$

Let γ be the acceleration due to the attraction of gravity alone, and ν the angle (nearly equal to λ) which its direction makes with the polar axis. [We have above in effect assumed that its direction lies in the plane of $z\xi$, as we have assumed that the axis of ξ intersects the polar axis, while we know that the centrifugal force lies in their common plane.] Let r be the distance of the point of suspension from the earth's centre, μ the angle its direction makes with the polar axis. Then

$$a = r\sin\mu\cos\omega t, \quad b = r\sin\mu\sin\omega t, \quad c = r\cos\mu.$$

With these data we transform equations (1) from x, y, z to ξ, η, ζ. The equations immediately obtained are inconveniently long for our columns. But they are easily simplified as follows.

We contemplate small vibrations only; so we may treat ξ as being practically equal to $-l$, and omit its differential coefficients. We also omit powers and products of η, ζ, and all terms in ω^2, except those in which it is multiplied by a large quantity. For it is known that the centrifugal force at the equator is about 1/289th of gravity, or that approximately

$$r\omega^2 = g/289.$$

With these considerations, and the condition that to the degree of approximation desired we have $\mathrm{T} = mg$, we still further simplify our equations. We are led to recognize that $\gamma\cos\nu = g\cos\lambda$; and thus we have finally

$$\left.\begin{array}{l} \dfrac{d^2\eta}{dt^2} - 2\omega\cos\lambda\dfrac{d\zeta}{dt} + \dfrac{g}{l}\eta = 0 \\ \dfrac{d^2\zeta}{dt^2} + 2\omega\cos\lambda\dfrac{d\eta}{dt} + \dfrac{g}{l}\zeta = 0 \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad (2).$$

These are the equations of the motion of the bob, referred to a horizontal plane fixed to the earth. The middle terms obviously depend upon the earth's rotation.

To interpret equations (2) it is convenient to employ a second change of coordinates—to refer the motion to axes revolving uniformly in the plane of η, ζ, with angular velocity Ω. If $\mathfrak{y}$, $\mathfrak{z}$ be the coordinates referred to the new axes, we have by analytical geometry

$$\eta = \mathfrak{y}\cos\Omega t - \mathfrak{z}\sin\Omega t, \quad \zeta = \mathfrak{y}\sin\Omega t + \mathfrak{z}\cos\Omega t,$$

the substitution of which in (2) leads to the equations

$$\frac{d^2\mathfrak{y}}{dt^2} + \frac{g\mathfrak{y}}{l} = 0, \qquad \frac{d^2\mathfrak{z}}{dt^2} + \frac{g\mathfrak{z}}{l} = 0 \quad . \quad . \quad . \quad . \quad . \quad (3),$$

provided we take $\qquad \Omega = -\omega\cos\lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4),$

and omit as before terms of the order ω^2.

(4) shows that the new axes rotate, in the *opposite* direction to that of the earth, with the component of the earth's angular velocity about the vertical at the place. And, in the plane so revolving, we see by (3) that the bob of the pendulum describes an approximately elliptic orbit, of which a straight line is a particular case.

A *circular* path being obviously possible, let us assume as particular integrals of (2)

$$\eta = c\cos(pt + a), \quad \zeta = c\sin(pt + a).$$

The substitution of these values gives the same result

$$p^2 + 2\omega p\cos\lambda - g/l = 0$$

in each of equations (2).

Put $g/l = n^2$, then the values of p are, to the degree of approximation above employed, $\pm n - \omega\cos\lambda$, so that the (apparent) angular velocity of a conical pendulum is increased or diminished by $\omega\cos\lambda$ according as its direction of rotation is negative or positive.

§ 159. The preceding problem is a particular case of the following general one. *To find the motion of a particle subjected to the action of given forces and under varying constraint.* It would lead us to details incompatible with our limits to enter upon a full discussion of so wide a question, but we give one or two simple and useful cases to show the commoner forms of procedure.

Varying constraint.

A particle under any forces, and resting on a smooth horizontal plane, is attached by an inextensible string to a point which moves *in a given manner in that plane; to determine the motion of the particle.*

Let x, y, $\bar{x}$, $\bar{y}$ be the coordinates, at time t, of the particle and point, a the length of the string, R the tension of the string, and m the mass of the particle.

For the motion of the particle we have

$$\left.\begin{aligned} m\frac{d^2x}{dt^2} &= mX - R\frac{x-\bar{x}}{a} \\ m\frac{d^2y}{dt^2} &= mY - R\frac{y-\bar{y}}{a} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

with the condition $(x-\bar{x})^2+(y-\bar{y})^2=a^2$.

Now $\bar{x}$, $\bar{y}$ are given functions of t. Take from both sides of the equations (1) the quantities $m\dfrac{d^2\bar{x}}{dt^2}$, $m\dfrac{d^2\bar{y}}{dt^2}$, respectively, and we have the equations of *relative* motion

$$\left.\begin{aligned} m\frac{d^2(x-\bar{x})}{dt^2} &= mX - R\frac{x-\bar{x}}{a} - m\frac{d^2\bar{x}}{dt^2} \\ m\frac{d^2(y-\bar{y})}{dt^2} &= mY - R\frac{y-\bar{y}}{a} - m\frac{d^2\bar{y}}{dt^2} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (2).$$

These are precisely the equations we should have had if the point had been fixed, and in addition to the forces X, Y, and R acting on the particle, we had applied, reversed in direction, the accelerations of the point's motion with the mass as a factor. It is evident that the same theorem will hold in three dimensions. The accelerations $\dfrac{d^2\bar{x}}{dt^2}$, $\dfrac{d^2\bar{y}}{dt^2}$ are known as functions of t, and therefore the equations of relative motion are completely determined.

Let there be no impressed forces, and suppose first that the point moves with constant velocity in a straight line.

Here $\dfrac{d\bar{x}}{dt}$, $\dfrac{d\bar{y}}{dt}$ are constant, and therefore no terms are introduced in the equations of motion.

Again, *suppose the point's motion to be rectilinear, but uniformly accelerated.*

The relative motion will evidently be that of a simple pendulum from side to side of the point's line of motion. In certain cases, when the angular velocity exceeds a certain limit, we shall have the string occasionally untended; and this will give rise to an impact when it is again tended. While the string is untended the particle moves, of course, in a straight line.

Suppose the point to move, with constant angular velocity ω, in a circle whose radius is r and centre origin.

Here, supposing the point to start from the axis of x,

$$\bar{x}=r\cos\omega t, \quad \bar{y}=r\sin\omega t.$$

Hence the equations of motion are, since

$$\frac{d^2\bar{x}}{dt^2}=-\omega^2\bar{x}, \quad \frac{d^2\bar{y}}{dt^2}=-\omega^2\bar{y},$$

$$\left.\begin{aligned} \frac{d^2(x-\bar{x})}{dt^2} &= -R\frac{x-\bar{x}}{a}+\omega^2\bar{x}, \\ \frac{d^2(y-\bar{y})}{dt^2} &= -R\frac{y-\bar{y}}{a}+\omega^2\bar{y}, \\ (x-\bar{x})^2&+(y-\bar{y})^2=a^2. \end{aligned}\right\}$$

Whence
$$(x-\bar{x})\frac{d^2(y-\bar{y})}{dt^2}-(y-\bar{y})\frac{d^2(x-\bar{x})}{dt^2}$$
$$=\omega^2\left\{(x-\bar{x})\bar{y}-(y-\bar{y})\bar{x}\right\};$$

or, in polar coordinates, for the relative motion,

$$\frac{d}{dt}\left(a^2\frac{d\theta}{dt}\right)=-\omega^2ar\sin(\theta-\omega t),$$

or
$$\frac{d^2(\theta-\omega t)}{dt^2}=-\omega^2\frac{r}{a}\sin(\theta-\omega t).$$

Now $\theta-\omega t$ is the inclination of the string to the radius passing through the point; call it ϕ, and we have

$$\frac{d^2\phi}{dt^2}=-\omega^2\frac{r}{a}\sin\phi,$$

the equation of motion of a simple pendulum whose length is $\dfrac{ga}{r\omega^2}$.

The particle therefore moves, with reference to the uniformly revolving radius of the circle described by the point, just as a simple pendulum with reference to the vertical.

A particle moves in a smooth straight tube which revolves with constant angular velocity round a vertical axis to which it is perpendicular; to determine the motion.

Here, referring the particle to polar coordinates in the plane of motion of the tube, we have $\dot{\theta}=\text{constant}=\omega$, $P=0$ (§ 47), and thus for the acceleration along the tube

$$\ddot{r}-r\omega^2=0;$$

whence
$$r=A\varepsilon^{\omega t}+B\varepsilon^{-\omega t}.$$

Suppose the motion to commence at time $t=0$ by the cutting of a string, length a, attaching the particle to the axis. The velocity of the particle at that instant along the tube is zero. Hence at $t=0$

$$r=a=A+B,$$
$$\dot{r}=0=A-B;$$

so that $A=B=\frac{1}{2}a$, and $r=\frac{1}{2}a(\varepsilon^{\omega t}+\varepsilon^{-\omega t})$.

In fig. 51 let OM be the initial position of the tube and A that of the particle, and let OL and Q be the tube and particle at time t. Then $OA=a$, arc $AP=a\omega t$, $OQ=r$, and we have

$$OQ=\tfrac{1}{2}OA\left(\varepsilon^{\frac{\text{arc AP}}{\text{OA}}}+\varepsilon^{-\frac{\text{arc AP}}{\text{OA}}}\right).$$

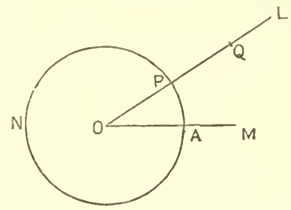


Fig. 51.

From this we see that OQ and the arc AP are corresponding values of the ordinate and abscissa of a catenary whose parameter is OA. Here the vertical pressure on the tube is equal to the weight of the particle, while the horizontal pressure is

$$-\frac{m}{r}\frac{d}{dt}(r^2\dot{\theta})=-2m\omega\dot{r}=-m\omega^2a(\varepsilon^{\omega t}-\varepsilon^{-\omega t}).$$

From this equation, combined with the value of r, we easily deduce for the horizontal pressure the value

$$2m\omega^2\sqrt{(r^2-a^2)},$$

and it is therefore proportional at any instant to the tangent drawn from Q to the circle APN.

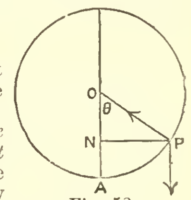


Fig. 52.

Let the tube be in the form of a circle turning with constant angular velocity about a vertical diameter. Let AO (fig. 52) be the axis, P the position of the particle at any time. Let $POA=\theta$ denote the particle's position, and R the pressure on the tube in the direction of OP.

We have
$$a\frac{d^2\cos\theta}{dt^2}=g-R\cos\theta,$$
$$a\frac{d^2\sin\theta}{dt^2}-\omega^2a\sin\theta=-R\sin\theta.$$

Eliminating R,

$$a\frac{d^2\theta}{dt^2}-a\omega^2\sin\theta\cos\theta=-g\sin\theta \quad . \quad . \quad . \quad . \quad (1).$$

The position of equilibrium will therefore be given by

$$\sin\theta=0; \text{ or by } \theta=\gamma, \text{ where } \cos\gamma=\frac{g}{a\omega^2}.$$

Integrating (1),

$$\left(\frac{d\theta}{dt}\right)^2=C+2\omega^2\cos\gamma\cos\theta-\omega^2\cos^2\theta \quad . \quad . \quad . \quad (2).$$

Suppose the particle to pass through the lowest point with velocity $a\omega_1$, we have

$$\left(\frac{d\theta}{dt}\right)^2=\omega_1^2-2\omega^2\cos\gamma(1-\cos\theta)+\omega^2\sin^2\theta$$
$$=\omega^2\left\{(1-\cos\gamma)^2+\frac{\omega_1^2}{\omega^2}-(\cos\theta-\cos\gamma)^2\right\},$$

and $\dfrac{d\theta}{dt}$ can never vanish if $\dfrac{\omega_1^2}{\omega^2}>4\cos\gamma$, or $\omega_1^2>\dfrac{4g}{a}$, that is, if the velocity at the lowest point be greater than that due to the level of the highest point.

If $\omega_1^2<\dfrac{4g}{a}$, the particle will oscillate; and, if $\dfrac{d\theta}{dt}=0$, when $\theta=\alpha$,

then
$$\left(\frac{d\theta}{dt}\right)^2=\frac{2g}{a}(\cos\theta-\cos\alpha)-\omega^2(\cos^2\theta-\cos^2\alpha),$$
$$=\omega^2(\cos\theta-\cos\alpha)\left(\frac{2g}{a\omega^2}-\cos\alpha-\cos\theta\right),$$
$$=\omega^2(\cos\theta-\cos\alpha)(2\cos\gamma-\cos\alpha-\cos\theta);$$

and therefore, if $2\cos\gamma-\cos\alpha>1$, the particle will oscillate through the lowest point.

If $1>2\cos\gamma-\cos\alpha>-1$, then, putting

$$2\cos\gamma-\cos\alpha=\cos\beta,$$
$$\left(\frac{d\theta}{dt}\right)^2=\omega^2(\cos\theta-\cos\alpha)(\cos\beta-\cos\theta),$$

and the particle will oscillate on one side of the vertical diameter.

In each of these three cases the complete solution of the problem can be exhibited in terms of elliptic functions. In the last two cases, when the arcs of oscillation are very small, a sufficient solution may easily be obtained by the usual methods of approximation. This is a particularly instructive example.

§ 160. As a final example of constrained motion of a particle, let us find the form of a curve such that a particle will slide down any arc of it, from the origin, in the same time as down the chord of that arc. If OA, OB (fig. 53) be any two chords, it is plain that the difference of the times down these chords must be equal to the time of describing the arc AB. But, if OA make an angle θ with the vertical, the time of descent along it is

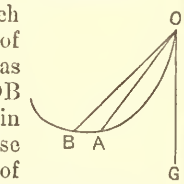


Fig. 53.

$$\sqrt{\frac{2\text{OA}}{g\cos\theta}},$$

And the velocity at A is $\sqrt{2g\text{OA}\cos\theta}$, so that the time of describing AB (considered as infinitesimal) is

$$\text{AB}/\sqrt{2g\text{OA}\cos\theta}.$$

If we put r for OA, our condition gives at once

$$\frac{d}{d\theta}\sqrt{\frac{2r}{g\cos\theta}}=\frac{\frac{ds}{d\theta}}{\sqrt{2gr\cos\theta}},$$

where s is the length of the arc OA. This equation is easily integrated, and the resulting relation is

$$r^2=a^2\sin 2\theta,$$

which belongs to the well-known lemniscate of Bernoulli. From its form we see that the vertical line from which θ is measured is a tangent at O; so that the motion in arc commences vertically.

Disturbed motion. § 161. To complete this elementary sketch of the dynamics of a single particle we take an instance or two of "disturbed motion." The essence of this question is usually that the disturbing forces are, at any instant, small in comparison with the forces producing the motion; so that, during any brief period, the motion is practically the same as if no disturbing cause had been at work. But, in time, the effects of the disturbance may become so great as entirely to change the dimensions and form of the orbit described. The mathematical method which has been devised to meet this question depends upon what has just been said. The *character* of the path is not, at any particular instant, affected by the disturbance; but its form and dimensions are. Hence, as the first depends upon the *form* of the equations which represent it, while the latter depend upon the actual and relative magnitudes of the constants involved, we settle, once for all, the *form* of the equation as if no disturbing cause had acted. But we are thus entitled to assume that the constants which it involves are quantities which vary with the time in consequence of the slight, but persistent, effects of the disturbance. And, as we know that, if at any moment the disturbance were to cease, the motion would forthwith go on for ever in the orbit *then being described*, we may assume that in the expressions for the components of the velocity no terms occur depending on the rate of alteration of the values of the constants. This, as will be seen below, very much simplifies the mathematical treatment of such questions.

Pendulum. *Suppose a cycloidal pendulum, or a simple pendulum vibrating through very small arcs, to be subjected to a simple harmonic disturbance in the direction of its motion.* The equation of motion will obviously be of the form

$$\ddot{\theta}+n^2\theta=\text{A}\cos mt,$$

where $n^2=l/g$, as in § 134.

The integral of this equation is

$$\theta=\text{P}\cos(nt+\text{Q})-\frac{\text{A}}{m^2-n^2}\cos mt.$$

We see then that the result is the superposition of a new simple harmonic motion on the natural simple harmonic motion of the undisturbed bob, and that it is altogether independent of the amplitude and phase of the undisturbed motion. So long as the disturbance is very small, this new part of the motion may be neglected, unless m is very nearly equal to n. For in that case the amplitude of the disturbance may become much greater than that of the original motion. When m is equal to n, the integral changes its form, and we have

$$\theta=\text{P}\cos(nt+\text{Q})+\text{A}\frac{t}{2n}\sin nt.$$

Harm[onic] motion with [dis]turba[nce] of san[me] period. This shows that, in the special case of a disturbance of the same period as the undisturbed motion, the nature of the motion is entirely changed. Thus, suppose the pendulum to be at rest at its lowest point when the disturbance is applied; then we have merely

$$\theta=\text{A}\frac{t}{2n}\sin nt,$$

a simple harmonic motion whose amplitude increases in proportion to the time elapsed since the disturbance commenced.

Point [of] suspen[sion] di[s]turbed. § 162. As another illustration, *suppose the point of suspension of a simple pendulum to have a simple harmonic motion of small amplitude in a horizontal line.*

Here the equations of motion are (to horizontal and vertical axes)

$$m\ddot{x}=-\text{T}\frac{x-\xi}{l},$$

$$m\ddot{y}=mg-\text{T}\frac{y}{l}.$$

But if we suppose the oscillations to be small, we may write $x-\xi=l\theta$, $y=l$, where l is the length of the pendulum, and θ the angle it makes with the vertical. Then we have

$$\ddot{x}=l\ddot{\theta}+\ddot{\xi}=l\ddot{\theta}+\text{A}\cos mt,\text{ suppose, and }\ddot{y}=0.$$

Hence $mg=\text{T}$,

and $l\ddot{\theta}+\text{A}\cos mt=-g\theta$,

which is precisely the equation of the preceding investigation.

Motion of a sli[ng]. We see from this how to explain the somewhat puzzling phenomenon which we observe when we produce complete rotations of a stone in a sling by a comparatively trifling motion of the hand. All that is necessary is that the hand should have a slight to and fro horizontal motion, in a period nearly equal to that in which the sling and stone would vibrate as a pendulum. This result of particle kinetics is (like that in § 161) of great value in other branches of physics, especially sound, light, and radiant heat.

Disturb[ance] general. To illustrate the general principle, let us take the case of one degree of freedom. Then the equation of motion of an unit mass must be of the form

$$\ddot{\theta}=\Theta+\Theta_1,$$

where Θ represents the normal force, and Θ_1 the abnormal or disturbing force. Leaving out Θ_1 for the moment, let the integral of $\ddot{\theta}=\Theta$ be

$$\theta=f(\alpha,\ \beta,\ t),$$

in which α and β are two arbitrary constants. We may now suppose α and β to be variable in such a way that the equation shall still be satisfied by this value of θ when the disturbing forces are included. This imposes only one condition on the two independent quantities α and β, so that to determine them completely we must impose a second. This we do, as already explained, by making the expression for the speed independent of the rates of alteration of α and β, and we gain the advantage that our solution will accord at every instant with what would be the actual future motion if the disturbance were suddenly to cease. The speed is

$$\dot{\theta}=f'(\alpha)\dot{\alpha}+f'(\beta)\dot{\beta}+f'(t).$$

We therefore assume

$$f'(\alpha)\dot{\alpha}+f'(\beta)\dot{\beta}=0.$$

Taking account of this and differentiating again, we have

$$\ddot{\theta}=\frac{d}{d\alpha}f'(t)\,.\,\dot{\alpha}+\frac{d}{d\beta}f'(t)\,.\,\dot{\beta}+f''(t).$$

Hence we have, for the determination of α and β, the equations

$$f'(\alpha)\frac{d\alpha}{dt}+f'(\beta)\frac{d\beta}{dt}=0,$$

$$\frac{d}{d\alpha}f'(t)\,.\,\frac{d\alpha}{dt}+\frac{d}{d\beta}f'(t)\,.\,\frac{d\beta}{dt}=\Theta_1.$$

These give the values of $\frac{d\alpha}{dt}$ and $\frac{d\beta}{dt}$, and so completely solve the problem.

Impulsive change of velocity. § 163. In a somewhat similar way we may treat the effects of a slight disturbance, made once for all, in the motion of a particle describing a definite path under given forces. A single example must suffice.

Thus, we have in an elliptic orbit about the focus, § 144 (9),

$$\frac{1}{2}v^2 = \frac{\mu}{r} - \frac{\mu}{2a}.$$

At the end of the major axis farthest from the focus this becomes

$$V^2 = \frac{\mu}{a}\,\frac{1-e}{1+e}.$$

Now if at this point V be made $V+\delta V$, without change of direction, we have the condition that in the new orbit $a(1+e)$ shall have the same value as in the old, since this will still be the apsidal distance.

Hence
$$\delta(V^2) = \delta\left(\frac{\mu}{a}\,\frac{1-e}{1+e}\right),$$

and
$$\delta\left\{a(1+e)\right\} = 0\;;$$

$$\therefore\; 2V\delta V = -\frac{\mu}{a}\,\frac{\delta e}{1+e},$$

or
$$\delta e = -2\sqrt{\left\{\frac{a}{\mu}(1-e^2)\right\}}\,\delta V,$$

and
$$\delta a = -\frac{a}{1+e}\delta e,$$

$$= 2\sqrt{\left(\frac{a^3}{\mu}\,\frac{1-e}{1+e}\right)}\delta V,$$

which determine the increase of the major axis and the diminution of the excentricity; and the same method is applicable to more complicated cases.

A very excellent series of examples of the elementary geometrical treatment of disturbed orbits is to be found in Airy's *Gravitation*.

Third Law. Kinetics of Two or More Particles.

Stress between particles. § 164. We have, by means of the first two laws, arrived at a *definition* and a *measure* of force, and have found how to compound, and therefore how to resolve, forces, and also how to investigate the conditions of equilibrium or motion of a single particle subjected to given forces. But more is required before we can completely understand the more complex cases of motion, especially those in which we have mutual actions between or amongst two or more bodies,—such as, for instance, tensions or pressures or transference of energy in any form. This is perfectly supplied by the third law, on which Newton comments nearly as follows.

Newton's comments on third law. § 165. If one body presses or draws another, it is pressed or drawn by this other with an equal force in the opposite direction. If any one presses a stone with his finger, his finger is pressed with an equal force in the opposite direction by the stone. A horse, towing a boat on a canal, is dragged backwards by a force equal to that which he impresses on the towing-rope forwards. By whatever amount, and in whatever direction, one body has its "motion" changed by impact upon another, this other body has its "motion" changed by the same amount in the opposite direction; for at each instant during the impact they exerted on each other equal and opposite pressures. When neither of the two bodies has any rotation, whether before or after impact, the changes of velocity which they experience are inversely as their masses. When one body attracts another from a distance, this other attracts it with an equal and opposite force.

Stress. § 166. We shall for the present take for granted that the mutual action between two particles may in every case be imagined as composed of equal and opposite forces in the straight line joining them, two such equal and opposite forces constituting a "stress" between the particles. From this it follows that the sum of the quantities of motion, parallel to any fixed direction, of the particles of any system influencing one another in any possible way, remains unchanged by their mutual action; also that the sum of the moments of momentum of all the particles round any line in a fixed direction in space, and passing through any point moving uniformly in a straight line in any direction, remains constant. From the first of these propositions we infer that the centre of mass of any system of mutually influencing particles, if in motion, continues moving uniformly in a straight line, except in so far as the direction or speed of its motion is changed by stresses between the particles and some other matter not belonging to the system; also that the centre of mass of any system of particles moves just as all their matter, if concentrated in a point, would move under the influence of forces equal and parallel to the forces really acting on its different parts. From the second we infer that the axis of resultant rotation through the centre of mass of any system of particles, or through any point either at rest or moving uniformly in a straight line, remains unchanged in direction, and the sum of moments of momentum round it remains constant, if the system experiences no force from without, or only forces whose resultant passes through the centre of inertia of the system. This principle is sometimes called "conservation of areas," a very misleading designation. Conservation of momentum, and of moment of momentum.

Consequences of Newton's scholium. § 167. Newton's scholium, which we treat as a fourth law, points out that resistances against acceleration are to be reckoned as reactions equal and opposite to the actions by which the acceleration is produced. Thus, if we consider any one material point of a system, its reaction against acceleration must be equal and opposite to the resultant of the forces which that point experiences, whether by the actions of other parts of the system upon it, or by the influence of matter not belonging to the system. In other words, it must be in equilibrium with these forces. Hence Newton's view amounts to this, that all the forces of the system, with the reactions against acceleration of the material points composing it, form groups of equilibrating systems for these points considered individually. Hence, by the principle of superposition of forces in equilibrium, all the forces acting on points of the system form, with the reactions against acceleration, an equilibrating set of forces on the whole system. This is the celebrated principle first explicitly stated and very usefully applied by D'Alembert in 1742, and still known by his name. D'Alembert's principle.

Abstract theory of energy. § 168. Thus Newton lays, in an admirably distinct and compact manner, the foundations of the abstract theory of "energy," which recent experimental discovery has raised to the position of the grandest of known physical laws. He points out, however, only its application to mechanics. The *actio agentis*, as he defines it, which is evidently equivalent to the product of the effective component of the force into the velocity of the point at which it acts, is simply, in modern English phraseology, the rate at which the agent works, called the "power" of the agent. The subject for measurement here is precisely the same as that for which Watt, a hundred years later, introduced the practical unit of a "horse-power," or the rate at which an agent works when overcoming 33,000 times the weight of a pound through the distance of a foot in a minute,—that is, producing 550 foot-pounds of work per second. The unit, however, which is most generally convenient is that which Newton's definition implies, namely, the rate of doing work in which the unit of work or energy is produced in the unit of time. Horse-power.

§ 169 Looking at Newton's words in this light, we see that they may be converted into the following:—

"Work done on any system of bodies (in Newton's

Newton's scholium. statement, the parts of any machine) has its equivalent in work done against friction, molecular forces, or gravity, if there be no acceleration; but if there be acceleration, part of the work is expended in overcoming the resistance to acceleration, and the additional kinetic energy developed is equivalent to the work so spent."

When part of the work is done against molecular forces, as in bending a spring, or against gravity, as in raising a weight, the recoil of the spring and the fall of the weight are capable, at any future time, of reproducing the work originally expended. But in Newton's day, and long afterwards, it was supposed that work was absolutely lost by friction.

§ 170. If a system of bodies, given either at rest or in motion, be influenced by no forces from without, the sum of the kinetic energies of all its parts is augmented in any time by an amount equal to the whole work done in that time by the stresses which we may imagine as taking place between its points. When the lines in which these stresses act remain all unchanged in length, the sum of the kinetic energies of the whole system remains constant. If, on the other hand, one of these lines varies in length during the motion, the stress in that line will do work or will consume work, according as the distance varies with or against it.

Conservative system. § 171. Experiment has shown that the mutual actions between the parts of any system of natural bodies always perform, or always consume, the same amount of work during any motion whatever, by which the system can pass from one particular configuration to another; so that each configuration corresponds to a definite amount of kinetic energy. Hence no arrangement is possible in which a gain of kinetic energy can be obtained when the system is restored to its initial configuration. In other words, "the perpetual motion" is impossible.

Potential energy. The "potential energy" (§ 113) of such a system, in the configuration which it has at any instant, is the amount of work that its mutual forces perform during the passage of the system from any one chosen configuration to the configuration at the time referred to. It is generally convenient so to fix the particular configuration chosen for the zero of reckoning of potential energy that the potential energy in every other configuration practically considered shall be positive.

As particular instances of this we may notice many of the results already given: for instance, the ordinary expression for the velocity acquired by a falling stone (§ 28), $\frac{1}{2}v^2 = gx$; for here $\frac{1}{2}mv^2$ is the kinetic energy acquired, while $mg.x$ is the work done by the weight (mg) during the fall. Similarly, we have in the motion of a planet, the expression $v^2 = \mu\left(\frac{2}{r} - \frac{1}{a}\right)$, which leads to $m\frac{v^2 - v_1^2}{2} = \frac{m\mu}{rr_1}(r_1 - r)$. Here $\frac{m\mu}{rr_1}$ is the "mean value" of the force for distances from r to r_1, and therefore the right-hand side is the work done by the force, while the left-hand side is the increase of kinetic energy produced.

To put this in an analytical form, we have merely to notice that, by what has just been said, the value of

$$\Sigma\int\left(X\frac{dx}{ds} + Y\frac{dy}{ds} + Z\frac{dz}{ds}\right)ds$$

is independent of the paths pursued from the initial to the final positions, and therefore that

$$\Sigma(Xdx + Ydy + Zdz)$$

is a complete differential. If, in accordance with what has just been said, this be called $-dV$, V is the potential energy, and

$$X_1 = -\frac{dV}{dx_1}, \ . \ . \ . \ .$$

Also, by the second law of motion, if m_1 be the mass of a particle of the system whose coordinates are x_1, y_1, z_1 we have

$$m_1\frac{d^2x_1}{dt^2} = X_1, \ \&c. = \&c.$$

and

Conservation of energy.

$$\Sigma\left\{m\left(\frac{dx}{dt}\frac{d^2x}{dt^2} + \frac{dy}{dt}\frac{d^2y}{dt^2} + \frac{dz}{dt}\frac{d^2z}{dt^2}\right)\right\}dt = \Sigma(Xdx + Ydy + Zdz) = -dV.$$

The integral is

$$\tfrac{1}{2}\Sigma(mv^2) + V = H,$$

that is, *the sum of the kinetic and potential energies is constant.* This is called the "*conservation of energy.*"

Friction dissipation. In abstract dynamics, with which alone this article is concerned, there is loss of energy by friction, impact, &c. This we simply leave as loss, to be accounted for by Thermodynamics.

Other side stress. § 172. Hitherto, as we have been dealing with the motion of a single particle only, we have not required the assistance of even the third law. For, in those cases, already treated, in which one of the forces was not given, it was at all events due to a given constraint, and the geometrical circumstances of the constraint supplied the means of determining it. In fact we were not, in any case, concerned with reaction; or, to use the more modern form of expression, we were engaged with one half, only, of a stress. When a stone's motion was investigated, no account was taken of the stone's attraction for the earth; when we dealt with central forces, the centre was supposed to be fixed; and, even in the cases in which variable constraint was supposed, the curve which produced it was assumed to move in a manner absolutely determined beforehand, and in no way affected by the reaction of the mass acted upon.

But, in nature, circumstances are not so simple. Though, for all practical purposes, we may calculate the motion of an ordinary projectile as if its attraction had no influence upon the motion of the earth, we cannot do so in the case of the motion of the moon about the earth. The mass of the moon is about $\frac{1}{80}$th of that of the earth, and its gravitation effects on the motion of the earth cannot be neglected. The moon, in fact, moves faster round the earth than would a projectile of less mass, though moving in precisely the same relative orbit (§ 146). If the earth's motion were not accelerated by the reaction of the moon, the sole crest of the lunar tide-wave would be on the side of the earth next the moon, and there would be full-tide once only in a single rotation of the earth about its axis. We need not give further instances here; they will present themselves in almost every case we investigate.

Examples of third law. § 173. To give a general notion of the applications of, and necessity for, the third law, we choose a few special cases, selected so as to give, in short compass, a sufficiently general glance at the whole subject.

Atwood's machine. We take, first, the case of two stones or bullets connected by an inextensible string passing over a smooth pulley. Let their masses be m and m'. Our physical condition is that the tension of the string, whatever be its value, is the same throughout; and this is accompanied by the geometrical condition that the length of the string is constant, or that the speeds of the two masses are equal but in opposite directions. Hence the amounts of increase of momentum in a given time are as the masses. But they are also as the forces, by the second law. Thus

$$m : m' :: T - mg : m'g - T.$$

This gives, at once,

$$T = \frac{2\,mm'}{m + m'}g;$$

so that the whole downward force on m' is

$$m'g - T = m'\frac{m' - m}{m' + m}g,$$

and the whole upward force on m is

$$T - mg = m\frac{m' - m}{m' + m}g.$$

The motion of the system is therefore of precisely the same character as that of a free mass falling in a vertical line, but the acceleration is less, in the ratio of the difference of the two masses to their sum.

§ 174. This is the essence of the arrangement called *Atwood's Machine*, which used to be employed for the demonstration (in a rough way) of the first and second laws of motion, in certain simple cases. The main feature of the method is the artificial reduction of the acceleration, so that the motion of the falling body is rendered slow enough to be followed by the eye with some degree of accuracy. To prove the first law, a bar of metal was laid across one of two equal masses suspended as in the example; and the system was allowed to move under acceleration until the preponderating mass passed through a ring which arrested the bar. The subsequent motion, with no acceleration, was then observed by noting the passage of the falling mass in front of a vertical scale, while the observer also listened to the ticking of a pendulum escapement. For the verification of the second law, so far as uniform force is concerned, the apparatus was adjusted by trial so that the extra load was detached from the preponderating mass after 1, 2, 3, &c., beats of the pendulum; and the subsequent uniform speed was found to be nearly in proportion to these numbers. And, again, to prove that momentum acquired is, *cæteris paribus*, proportional to the force, the effects of bars of different masses were compared by the same process.

If x and $l-x$ be the portions of the string on opposite sides of the pulley at time t, we have

$$m\frac{d^2x}{dt^2}=mg-\mathrm{T}=m\ddot{x},$$

$$m'\frac{d^2}{dt^2}(l-x)=m'g-\mathrm{T}=-m'\ddot{x}.$$

Hence by elimination of T we have

$$\frac{m-m'}{m+m'}g=\ddot{x},$$

and by elimination of $\ddot{x}$

$$\mathrm{T}=\frac{2mm'}{m+m'}g,\text{ as before.}$$

When one of the masses is vibrating pendulum-wise, the problem assumes a very much more difficult aspect. We will take it later as an example of the application of Lagrange's general method.

§ 175. Let us now suppose these masses, so connected, to be thrown like a chain-shot. We see by § 166 that their centre of inertia moves as if the masses were concentrated there. Also that the moment of momentum is unaffected. Hence we have only to find the initial position and motion of the centre of inertia, and the plane and amount of the initial moment of momentum; and the complete determination of the motion follows. This case is precisely the same as that of a well-thrown quoit, the rotation of which is about its axis of symmetry. It is, so far as § 166 goes, the case of an ill-thrown quoit, which appears to wabble about in an irregular manner. But these are matters properly to be treated under Kinetics of a Rigid System.

§ 176. Suppose, next, two masses m_1 and m_2 to be connected together by an elastic string, the extension of the string being proportional to the tension. Let m_1 be held in the hand, while m_2 hangs at rest. Then let the system be allowed to fall. What is the nature of the motion? Without mathematical investigation it is easy to see that, the moment the masses are left free to fall, the tension of the stretched string will gradually draw them together. When it has thus contracted to its normal length, l, the *relative* speed of the two masses will have a definite value. This will continue to be the relative speed until they have passed one another and again arrived at a mutual distance l. At that instant the tension of the string comes into play again; the relative speed becomes less and less, finally vanishing when the distance between the masses is what it was at starting. Then the relative speed becomes again one of approach, increasing steadily till the distance between the masses is l. This maximum speed of approach continues till, after again passing one another, the particles once more reach the relative distance l. And so on. All this time, however, their common centre of inertia has been steadily falling with uniformly accelerated speed, as if the masses had been concentrated at it into one. Since l is the unstretched length of the string, if we call E its modulus of elasticity, its tension at any other length, λ, is

$$\mathrm{T}=\mathrm{E}\frac{\lambda-l}{l}$$

by Hooke's law. Hence, if initially m_1 were at the origin, and the axis of x be taken vertically downwards, we have for the initial coordinate of m_2

$$(x_2)_0=\left(\frac{m_2g}{\mathrm{E}}+1\right)l.$$

When the masses are moving, the third law informs us that the tension of the string acts equally and in opposite directions on them. Thus the equations of motion are

$$m_1\ddot{x}_1=m_1g+\mathrm{T},$$
$$m_2\ddot{x}_2=m_2g-\mathrm{T}.$$

By eliminating T we have at once

$$m_1\ddot{x}+m_2\ddot{x}_2=(m_1+m_2)g.$$

But
$$m_1x_1+m_2x_2=(m_1+m_2)\xi,$$

if ξ be the coordinate of the centre of inertia of the two masses. Hence

$$\ddot{\xi}=g,$$

the ordinary equation for the fall of a stone. Thus

$$m_1x_1+m_2x_2=\mathrm{A}+\mathrm{B}t+\tfrac{1}{2}(m_1+m_2)gt^2.$$

Since $x_1=0$, $\dot{x}_1=0$, $x_2=\left(\frac{m_2g}{\mathrm{E}}+1\right)l$, $\dot{x}_2=0$, when $t=0$, we have

$$\mathrm{A}=m_2\left(\frac{m_2g}{\mathrm{E}}+1\right)l,\quad \mathrm{B}=0,$$

and thus
$$m_1x_1+m_2x_2=m_2\left(\frac{m_2g}{\mathrm{E}}+1\right)l+\tfrac{1}{2}(m_1+m_2)gt^2.$$

So long as $x_2-x_1>l$ we have also

$$\mathrm{T}=\mathrm{E}\left(\frac{x_2-x_1}{l}-1\right).$$

Hence, multiplying the first of the equations of motion by m_2, and the second by m_1, and taking the difference, we have

$$m_1m_2(\ddot{x}_2-\ddot{x}_1)=-(m_1+m_2)\mathrm{E}\left(\frac{x_2-x_1}{l}-1\right).$$

The integral is

$$x_2-x_1=l+\mathrm{P}\cos(nt+\mathrm{Q}),$$

where
$$n^2=\frac{m_1+m_2}{lm_1m_2}\mathrm{E}.$$

Also, by the data at starting, we have

$$\mathrm{Q}=0,\qquad \mathrm{P}=\frac{m_2gl}{\mathrm{E}}.$$

Hence, finally,

$$x_1=\frac{1}{m_1+m_2}\left(m_2\left(\frac{m_2g}{\mathrm{E}}+1\right)l+\tfrac{1}{2}(m_1+m_2)gt^2-m_2l-\frac{m_2^2gl}{\mathrm{E}}\cos nt\right).$$

$$=\tfrac{1}{2}gt^2+\frac{m_2^2gl}{\mathrm{E}(m_1+m_2)}(1-\cos nt),$$

whence the value of x_2 can easily be found.

As soon as we have $nt>\frac{1}{2}\pi$ these values cease to represent the coordinates of the two masses, because they are deduced from equations involving constraint which, in the case supposed, has ceased for a time.

At the instant $nt=\frac{1}{2}\pi$ the relative speed of the masses is

$$-\frac{m_2gl}{\mathrm{E}}\sqrt{\frac{(m_1+m_2)\mathrm{E}}{m_1m_2l}},$$

and their distance l.

This distance diminishes thenceforward with the above speed until the uppermost stone, having passed the lower one, falls below it to a distance l. We must, in order to trace the next part of the motion, reapply the differential equations above,—integrating them, and determining the constants by the new conditions. This we leave to the reader.

Complex pendulum.

§ 177. Next let us take the case of a *Complex Pendulum*,—the motion of two or more pellets attached, at different points, to the same thread, supported at one end. The general solution of this question presents considerable difficulties, but if we confine our attention to slight disturbances it is easily treated by very elementary processes. In fact, just as a simple pendulum, *slightly* disturbed in a vertical plane, has simple harmonic motion which may be regarded as the resolved part of conical pendulum motion, so we may treat of a complex conical pendulum, and resolve its motions parallel to any vertical plane.

If there be but two masses attached to the string, it is clear that they must, if the motion is to be a persistent conical one, be always in one vertical plane with the point of suspension. And there are obviously *two* dispositions of the string which are consistent with kinetic stability.

Let A (fig. 54) be the point of suspension, then the masses may rotate steadily in either of the two configurations sketched. To keep either mass moving in a horizontal circle, all that is required is that the resultant force on it shall be horizontal, directed towards the centre, and producing an acceleration equal to V^2/R, as in § 34. Let the whole system turn with angular velocity ω, and let the lengths of the strings be a and b, their directions making angles θ, ϕ with the vertical.

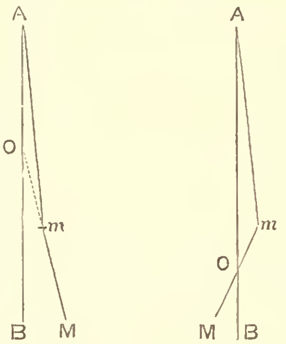


Fig. 54.

We will treat only the case in which these angles are so small that the arcs may be written in place of their sines. Then m requires a horizontal resultant force $ma\theta\omega^2$ directed towards the axis, and M requires $M(a\theta+b\phi)\omega^2$ similarly directed. Also, as the strings are both very nearly vertical, the tension of the lower string may be taken as the weight of M, and that of the upper as the sum of the weights of M and m. Treating it, then, as a statical problem, we have for the mass m

$$ma\theta\omega^2=(M+m)g\theta-Mg\phi\,;$$

and for M

$$M(a\theta+b\phi)\omega^2=+Mg\phi\,.$$

These formulæ correspond to the first configuration, but a change of sign of ϕ adapts them to the second.

These two equations involve three unknown quantities ω^2, θ, ϕ. But the *ratio*, only, of θ and ϕ is involved, so that two equations are sufficient. [We have confined ourselves to small values of θ and ϕ, but have not assigned any limit to their smallness; so that their ratio has still an infinite range of values.]

Eliminate the ratio ϕ/θ between the two equations; and we have, putting ψ for g/ω^2,

$$Ma\psi=(\psi-b)((M+m)\psi-ma)\,,$$

or

$$(\psi-a)(\psi-b)=\frac{M}{M+m}ab\,.$$

It is clear that, because the right-hand member is essentially less than ab, there are always two real values of ψ, both positive, but one greater than the greater of a, b, the other less than the lesser. These correspond to two values of ϕ/θ, one positive, the other negative.

§ 178. The most general motion, then, of the double complex pendulum, when it vibrates in one plane, consists (for each of the masses) of the resultant of two simple harmonic motions, whose periods are

$$2\pi/\omega-2\pi\sqrt{\psi/g}\,,$$

ψ having one or other of the two positive values given by the equation above, and being therefore the length of the equivalent simple pendulum. Thus the double complex pendulum supplies at once the mechanical means of tracing (by ink, sand, electric sparks, &c., § 156) a graphical representation of the composition of two simple harmonic motions, of different periods, in one line.

Analytically thus. For *any* displacement in one plane we have, θ and ϕ being, as before, the deflexions and T, T′ the tensions of the strings,

$$ma\left(\frac{d}{dt}\right)^2\sin\theta=-T\sin\theta+T'\sin\phi\,,$$

$$ma\left(\frac{d}{dt}\right)^2\cos\theta=mg-T\cos\theta+T'\cos\phi\,,$$

$$M\left(\frac{d}{dt}\right)^2(a\sin\theta+b\sin\phi)=-T'\sin\phi$$

$$M\left(\frac{d}{dt}\right)^2(a\cos\theta+b\cos\phi)=Mg-T'\cos\phi\,,$$

four equations to determine θ, ϕ, T, and T′. They become much more manageable if we assume that θ and ϕ are so small that their squares may be neglected. For then we have $\sin\theta=\theta$, $\cos\theta=1$, &c., and the equations become

$$ma\ddot\theta=-T\theta+T'\phi,\qquad 0=mg-T+T',$$

$$M(a\ddot\theta+b\ddot\phi)=-T'\phi,\qquad 0=Mg-T'.$$

Thus $\quad T'=Mg\,,\ T=(M+m)g\,,$

and we have $\quad ma\ddot\theta=-(M+m)g\theta+Mg\phi\,,$

$$a\ddot\theta+b\ddot\phi=-g\phi\,.$$

Introducing an arbitrary multiplier λ, we have

$$\left(\frac{d}{dt}\right)^2\Big\{(m+\lambda)a\theta+\lambda b\phi\Big\}=-g\Big\{(M+m)\theta+(\lambda-M)\phi\Big\}\,.$$

If we choose λ so that

$$\frac{\lambda b}{(m+\lambda)a}=\frac{\lambda-M}{M+m}=e,\quad\ldots\ldots\quad(1).$$

the equation can be put in the form

$$\left(\frac{d}{dt}\right)^2(\theta+e\phi)=-\frac{g(M+m)}{(m+\lambda)a}(\theta+e\phi).$$

Now (1) is a quadratic equation in λ, and has obviously real roots, a positive root greater than M, and a negative root numerically less than m. Write (1) as the equation of an hyperbola, in the form

$$\mu=\frac{\lambda b}{(m+\lambda)a}-\frac{\lambda-M}{M+m}\,,$$

and we see that $\lambda+m=0$ is an asymptote. The branch on the positive side of this asymptote lies mainly below the axis of λ. But μ is positive for $\lambda=M$, and also for $\lambda=0$.

Hence μ must pass through the value zero while λ is greater than M, and for another value of λ between zero and $-m$. But it is obvious that, for each of these values of λ, $m+\lambda$ is positive. Hence the equation may be written

$$\left(\frac{d}{dt}\right)^2(\theta+e\phi)=-n^2(\theta+e\phi)\,,$$

where e and n have two sets of real values given as above; and thus we have the complete solution, with the four requisite arbitrary constants, in the form

$$\theta+e_1\phi=P_1\cos(n_1t+Q_1)\,,$$

$$\theta+e_2\phi=P_2\cos(n_2t+Q_2)\,.$$

This applies to every possible set of values of a, b, m, M; for, as we have seen, the two values of λ are essentially different, at least *so long as neither of the masses becomes zero*. Thus, in this particular case, we are not met by the difficulty of equal roots. But it is very interesting to contrast this case, when m is much greater than M, and $a=b$, with the case discussed in § 162 where the point of suspension of a simple pendulum has a horizontal simple harmonic motion of the period of the pendulum and in the vertical plane in which it vibrates. There the oscillations increase indefinitely; here they are in all cases essentially finite, in accordance with the assumptions made. There is, in fact, no increase of the energy of the system.

A very slight modification of the process gives us the result of small displacements not in one plane.

Kinetics of a System of Free Particles.

§ 179. A system of free particles is subject only to their mutual attractions; to investigate the motion of the system.

System of free particles. Let, at time t, x_n, y_n, z_n be the coordinates of the particle whose mass is m_n, and let $\phi'(D)$ be the law of attraction. Let ${}_pr_q$ express the distance between the particles m_p and m_q; then we have, for the motion of m_1,

$$m_1\frac{d^2x_1}{dt^2} = \Sigma\left\{ m_1 m_n \phi'({}_1r_n)\frac{x_n - x_1}{{}_1r_n}\right\} \quad . \quad . \quad . \quad . \quad (1),$$

$$m_1\frac{d^2y_1}{dt^2} = \Sigma\left\{ m_1 m_n \phi'({}_1r_n)\frac{y_n - y_1}{{}_1r_n}\right\} \quad . \quad . \quad . \quad . \quad (2),$$

$$m_1\frac{d^2z_1}{dt^2} = \Sigma\left\{ m_1 m_n \phi'({}_1r_n)\frac{z_n - z_1}{{}_1r_n}\right\} \quad . \quad . \quad . \quad . \quad (3),$$

with similar equations for each of the others, the summations being taken throughout the system. Before we can make any attempt at a solution of these equations, we must know their number, and the laws of attraction between the several pairs of particles. But some general theorems, independent of these data, may easily be obtained.

Conservation of momentum. First, we have *Conservation of Momentum*. In the expression for $m_p\frac{d^2x_p}{dt^2}$, we have a term $m_p m_q \phi'({}_pr_q)\frac{x_q - x_p}{{}_pr_q}$,

and in $m_q\frac{d^2x_q}{dt^2}$ we have $m_q m_p \phi'({}_qr_p)\frac{x_p - x_q}{{}_qr_p}$.

Hence, if we add all the equations of the form (1) together, the result will be

$$m_1\frac{d^2x_1}{dt^2} + m_2\frac{d^2x_2}{dt^2} + \quad . \quad . \quad . \quad . \quad = 0\,;$$

or

$$\Sigma\left(m\frac{d^2x}{dt^2}\right) = \frac{d^2\bar{x}}{dt^2}\Sigma(m) = 0\,.$$

Similarly $\frac{d^2\bar{y}}{dt^2}\Sigma(m) = 0$, and $\frac{d^2\bar{z}}{dt^2}\Sigma(m) = 0$,

where (§ 109) $\bar{x}$, $\bar{y}$, $\bar{z}$ is the centre of inertia of the system.

These equations show that the speed of the centre of inertia parallel to each of the coordinate axes remains invariable during the motion; that is, that *the centre of inertia of the system remains at rest, or moves with constant speed in a straight line.*

Of moment of momentum. Next we have *Conservation of Moment of Momentum*. For if we multiply in succession equation (1) by y_1, and equation (2) by x_1, and subtract, and take the sum of all such remainders through the system of equations of the forms (1) and (2), we have

$$\Sigma[m(x\ddot{y} - y\ddot{x})] = 0\,.$$

Integrating once, we have

$$\Sigma[m(x\dot{y} - y\dot{x})] = 2A_3\,,$$

where the left-hand member is the moment of momentum of the system about the axis of z.

This equation shows (since xy is any plane) that generally in the motion of a free system of particles, subject only to their mutual attractions, *the moment of momentum about every axis remains constant.*

Of energy. Finally, we have *Conservation of Energy*. Multiply (1) by $\frac{dx_1}{dt}$, (2) by $\frac{dy_1}{dt}$, (3) by $\frac{dz_1}{dt}$; and, treating similarly all the other equations, add them all together.

Let us consider the result as regards the term on the right-hand side involving the product m_pm_q.

Written at length it is

$$\frac{m_pm_q\phi'({}_pr_q)}{{}_pr_q}\left\{(x_q - x_p)\frac{dx_p}{dt} + (x_p - x_q)\frac{dx_q}{dt}\right.$$
$$\left. + \text{similar terms in } y \text{ and } z\right\};$$

and the portion in brackets is equal to

$$-\left\{(x_q - x_p)\frac{d}{dt}(x_q - x_p) + \text{similar terms in } y, z\right\};$$

or

$$-{}_pr_q\frac{d}{dt}({}_pr_q)\,;$$

hence

$$\Sigma\left\{m\left(\frac{dx}{dt}\frac{d^2x}{dt^2} + \frac{dy}{dt}\frac{d^2y}{dt^2} + \frac{dz}{dt}\frac{d^2z}{dt^2}\right)\right\}$$
$$+ \Sigma\left\{m_pm_q\phi'({}_pr_q)\frac{d}{dt}({}_pr_q)\right\} = 0\,;$$

therefore, on integration,

$$\tfrac{1}{2}\Sigma(mv^2) + \Sigma\{m_pm_q\phi({}_pr_q)\} = H\,.$$

We see therefore that *the change in the kinetic energy of the system in any time depends only on the relative distances of the particles at the beginning and end of that time.*

Virial. Another general expression for the kinetic energy of a system of particles, in terms of a function of the mutual forces, and the constraining forces if there be such, is readily found as follows.

If x, y, z be the coordinates, at time t, of the particle m, we have

$$\left(\frac{d}{dt}\right)^2\Sigma m(x^2 + y^2 + z^2) = 2\Sigma m(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) + 2\Sigma m(x\ddot{x} + y\ddot{y} + z\ddot{z})\,.$$

But if X, Y, Z be the components of the forces (of whatever kind) acting on m, we have (§ 119)

$$m\ddot{x} = X,\ m\ddot{y} = Y,\ m\ddot{z} = Z\,.$$

Thus

$$\left(\frac{d}{dt}\right)^2\Sigma m(x^2 + y^2 + z^2) = 2\Sigma m(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) + 2\Sigma(Xx + Yy + Zz)\,.$$

This expression was originally devised by Clausius for application to the kinetic theory of gases. The quantity $\Sigma m(x^2 + y^2 + z^2)$ is obviously half the sum of the three principal moments of inertia of the group of particles about the origin (§ 234).

In all cases of motion of a group, in which this sum is either constant or oscillates in an extremely short period about a constant value, the left-hand side may be regarded as (on the average at least) a vanishing quantity. Thus an equivalent of the kinetic energy is expressible as

$$-\tfrac{1}{2}\Sigma(Xx + Yy + Zz)\,.$$

This expression is called the "virial."

In so far as it arises from the mutual action between two particles m_p and m_q, its value is (in the notation above)

$$-\tfrac{1}{2}\left(m_p\,m_q\phi'({}_pr_q)\frac{x_q - x_p}{{}_pr_q}x_p + m_q\,m_p\phi'({}_pr_q)\frac{x_p - x_q}{{}_pr_q}x_q\right),$$

with corresponding terms in y and z, altogether

$$= \tfrac{1}{2}m_p\,m_q\phi'({}_pr_q){}_pr_q\,.$$

Hence if we write, generally, r for the distance between two of the particles, and R for the stress between them as depending on their mutual action, the corresponding part of the virial is

$$\tfrac{1}{2}\Sigma(Rr)\,.$$

This is positive when the stresses are of the nature of tension.

When the mutual action is due to gravity only,

$$\phi'({}_pr_q) = \frac{1}{{}_pr_q^2}\,,$$

and the part of the virial corresponding to this is

$$\tfrac{1}{2}m_p\,m_q/{}_pr_q\,,$$

expressing half the exhaustion of the potential energy of the system.

Virial of a gas contained in a vessel. When the particles are in very great numbers, and enclosed in a vessel from the sides of which they rebound—as is supposed in the kinetic gas theory—the pressure p, per unit of surface, on the walls of the vessel must be taken into account. If l, m, n be the direction cosines of the normal to the element dS of the wall of the vessel whose coordinates are x, y, z, the corresponding part of the virial is

$$\tfrac{1}{2}p\iint dS(lx + my + nz)$$

extended over the whole internal surface. We here assume that p is constant. But $lx + my + nz$ is the perpendicular from the origin on the plane of dS, so that the integral expresses three times the volume V of the vessel. Hence this part of the virial is

$$\tfrac{3}{2}pV.$$

Thus, in the case of a gas not acted on by external forces, the kinetic energy is

$$\tfrac{3}{2}pV + \tfrac{1}{2}\Sigma(Rr)\,.$$

Impact of Smooth Spheres.

§ 180. There remains to be treated, so far as particle dynamics is concerned, the self-contained subject of *Impact*. (Impact.) In connexion with it we must once more refer to the second and third of Newton's laws. We are now dealing with forces which produce, in finite masses, finite changes of momentum in excessively short periods of time. It is clear from this statement that their effects may be treated altogether independently of finite forces, which may be acting along with them, but which produce during the very short periods in question only infinitesimal results. And, as in general we have no knowledge of the actual force exerted at any instant during the impact, nor of the time during which the action lasts, we confine ourselves to the quantity, called the "impulse," which measures the amount of momentum lost by one of the impinging bodies and acquired by the other. (Impulse.)

Impact of small spheres.

§ 181. When two balls of glass or ivory impinge on one another, the portions of the surfaces immediately in contact are disfigured and compressed until the molecular reactions thus called into play are sufficient to resist further distortion and compression. At this instant it is evident that the points in contact are moving with the same velocity. But as solids in general possess a certain degree of elasticity both of form and of volume, the balls tend to recover their spherical form, and an additional impulse is generated. This is proportional, as Newton found by experiment, to that exerted during the compression, provided neither of the bodies is permanently distorted. The coefficient of proportionality is a quantity determinable by experiment, and may be conveniently termed the "coefficient of restitution." It is always less than unity.

§ 182. The method of treating questions involving actions of this nature will be best explained by taking as an example the case of *direct impact of one spherical ball on another.* It is evident that in the case of direct impact of smooth or non-rotating spheres we may consider them as mere particles, since everything is symmetrical about the line joining their centres. If the impinging masses are of large dimensions, of the size of the earth, for instance, we cannot treat the effects of the impact independently of the other forces involved; for the duration of collision in such a case may be one of hours instead of fractions of a second.

§ 183. Suppose that a sphere of mass M, moving with a speed v, overtakes and impinges on another of mass M′, moving in the same straight line with speed v', and that, at the instant when the mutual compression is completed, the spheres are moving with a common speed V. Let R be the impulse during the compression, then

$$M(v-V)=M'(V-v')=R\,;$$

whence
$$V=\frac{Mv+M'v'}{M+M'}\,,\ \text{and}\ R=\frac{MM'}{M+M'}(v-v')\quad . \quad . \quad . \quad (1).$$

From these results we see that the whole momentum after impact is the same as before, and that the common speed is that of the centre of inertia before impact. The quantity V can vanish only if

$$Mv+M'v'=0\,,$$

that is, if the momenta were originally equal and opposite.

This is the complete solution of the problem if the balls be inelastic, or have no tendency to recover their original form after compression.

§ 184. If the balls be elastic, there will be generated, by their tendency to recover their original forms, an additional impulse proportional to R.

Let e be the coefficient of restitution, and v_1, v_1' the speeds of the balls when finally separated. Then, as before,

$$M(V-v_1)=eR\,,$$
$$M'(v_1'-V)=eR\,;$$

whence
$$Mv_1=M\frac{Mv+M'v'}{M+M'}-e\frac{MM'}{M+M'}(v-v')\,,$$

and
$$v_1=\frac{(M-eM')v+M'(1+e)v'}{M+M'}=v-\frac{M'}{M+M'}(1+e)(v-v')\,;$$

with a similar expression for v_1'.

These results may be more easily obtained by the simple consideration that the whole impulse is $(1+e)R$; for this gives at once $M(v-v_1)=M'(v_1'-v')=(1+e)R$.

Impact on fixed plane.

If M′ be infinite, and $v'=0$, we have the result of direct impact on a *fixed* surface, viz., $v-v_1=(1+e)v$ or $v_1=-ev$. The ball rebounds from the fixed surface with a speed e times that with which it impinged.

§ 185. Suppose, now, $M=M'$, $e=1$; that is, let the balls be of equal mass, and their coefficient of restitution unity (or, in the usual but most misleading phraseology, suppose the balls to be "perfectly elastic"); then $2R=M(v-v')$; $v_1=v'$, and similarly $v_1'=v$; or the balls, whatever be their speeds, interchange them, and the motion is the same as if they had passed through one another without exerting any mutual action whatever.

Thus if a number of equal solitaire balls or billiard balls be arranged in contact in a horizontal groove, and another equal ball impinge on one extremity of the row, it is reduced to rest, and the ball at the other end of the row goes off with the original speed of impact. If two impinge, two go off, and so on.

§ 186. We may write the above expressions in terms of the impulse, thus

Conservation of momentum.

$$\left.\begin{aligned} v_1&=v-\frac{R(1+e)}{M}\\ v_1'&=v'+\frac{R(1+e)}{M'}\end{aligned}\right\}\quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

Hence $Mv_1+M'v_1'=Mv+M'v'$, whatever e be, or there is no momentum lost. This is, of course, a direct consequence of the third law of motion.

Again
$$\begin{aligned}\tfrac{1}{2}Mv_1^2+\tfrac{1}{2}M'v_1'^2&=\tfrac{1}{2}Mv^2+\tfrac{1}{2}M'v'^2\\ &\quad-R(1+e)(v-v')+\tfrac{1}{2}R^2(1+e)^2\frac{M+M'}{MM'}\\ &=\tfrac{1}{2}Mv^2+\tfrac{1}{2}M'v'^2-\tfrac{1}{2}R^2(1-e^2)\frac{M+M'}{MM'}\\ &=\tfrac{1}{2}Mv^2+\tfrac{1}{2}M'v'^2-\tfrac{1}{2}(1-e^2)\frac{MM'}{M+M'}(v-v')^2\,.\end{aligned}$$

Loss of energy.

The last term of the right hand side is therefore the kinetic energy apparently destroyed by the impact. When $e=0$, its magnitude is greatest, and equal to

$$\frac{1}{2}\frac{MM'}{M+M'}(v-v')^2=\tfrac{1}{2}R(v-v')\,.$$

When $e=1$, its magnitude is zero; that is, when the coefficient of restitution is unity no kinetic energy is lost.

The kinetic energy which appears to be destroyed in any of these cases is, as we see from § 171, only transformed—partly it may be into heat, partly into sonorous vibrations, as in the impact of a hammer on a bell. But, in spite of this, the elasticity may be "perfect." Hence the absurdity of the designation alluded to in § 185. Also by (2)

$$\begin{aligned}v_1'-v_1&=v'-v+R(1+e)\frac{M+M'}{MM'}\\ &=e(v-v')\ \text{by (1)}.\end{aligned}$$

Hence the velocity of separation is e times that of approach.

Oblique impact.

§ 187. *Two smooth spheres, moving in given paths and with given speeds, impinge; to determine the impulse and the subsequent motion.*

Let the masses of the spheres be M, M′, their speeds before impact v and v', and let the original directions of motion make with the line which joins the centres at the instant of impact the angles α, α', which may be calculated from the data, if the radii of the spheres be given.

Since the spheres are smooth, the entire impulse takes place in the line joining the centres at the instant of impact, and the future motion of each sphere will be in the plane passing through this line and its original direction of motion.

Let R be the impulse, e the coefficient of restitution; then, since the speeds in the line of impact are $v\cos\alpha$ and $v'\cos\alpha'$, we have for their final values v_1, v_1', after restitution, by § 184 the expressions

$$v_1=v\cos\alpha-\frac{M'}{M+M'}(1+e)(v\cos\alpha-v'\cos\alpha')\,,$$

$$v_1'=v'\cos\alpha'+\frac{M}{M+M'}(1+e)(v\cos\alpha-v'\cos\alpha')\,,$$

and the value of R is

$$\frac{MM'}{M+M'}(1+e)(v\cos\alpha-v'\cos\alpha')\,.$$

Hence, the sphere M has finally a speed v_1 in the line joining the centres, and a speed $v \sin \alpha$ in a known direction perpendicular to this, namely, in the plane through this and its original direction of motion. And similarly for the sphere M′. Thus the consequences of the impact are completely determined.

§ 188. When a sphere of mass M impinges directly, with speed V, on another M′ at rest, the speed acquired by M′ is

$$\frac{MV(1+e)}{M+M'}.$$

But, if another sphere of mass μ, also at rest, be interposed between them, M′ will acquire a speed

$$\frac{\mu MV(1+e)^2}{(M+\mu)(M'+\mu)}.$$

This is greatest when μ is the geometric mean of M and M′, and its value is then

$$\frac{MV(1+e)^2}{(\sqrt{M}+\sqrt{M'})^2}.$$

The ratio of this to the speed which M′ would have acquired without the interposition of the third sphere is

$$\frac{1+e}{1+\frac{2\sqrt{MM'}}{M+M'}}.$$

There is thus a gain by the interposition if, and only if,

$$e > \frac{2\sqrt{MM'}}{M+M'}.$$

This condition is always satisfied when the coefficient of restitution is unity, except in the special case of equal masses. If an infinite number of spheres be interposed between M and M′, so adjusted as to give the greatest possible speed to M′, that greatest speed is $V\sqrt{M'/M}$, provided we have $e=1$.

Continuous Succession of Indefinitely Small Impacts.

Infinite series of infinitesimal impacts. § 189. We may now consider the case of a continuous series of indefinitely small impacts, whose effect is comparable with that of a finite force. One obvious method of considering such a problem is to estimate *separately* the changes in the velocity produced by the finite forces and by the impacts, in the same indefinitely small time δt, and compound these for the actual effect on the motion in that period.

Another way, of course, is to equate the rate of increase of momentum per unit of time to the force producing it.

A mass, under no forces, moves through a uniform cloud of little particles which are at rest. Those it meets adhere to it. Find the motion.

At time t let μ be the mass, and let x denote its position in its line of motion. Then, as there is no loss of momentum, we have

$$\frac{d}{dt}(\mu\dot{x})=0.$$

But if M be the original mass, μ_0 the mass of the particles picked up in unit of length, obviously

$$\mu = M+\mu_0 x.$$

Substitute and integrate, supposing $x=0$, $\dot{x}=V$, when $t=0$; and we get

$$(M+\mu_0 x)\dot{x}=MV,$$

from which x can be easily found.

It is interesting to observe that we have

$$\ddot{x} = -\frac{\mu_0 M^2 V^2}{(M+\mu_0 x)^3};$$

so that the mass moves as if acted on by an attraction varying inversely as the cube of the distance from a point in its line of motion.

This problem obviously leads to the same result as the following:—*A cannon-ball attached to one end of a chain, which is coiled up on a smooth horizontal plane, is projected along the plane. Determine its motion.*

Rocket. § 190. Another excellent instance of the application of this process is furnished by the motion of a rocket, where the motive power depends on the fact that a portion of the mass is detached with considerable relative velocity. The increase of the momentum of the rocket due to this cause is equal to the relative momentum with which the products of combustion escape. If we suppose the rocket, originally of mass M, to lose eM in unit of time, projected from it with relative velocity V, the gain of momentum in time δt due to this cause is

$$eMV\delta t.$$

The total upward acceleration is therefore

$$\frac{eMV}{M-eMt}-g.$$

Unless this be positive the rocket cannot rise. It will rise at once if $V>g/e$, and it cannot rise at all unless $MV/M' > g/e$, M′ being the mass of the case, stick, &c., which are not burned away.

From the above data it is easy to calculate that the greatest speed acquired during the flight (the resistance of the air being left out of account) is

$$V\log\frac{M}{M'}-\frac{g}{e}\left(1-\frac{M'}{M}\right).$$

Dynamics of a System of Particles Generally.

§ 191. The law of energy, in abstract dynamics, may be expressed as follows:—the whole work done in any time, on any limited material system, by applied forces, is equal to the whole effect in the forms of potential and kinetic energy produced in the system, together with the work lost in friction. This principle may be regarded as comprehending the whole of abstract dynamics, because the conditions of equilibrium and of motion, in every possible case, may be derived from it. Motion of a system of particles.

§ 192. A material system, whose relative motions are unresisted by friction, is in equilibrium in any configuration if, and is not in equilibrium unless, the rate at which the applied forces perform work at the instant of passing through it is equal to that at which potential energy is gained, in every possible motion through that configuration. This is the celebrated principle of "virtual velocities," which Lagrange made the basis of his *Mécanique Analytique.* Condition of equilibrium. Virtual velocities.

§ 193. To prove it, we have first to remark that the system cannot possibly move away from any particular configuration except by work being done upon it by the forces to which it is subject; it is therefore in equilibrium if the stated condition is fulfilled. To ascertain that nothing less than this condition can secure the equilibrium, let us first consider a system having only one degree of freedom to move. Whatever forces act on the whole system, we may always hold it in equilibrium by a single force applied to any one point of the system in its line of motion, opposite to the direction in which it tends to move, and of such magnitude that, in any infinitely small motion in either direction, it shall resist or shall do as much work as the other forces, whether applied or internal, altogether do or resist. Now, by the principle of superposition of forces in equilibrium, we might, without altering their effect, apply to any one point of the system such a force as we have just seen would hold the system in equilibrium, and another force equal and opposite to it. All the other forces being balanced by one of these two, they and it might again, by the principle of superposition of forces in equilibrium, be removed; and therefore the whole set of given forces would produce the same effect, whether for equilibrium or for motion, as the single force which is left acting alone. This single force, since it is in a line in which the point of its application is free to move, must move the system. Hence the given forces, to which the single force has been proved equivalent, cannot possibly be in equilibrium unless their whole work for an infinitely small motion is nothing, in which case the single equivalent force is reduced to nothing. But whatever amount of freedom to move the whole system may have, we may always, by the application of frictionless constraint, limit it to one degree of freedom only; and this may be freedom to execute any particular motion whatever, possible under the given conditions of the system. If, therefore, in any such infinitely small motion there is variation of potential energy uncompensated by work of the applied forces, constraint limiting the freedom of the system to only this motion will bring us to the case in which we have just demonstrated there cannot be equilibrium. But the application of constraints limiting motion cannot possibly disturb equilibrium, and therefore the given system under the actual conditions cannot be in equilibrium in any particular configuration if the rate of doing work is greater than that at which potential energy is stored up in any possible motion through that configuration.

Neutral equilibrium.

§ 194. If a material system, under the influence of internal and applied forces, varying according to some definite law, is balanced by them in any position in which it may be placed, its equilibrium is said to be neutral. This is the case with any spherical body of uniform material resting on a horizontal plane. A right cylinder or cone, bounded by plane ends perpendicular to the axis, is also in neutral equilibrium on a horizontal plane. Practically, any mass of moderate dimensions is in neutral equilibrium when its centre of inertia only is fixed, since, when its longest dimension is small in comparison with the earth's radius, the action of gravity is, as we shall see (§ 222), approximately equivalent to a single force through this point.

Stable equilibrium.

§ 195. But if, when displaced infinitely little in any direction from a particular position of equilibrium, and left to itself, it commences and continues vibrating, without ever experiencing more than infinitely small deviation, in any one of its parts, from the position of equilibrium, the equilibrium in this position is said to be stable. A weight suspended by a string, a uniform sphere in a hollow bowl, a loaded sphere resting on a horizontal plane with the loaded side lowest, an oblate body resting with one end of its shortest diameter on a horizontal plane, a plank, whose thickness is small compared with its length and breadth, floating on water, are all cases of stable equilibrium,—if we neglect the motions of rotation about a vertical axis in the second, third, and fourth cases, and horizontal motion in general in the fifth, for all of which the equilibrium is neutral.

Unstable equilibrium.

§ 196. If, on the other hand, the system can be displaced in any way from a position of equilibrium, so that when left to itself it will not vibrate within infinitely small limits about the position of equilibrium, but will move farther and farther away from it, the equilibrium in this position is said to be unstable. Thus a loaded sphere resting on a horizontal plane with its load as high as possible, an egg-shaped body standing on one end, a board floating edgewise in water, would present, if they could be realized in practice, cases of unstable equilibrium.

§ 197. When, as in many cases, the nature of the equilibrium varies with the direction of displacement, if unstable for any possible displacement it is practically unstable on the whole. Thus a circular disk standing on its edge, though in neutral equilibrium for displacements in its plane, yet being in unstable equilibrium for those perpendicular to its plane, is practically unstable. A sphere resting in equilibrium on a saddle presents a case in which there is stable, neutral, or unstable equilibrium according to the direction in which it may be displaced by rolling; but practically it is unstable.

Energy test of equilibrium.

§ 198. The theory of energy shows a very clear and simple test for discriminating these characters, or determining whether the equilibrium is neutral, stable, or unstable, in any case. If there is just as much potential energy stored up as there is work performed by the applied and internal forces in any possible displacement, the equilibrium is neutral, but not unless. If in every possible infinitely small displacement from a position of equilibrium there is more potential energy stored up than work done, the equilibrium is thoroughly stable, and not unless. If in any or in every infinitely small displacement from a position of equilibrium there is more work done than energy stored up, the equilibrium is unstable. It follows that if the system is influenced only by internal forces, or if the applied forces follow the law of doing always the same amount of work upon the system while passing from one configuration to another by all possible paths, the whole potential energy must be constant in all positions for neutral equilibrium, must be a minimum for positions of thoroughly stable equilibrium, and must be either a maximum for all displacements or a maximum for some displacements and a minimum for others when there is unstable equilibrium.

Formation of general equation of motion.

§ 199. We have seen that, according to D'Alembert's principle, as explained above, forces acting on the different points of a material system, and their reactions against the accelerations which they actually experience in any case of motion, are in equilibrium with one another. Hence, in any actual case of motion, not only is the actual work by the forces equal to the kinetic energy produced in any infinitely small time, in virtue of the actual accelerations, but so also is the work which would be done by the forces, in any infinitely small time, if the velocities of the points constituting the system were at any instant changed to any possible infinitely small velocities, and the accelerations unchanged. This statement, when put into the concise language of mathematical analysis, constitutes Lagrange's application of the "principle of virtual velocities" to express the conditions of D'Alembert's equilibrium between the forces acting and the resistances of the masses to the acceleration. It comprehends, as we have seen, every possible condition of every case of motion. The "equations of motion" in any particular case are, as Lagrange has shown, deduced from it with great ease.

Commencing again with the equations of motion of a particle

$$m\ddot{x}=X+X',\ m\ddot{y}=Y+Y',\ m\ddot{z}=Z+Z',$$

let us introduce quantities δx, &c., consistent with the conditions, otherwise perfectly arbitrary, and we have the general equation

$$\Sigma m(\ddot{x}\delta x+\ .\ .\ .\ )=\Sigma(X\delta x+\ .\ .\ .\ ),$$

in which, by D'Alembert's principle, the forces X′, Y′, Z′, due to the constraints, do not appear.

If the system be conservative the right-hand member of this is, of course, equal to the loss of potential energy, so that

$$-\delta V=\Sigma(X\delta x+\ .\ .\ .\ ),$$

and therefore, quite generally in such a system,

$$\Sigma m(\ddot{x}\delta x+\ .\ .\ .\ )=-\delta V\ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ (1).$$

In the actual motion of any system we have, for each particle, $\delta x=\dot{x}\delta t$, &c., so that we have

$$\Sigma m(\dot{x}\ddot{x}+\dot{y}\ddot{y}+\dot{z}\ddot{z})=\Sigma(X\dot{x}+Y\dot{y}+Z\dot{z})\,.$$

This is the complete statement of Newton's scholium, § 2 above.

The right-hand member is the expression of the algebraic sum of the *actiones agentium* and of the *reactiones resistentium*, so far as these depend upon gravity, friction, &c., and the left-hand member that of the *reactiones* due to the accelerations of the several particles.

If the system be conservative, this becomes

$$\Sigma m(\dot{x}\ddot{x}+\dot{y}\ddot{y}+\dot{z}\ddot{z})=-\frac{dV}{dt}\,,$$

whose integral

$$\tfrac{1}{2}\Sigma m(\dot{x}^2+\dot{y}^2+\dot{z}^2)+V=H$$

is of course, the general statement of the conservation of energy.

In Lagrange's general equation above, as we have stated, the variations δx, &c., are not usually independent. We must take account of the various constraints imposed on the system. If these retain the same character throughout the motion they may be expressed by a (generally finite) number of equations of the form

$$f(x_1, y_1, z_1, x_2, y_2, z_2, \ldots) = 0 .$$

Each of these gives rise to a purely kinematical relation affecting some one or more of the quantities δx, &c., of the form

$$\Sigma\left(\left(\frac{df}{dx}\right)\delta x + \left(\frac{df}{dy}\right)\delta y + \ldots\right) = 0 .$$

By introducing, as usual, a set of undetermined multipliers μ, one for each of the conditions of constraint, we obtain on adding all these equations to the general equation above

$$\Sigma m(\ddot{x}\delta x + \ldots) = \Sigma\left[\left(X + \mu\left(\frac{df}{dx}\right) + \mu_1\left(\frac{df_1}{dx}\right) + \ldots\right)\delta x + \ldots\right] (2).$$

If there be p particles of the system, there are $3p$ coordinates x, y, z, connected by (say) q equations of constraint, so that there are $3p-q$ degrees of freedom, and therefore $3p-q$ independent coordinates.

Equating separately to zero the multipliers of δx_1, δy_1, &c., in the resultant equation above, we have $3p$ equations of which we write only one as a type, viz.,

$$m\ddot{x} = X + \Sigma\mu\left(\frac{df}{dx}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Taken along with the q equations of the form

$$f = 0$$

these form a group of $3p+q$ equations, theoretically necessary and sufficient to determine the $3p$ quantities x_1, y_1, z_1, &c., and the q quantities μ, in terms of t. Thus we have the complete analytical statement of the conditions, and the rest of the solution is a question of pure mathematics.

Non-conservative system. When we deal with a non-conservative system (which is equivalent in nature to saying "when we take an incomplete view of the question"), some of the conditions may vary in character during the motion. This will be expressed analytically by the entrance of t explicitly into one or more of the equations of condition f. But, if we think of the mode of formation of Lagrange's equation, we see that it was built up of separate equations, such as

$$m\ddot{x} = X + X',$$

which are true whether the equations of condition involve t explicitly or not. Each of these was multiplied by a quantity δx, &c., the only limitation on which was that it should be consistent with the conditions of the system at the instant considered, whatever instant that might be. Hence equation (2) still holds good.

When, however, we introduce in that equation multipliers corresponding to the actual motion of the system, so that

$$\delta x = \dot{x}\delta t , \text{ \&c.},$$

we find a remarkably simple expression for the energy given to, or withdrawn from, the system in consequence of the varying conditions. For the unintegrated equation (2) now becomes

$$\frac{d}{dt}\left(\tfrac{1}{2}\Sigma m(\dot{x}^2 + \dot{y}^2 + \dot{z}^2)\right) = \Sigma(X\dot{x} + Y\dot{y} + Z\dot{z}) - \Sigma\mu\left(\frac{df}{dt}\right) ,$$

where the differential coefficient of f is partial. This follows at once from equations of the form

$$\frac{df}{dt} = \left(\frac{df}{dt}\right) + \left(\frac{df}{dx}\right)\dot{x} + \text{\&c.} = 0 ,$$

which are obtained by differentiating the equations of condition with regard to t. When the conditions do not vary, the quantities $\left(\frac{df}{dt}\right)$, &c., all vanish, and we see that the constraint does not alter the energy of the system.

Least and Varying Action.

Action. § 200. To complete our sketch of kinetics of a particle we will now briefly consider the important quantity called "action." This, for a single particle, may be defined either as the space integral of the momentum or as double the time integral of the kinetic energy, calculated from any assumed position of the moving particle, or from an assigned epoch. For a system its value is the sum of its separate values for the various particles of the system. No one has, as yet, pointed out (in the simple form in which it is all but certain that they can be expressed) the true relations of this quantity. It was originally introduced into kinetics to suit the metaphysical necessity that something should be a minimum in the path of a luminous corpuscle (see an extract from Hamilton in the article LIGHT, vol. xiv. p. 598). But there can be little doubt that it is destined to play an important part in the final systematizing of the fundamental laws of kinetics.

The importance of the quantity called action, so far as is at present known, depends upon the two principles of "least action" and of "varying action," the first as old as Maupertuis, the other discovered by Hamilton about half a century ago.

The first is—*If the sum of the potential and kinetic energies of a system is the same in all its configurations, then, of all the sets of paths by which the parts of the system can be guided by frictionless constraint to pass from one given configuration to another, that one for which the action is least is the natural one or requires no constraint.* Least action.

§ 201. Unfortunately it is not easy to give examples of this important principle which can be satisfactorily treated by elementary methods,—except, indeed, the very simplest, such as those furnished by the corpuscular theory of light. Thus it is obvious that, as long as a medium is homogeneous and isotropic, the speed of a corpuscle in it is constant. The action is thus reduced to the product of the constant speed of the corpuscle by the length of its path. Hence the principle at once shows that the path must be a straight line. When the corpuscle is refracted from one such medium into another, the path is a broken line such that the product of each of its parts by the corresponding speed of the corpuscle is the least possible. This gives the law of the sines, but to agree with experiment the speed would have to be greater in the denser medium than in the rarer.

§ 202. The problem *to find change of action as depending on change (nowhere finite) of the mode of passage from one given configuration to another* (restricted by the condition already mentioned), is expressed mathematically by Change of action.

$$\delta A = \delta\int\Sigma m\dot{s}ds = \delta\int\Sigma m(\dot{x}dx + \dot{y}dy + \dot{z}dz) ,$$

while $\quad T = \tfrac{1}{2}\Sigma m\dot{s}^2 = \tfrac{1}{2}\Sigma m(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) = H - V ,$

H being the constant energy of the system, and the integral being taken between limits supplied by the two given configurations.

The first equation gives

$$\delta A = \int\Sigma m(dx\delta\dot{x} + dy\delta\dot{y} + dz\delta\dot{z} + \dot{x}d\delta x + \dot{y}d\delta y + \dot{z}d\delta z)$$
$$= \Sigma m(\dot{x}\delta x + \ldots) + \int\Sigma m(dx\delta\dot{x} + dy\delta\dot{y} + dz\delta\dot{z} - d\dot{x}\delta x - d\dot{y}\delta y - d\dot{z}\delta z)$$

by partial integration. But the integrated part

$$\Sigma m(\dot{x}\delta x + \dot{y}\delta y + \dot{z}\delta z), \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

obviously vanishes at both limits, because the initial and final configurations are given.

If we now take the corresponding variation of the expressions for the kinetic energy, we have

$$\delta T = \Sigma m\dot{s}\delta\dot{s} = \Sigma m(\dot{x}\delta\dot{x} + \dot{y}\delta\dot{y} + \dot{z}\delta\dot{z}),$$

from which we have

$$\int\Sigma m(dx\delta\dot{x} + dy\delta\dot{y} + dz\delta\dot{z}) = \int\delta T dt .$$

Also we have

$$d\dot{x}\delta x + d\dot{y}\delta y + d\dot{z}\delta z = (\ddot{x}\delta x + \ddot{y}\delta y + \ddot{z}\delta z)dt ;$$

so that finally

$$\delta A = \int dt\left[\delta T - \Sigma m(\ddot{x}\delta x + \ddot{y}\delta y + \ddot{z}\delta z)\right] ,$$

which so far is a mere kinematical result. But it can be rendered physical by putting $-\delta V$ for δT, in accordance with the above condition. This we will suppose done.

If now we desire to make δA vanish, so as to obtain what is called the "stationary condition," we must make the factor in square brackets in the integral vanish; *i.e.*, we must have

$$\Sigma m(\ddot{x}\delta x + \ddot{y}\delta y + \ddot{z}\delta z) + \delta V = 0$$

for all admissible simultaneous values of δx, δy, δz for the various particles of the system. But this is precisely the general equation which, as we found in § 199 (1), determines the undisturbed motion of the system.

§ 203. The expression $\delta A = 0$ really signifies that any infinitesimal change from the natural mode of passage produces an infinitely smaller change in the corresponding amount of the action between the terminal configurations. Stationary action.

§ 204. It will be noticed that the essential characteristic of the modes of passage considered in this investigation is that all shall have the same terminal configurations, and that the system shall

Varying action.

always have the same definite amount of energy. All, except the natural mode of passage, in general require constraint in order that they may be described. Hamilton's grand extension of the subject depended on comparing the actions in a number of *natural* modes of passage, differing from one another by slight changes in their terminal configurations, and slight changes in the whole initial energy.

In this new form of statement the unintegrated part of the expression for δA vanishes, since all the modes of passage contemplated are natural. The alteration of the whole energy, however, adds a special term to the equation, and we can at once write, from the expression (A) § 202, the equation for the change in the action under the new conditions, viz.,

$$\delta A = \left[\Sigma m(\dot{x}\delta x + \dot{y}\delta y + \dot{z}\delta z)\right] + t\delta H,$$

the part in brackets having to be taken between limits corresponding to the terminal configurations, and the variations δx, δy, δz at these being subject to the conditions of the system.

We cannot here consider this equation in its general form. We content ourselves with the simpler special deductions from it required for completing our sketch of Kinetics of a Particle.

The last given equation, written in full for a single particle of unit mass, is

$$\delta A = [\dot{x}\delta x + \dot{y}\delta y + \dot{z}\delta z] - (\dot{x}_0\delta x_0 + \dot{y}_0\delta y_0 + \dot{z}_0\delta z_0) + t\delta H,$$

where x_0, y_0, z_0 is the initial point, and x, y, z any other point, of the path. If the particle be altogether free, the seven variations on the right-hand side are independent of one another; and thus we have the following remarkable properties of the quantity A, regarded as a function of seven independent variables (the initial and final coordinates of the particle, and its constant energy), viz.,

$$\left(\frac{dA}{dx}\right) = \frac{dx}{dt}, \quad \left(\frac{dA}{dx_0}\right) = -\frac{dx_0}{dt},$$

$$\left(\frac{dA}{dy}\right) = \frac{dy}{dt}, \quad \left(\frac{dA}{dy_0}\right) = -\frac{dy_0}{dt},$$

$$\left(\frac{dA}{dz}\right) = \frac{dz}{dt}, \quad \left(\frac{dA}{dz_0}\right) = -\frac{dz_0}{dt},$$

$$\left(\frac{dA}{dH}\right) = t.$$

From these we gather at once that A satisfies the partial differential equations

$$\left(\frac{dA}{dx}\right)^2 + \left(\frac{dA}{dy}\right)^2 + \left(\frac{dA}{dz}\right)^2 = v^2 = 2(H - V) \quad . \quad . \quad (1),$$

$$\left(\frac{dA}{dx_0}\right)^2 + \left(\frac{dA}{dy_0}\right)^2 + \left(\frac{dA}{dz_0}\right)^2 = v_0^2 = 2(H - V_0) \quad . \quad . \quad (2).$$

Characteristic function.

§ 205. The whole circumstances of the motion are thus dependent on the function A, called by Hamilton the "characteristic function." The determination of this function is troublesome, even in very simple cases of motion; but the fact that such a mode of representation is possible is extremely remarkable.

§ 206. More generally, omitting all reference to the initial point, and the equation § 204 (2) which belongs to it, let us consider A simply as a function of x, y, z. Then

Any function, A, which satisfies the partial differential equation

$$\left(\frac{dA}{dx}\right)^2 + \left(\frac{dA}{dy}\right)^2 + \left(\frac{dA}{dz}\right)^2 = v^2 = 2(H - V) \quad . \quad . \quad . \quad (1),$$

possesses the property that $\frac{dA}{dx}, \frac{dA}{dy}, \frac{dA}{dz}$ *represent the rectangular components of the velocity of a particle in a motion possible under the forces whose potential is V.*

For, by partial differentiation of (1) we have

$$\frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2} = X = -\frac{dV}{dx} = \frac{dA}{dx}\frac{d^2A}{dx^2} + \frac{dA}{dy}\frac{d^2A}{dxdy} + \frac{dA}{dz}\frac{d^2A}{dxdz},$$

with other two equations of the same form.

But we have also three equations of the form

$$\frac{d}{dt}\left(\frac{dA}{dx}\right) = \frac{dx}{dt}\frac{d^2A}{dx^2} + \frac{dy}{dt}\frac{d^2A}{dxdy} + \frac{dz}{dt}\frac{d^2A}{dxdz}.$$

Comparing, we see that

$$\frac{dx}{dt} = \frac{dA}{dx}, \quad \frac{dy}{dt} = \frac{dA}{dy}, \quad \frac{dz}{dt} = \frac{dA}{dz}$$

satisfy simultaneously the two sets of equations.

§ 207. Also if α, β be constants, which, along with H, are involved in a complete integral of the above partial differential equation *the corresponding path, and the time of its description, are given by*

$$\left(\frac{dA}{d\alpha}\right) = \alpha_1, \quad \left(\frac{dA}{d\beta}\right) = \beta_1, \quad \left(\frac{dA}{dH}\right) = t + \epsilon,$$

where α_1, β_1, ϵ *are three additional arbitrary constants.*

For these equations give, by complete differentiation with regard to t,

$$\left.\begin{aligned} \frac{d^2A}{dxd\alpha}\frac{dx}{dt} + \frac{d^2A}{dyd\alpha}\frac{dy}{dt} + \frac{d^2A}{dzd\alpha}\frac{dz}{dt} &= 0 \\ \frac{d^2A}{dxd\beta}\frac{dx}{dt} + \frac{d^2A}{dyd\beta}\frac{dy}{dt} + \frac{d^2A}{dzd\beta}\frac{dz}{dt} &= 0 \\ \frac{d^2A}{dxdH}\frac{dx}{dt} + \frac{d^2A}{dydH}\frac{dy}{dt} + \frac{d^2A}{dzdH}\frac{dz}{dt} &= 1 \end{aligned}\right\} \quad . \quad . \quad . \quad (a).$$

But, differentiating § 206 (1) with respect to α, β, H respectively, we get

$$\left.\begin{aligned} \frac{d^2A}{d\alpha dx}\frac{dA}{dx} + \frac{d^2A}{d\alpha dy}\frac{dA}{dy} + \frac{d^2A}{d\alpha dz}\frac{dA}{dz} &= 0 \\ \frac{d^2A}{d\beta dx}\frac{dA}{dx} + \frac{d^2A}{d\beta dy}\frac{dA}{dy} + \frac{d^2A}{d\beta dz}\frac{dA}{dz} &= 0 \\ \frac{d^2A}{dHdx}\frac{dA}{dx} + \frac{d^2A}{dHdy}\frac{dA}{dy} + \frac{d^2A}{dHdz}\frac{dA}{dz} &= 1 \end{aligned}\right\} \quad . \quad . \quad . \quad (b).$$

The values of $\frac{dx}{dt}$, &c., in (a) are evidently equal respectively to those of $\frac{dA}{dx}$, &c., in (b). Hence the proposition.

§ 208. "Equiactional surfaces," *i.e.*, those whose common equation is — Surfaces of equal action.

$$A = \text{const.},$$

are cut at right angles by the trajectories.

For the direction cosines of the normal are obviously proportional to

$$\left(\frac{dA}{dx}\right), \left(\frac{dA}{dy}\right), \left(\frac{dA}{dz}\right), \text{ that is, to } \frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt}.$$

Thus the determination of equiactional surfaces is resolved into the problem of finding the orthogonal trajectories of a set of given curves in space, whenever the conditions of the motion are given.

The distance between consecutive equiactional surfaces is, at any point, inversely as the velocity in the corresponding path.

This may be seen at once as follows: the element of the action, which is the same at all points, is $v\delta s$ (where δs, being an element of the path, is the normal distance between the surfaces).

§ 209. In consequence of the importance of the method we will take two examples of its application. First a direct example, then one depending on the equiactional surfaces. — Planetary motion.

To deduce from the principle of "varying action" the form and mode of description of a planet's orbit.

In this case it is obvious that $-\frac{dV}{dr}$ represents the attraction of gravity ($-\mu/r^2$). Hence the right-hand member of § 206 (1) may be written $2(H + \mu/r)$.

Let us take the plane of xy as that of the orbit, then the equation § 206 (1) becomes

$$v^2 = \left(\frac{dA}{dx}\right)^2 + \left(\frac{dA}{dy}\right)^2 = 2\left(H + \frac{\mu}{r}\right) \quad . \quad . \quad . \quad . \quad (1).$$

It is not difficult to obtain a satisfactory solution of this equation, but the operation is very much simplified by the use of polar coordinates. With this change, (1) becomes

$$\left(\frac{dA}{dr}\right)^2 + \frac{1}{r^2}\left(\frac{dA}{d\theta}\right)^2 = 2\left(H + \frac{\mu}{r}\right) \quad . \quad . \quad . \quad . \quad (2),$$

which is obviously satisfied by

$$\left.\begin{aligned} \left(\frac{dA}{d\theta}\right) &= \text{constant} = \alpha, \\ \left(\frac{dA}{dr}\right)^2 &= 2\left(H + \frac{\mu}{r}\right) - \frac{\alpha^2}{r^2} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (3).$$

Hence $$A = \alpha\theta + \int dr\sqrt{2(H + \mu/r) - \alpha^2/r^2} \quad . \quad . \quad . \quad . \quad (4).$$

The final integrals are therefore, by § 207,

$$\left(\frac{dA}{d\alpha}\right) = \alpha_1 = \theta - \alpha\int\frac{dr}{r^2\sqrt{2(H + \mu/r) - \alpha^2/r^2}} \quad . \quad . \quad . \quad (5),$$

and $$\left(\frac{dA}{dH}\right) = t + \epsilon = \int\frac{dr}{\sqrt{2(H + \mu/r) - \alpha^2/r^2}} \quad . \quad . \quad . \quad (6).$$

These equations contain the complete solution of the problem, for they involve four constants, α_1, α, H, ϵ. (5) gives the equation of the orbit, and (6) the time in terms of the radius-vector.

To complete the investigation, let us assume

$$\mu/\alpha^2 = 1/l, \qquad 2H/\alpha^2 = (e^2 - 1)/l^2,$$

where l and e are two new arbitrary constants introduced in place of α and H. With these (5) becomes

$$\alpha_1=\theta-\int\frac{dr}{r^2\sqrt{(e^2-1)/l^2+2/lr-1/r^2}}$$

$$=\theta-\int\frac{dr}{r^2\sqrt{e^2/l^2-(1/r-1/l)^2}}=\theta-\cos^{-1}\frac{l}{e}(r^{-1}-l^{-1}),$$

or

$$r=\frac{l}{1+e\cos(\theta-\alpha_1)},$$

the general polar equation of conic sections referred to the focus.

Also by differentiating (5) with respect to r, we have

$$\frac{\alpha dr}{r^2\sqrt{2(\mathrm{H}+\mu/r)-\alpha^2/r^2}}=d\theta,$$

from which, by (6), we immediately obtain

$$t+\epsilon=\frac{1}{\alpha}\int r^2d\theta=\frac{1}{\sqrt{\mu l}}\int r^2 d\theta.$$

This involves, again, the equation of equable description of areas. Compare § 144.

Action in orbit of planet. § 210. In a planet's elliptic orbit *the time is measured by the area described about one focus, and the action by that described about the other.*

For with the usual notation we have

$$d\mathrm{A}=vds=\frac{h}{p}ds,$$

by the result of § 47. But in the ellipse or hyperbola, p' being the perpendicular from the second focus,

$$pp'=\pm b^2.$$

Hence

$$d\mathrm{A}=\pm\frac{h}{b^2}p'ds,$$

which expresses the result stated above.

It is easy to extend this to a parabolic orbit, for which, indeed, the theorem is even more simple.

Example. § 211. *Unit particles are projected simultaneously and horizontally in all directions from every point of a vertical axis, all having the same total energy at starting; find the surfaces of equal action.*

We may obviously confine ourselves to a plane section through the axis. Let x be the vertical coordinate of a particle, measured downwards from the level at which the common energy is wholly potential, k the coordinate of the point in the axis from which it was projected. Then we have, after the lapse of time t,

$$\left.\begin{aligned}x&=k+\tfrac{1}{2}gt^2\\ y&=\sqrt{2gk}\,t\end{aligned}\right\}.$$

Eliminating t, we have the equation of the parabolic path—

$$x=k+\frac{y^2}{4k}.$$

To find the orthogonal trajectory (the meridian section of the surface of equal action), differentiate, put $-\frac{dx}{dy}$ for $\frac{dy}{dx}$, and eliminate k. We thus have

$$-\frac{dy}{dx}=\frac{y}{2k}=\frac{y}{x+\sqrt{x^2-y^2}}=\frac{\sqrt{x+y}-\sqrt{x-y}}{\sqrt{x+y}+\sqrt{x-y}}$$

or

$$-\sqrt{x+y}(dx+dy)+\sqrt{x-y}(dx-dy)=0,$$

so that

$$(x+y)^{\frac{3}{2}}\pm(x-y)^{\frac{3}{2}}=\text{const}.$$

If we turn the axes through $\frac{1}{4}\pi$ in their own plane, the coordinates being now ξ and η, this equation becomes

$$\xi^{\frac{2}{3}}+\eta^{\frac{2}{3}}=a^{\frac{2}{3}}.$$

In fig. 55, AM is the axis. A few of the paths are shown by full lines, and two of the sections of surfaces of equal action by dotted lines. These sections indicate cusps lying on the line AH, which makes an angle $\frac{1}{4}\pi$ with the vertical, and is touched by all the paths. The path whose vertex is G touches this line in H, and therefore passes through the cusp of which the branches are HK and HL. HK belongs to all paths whose vertices are above G, HL to those (such as ML) whose vertices are below G.

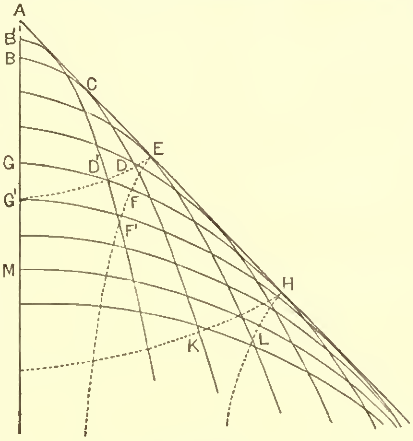


Fig. 55.

It is worthy of note that, by the first equations above,

$$x\pm y=(\sqrt{k}\pm\sqrt{\tfrac{1}{2}g}.t)^2,$$

by the substitution of which in the equation of action we see how the time of reaching a particular surface of equal action depends upon the position of the starting point.

Plane currents. § 212. A very interesting plane example, which has elegant applications in fluid motion, and in the conduction of electric currents in plates of uniform thickness, is furnished by assuming

$$\mathrm{A}=\log r,\ \text{or}\ \mathrm{A}'=\theta,$$

where r and θ are the polar coordinates of the moving particle.

In the former, where the curves of equal action are circles with the origin as centre, we have

$$\frac{d\mathrm{A}}{dx}=\dot{x}=\frac{x}{r^2},\qquad \frac{d\mathrm{A}}{dy}=\dot{y}=\frac{y}{r^2},$$

so that the paths are radii vectores described with velocity $1/r$. Also we have

$$2(\mathrm{H}-\mathrm{V})=\left(\frac{d\mathrm{A}}{dx}\right)^2+\left(\frac{d\mathrm{A}}{dy}\right)^2=\frac{1}{r^2};$$

so that the force is central, and its value is

$$-\frac{d\mathrm{V}}{dr}=-\frac{1}{r^3}.$$

In the second case, where the curves of equal action are radii drawn from the pole and

$$\mathrm{A}'=\theta=\tan^{-1}\frac{y}{x},$$

we have

$$\frac{d\mathrm{A}'}{dx}=\dot{x}=-\frac{y}{r^2},\quad \frac{d\mathrm{A}'}{dy}=\dot{y}=\frac{x}{r^2}.$$

The kinetic energy is still $1/2r^2$, and the central force $-1/r^3$, but the paths are circles with the origin as centre. Thus the lines of equal action and the paths of individual particles are convertible.

We have also, in each of these cases,

$$\left(\frac{d\dot{x}}{dx}\right)+\left(\frac{d\dot{y}}{dy}\right)=0.$$

This shows (as in § 94) that, whatever be originally the grouping of a set of particles moving all according to one or other of these conditions, the density at any part of the group remains unchanged during the motion. In fact, as it is easy to prove, A and A′ are elementary solutions of the partial differential equation

$$\frac{d^2\mathrm{A}}{dx^2}+\frac{d^2\mathrm{A}}{dy^2}=0\quad .\ .\ .\ .\ .\ .\ .\quad (1);$$

and they are conjugate, in the sense that

$$\frac{d\mathrm{A}}{dx}=\frac{d\mathrm{A}'}{dy},\quad \frac{d\mathrm{A}}{dy}=-\frac{d\mathrm{A}'}{dx}.$$

For this reason the paths belonging to the two systems are everywhere orthogonal to one another.

Also, as the differential equation (1) for A is linear, any linear function of particular integrals is an integral. Thus, for instance, we may take (p being any constant)

$$\mathrm{A}=\log r-p\theta,$$

with

$$\mathrm{A}'=p\log r+\theta.$$

These, representing orthogonal sets of logarithmic spirals, possess the same properties with regard to action as did the concentric circles and their radii, which, in fact, are the mere particular case when $p=0$.

Graphic method. § 213. It is easy to give graphic methods of tracing these curves of action by means of an old process recently much developed by Clerk Maxwell. The present example, though a very simple one, is quite sufficient to illustrate the process.

Draw, as in fig. 56, a set of circles whose radii are ε^{a}, ε^{2a}, ε^{3a}, &c., and a set of radii vectores making with the initial line the successive angles, $\frac{a}{p}$, $2\frac{a}{p}$, $3\frac{a}{p}$, &c., a being a quantity which may have any convenient value. These lines will form a network, finer as a is smaller. Now suppose we wish to trace the curve

$$\mathrm{A}=na.$$

We take the intersection of the circle whose radius is ε^{sa} with the radius-vector corresponding to the angle

$$(s-n)\frac{a}{p}.$$

Thus we have for the value of A at the point of intersection

$$\mathrm{A}=\log\varepsilon^{sa}-p\frac{s-n}{p}a$$

$$=na,\ \text{as required}.$$

By marking the intersections corresponding to different values of s, we have a series of points in the required curve which, by adjustment of the value of a, may be made to lie as close together as is found necessary for tracing the curve of action through them *libera manu*.

In fig. 56 portions of three separate sets of mutually orthogonal logarithmic spirals have been traced, by using the intersections of the fundamental straight lines and circles.

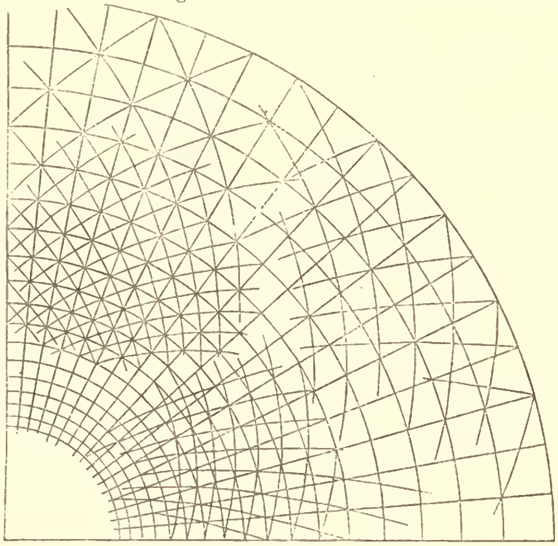


Fig. 56.

We may pursue the subject much farther, by combining particular solutions like those given but taken from different origins. We can afford space for one only. Let P, Q (fig. 57) be points on the axis of x, distant a and $-a$ from the origin, R any point in the plane of the figure. Let $PR=r$, $\angle RPx=\theta$, $RQ=r_1$, $\angle RQx=\theta_1$. Then if

$$A=\log r-\log r_1\,,$$
$$A'=\theta-\theta_1\,,$$

we must have, not only the equation

$$\frac{d^2A}{dx^2}+\frac{d^2A}{dy^2}=0$$

satisfied by each of A and A′, but also the conditions

$$\frac{dA}{dx}=\frac{dA'}{dy}\,,\quad \frac{dA}{dy}=-\frac{dA'}{dx}\,.$$

This follows at once from the fact that all the equations are linear.

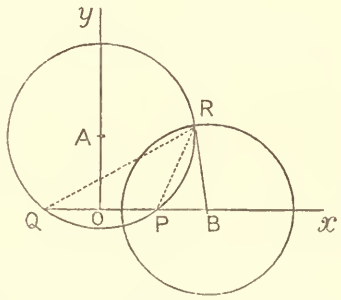


Fig. 57.

§ 214. In fig. 57 we have $\epsilon^A=PR/QR$. Hence the locus of R is a circle, whose centre, B, is on QP produced.

Again $A'=\angle RPx-\angle RQx=\angle PRQ$. The locus of R is, in this case, any circle passing through P and Q.

These circles evidently cut one another orthogonally in R; for BR, which is a radius of the one, is a tangent to the other.

Thus particles moving in a plane, so that the speed at any point R is inversely as PR . RQ, may describe circles in which PQ is a chord. In this case the curves of equal action are circles defined by the condition that the ratio PR : RQ is constant. Or they may move in the latter system of circles, in which case the former system gives the lines of equal action. For the equations in the preceding section give

$$v^2=\left(\frac{dA}{dx}\right)^2+\left(\frac{dA}{dy}\right)^2=\left(\frac{dA'}{dx}\right)^2\quad\left(\frac{dA'}{dy}\right)^2=\frac{4a^2}{r^2r_1^2}\,;$$

from which the conclusion is obvious.

We may easily extend this example to other sets of orthogonal curves whose equations are

$$A_1=pA+A',$$
$$A_1'=-A+pA',$$

where A and A′ have their recent values. Or we may extend the example by assuming at starting

$$A=m\log r-m_1\log r_1\,,$$

in which case it will be found that we must have

$$A'=m\theta-m_1\theta_1\,.$$

These pairs may again be combined into

$pA+A'$ and $-A+pA'$, and so on.

It will be noticed that in these examples the curves of equal action and the paths of the particles correspond in steady fluid motion to curves of equal pressure and lines of flow, and in electric conduction to equipotential lines and current lines. In such cases in fact, where there is no vortex-motion, the action is closely analogous to what is called the "velocity potential" in a fluid. Analogy between action and velocity potential.

Generalized Coordinates.

§ 215. By the help of the result already obtained in connexion with least action, we may easily obtain in a simple, though indirect, way the remarkable transformation of the equations of motion of a system which was first given by Lagrange. We are not prepared to give here the transformation to *Generalized Coordinates* in its most general form; but, even in the restricted form to which we proceed, it is almost invaluable in the treatment of the motion of conservative systems of particles in which the number of degrees of freedom is less than three times that of the particles. The one point to be noticed is that, when we restrict ourselves to a system of this kind, the expression for the kinetic energy, T, is necessarily a pure quadratic function of the rates of increase of the generalized coordinates. This is obvious from § 19. Repeating with generalized coordinates the investigation of § 202, we have Generalized coordinates.

$$A=2\int Tdt=\int(T+H-V)dt.$$

Hence
$$\delta A=\int(\delta T+\delta H-\delta V)dt\,.$$

Now let θ, ϕ, ψ, &c., be the generalized coordinates, and we have

$$2T=P\dot\theta^2+2Q\dot\theta\dot\phi+R\dot\phi^2+\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.$$

where P, Q, R, . . . are in general functions of θ, ϕ, ψ, . . . Of course V is a function of θ, ϕ, ψ . . . alone, and does not involve $\dot\theta$, $\dot\phi$, $\dot\psi$, &c.

Thus we have, writing for one only of the generalized coordinates,

$$\delta A=\Sigma\int\left(\left(\frac{dT}{d\dot\theta}\right)\delta\dot\theta+\left(\frac{dT}{d\theta}\right)\delta\theta-\left(\frac{dV}{d\theta}\right)\delta\theta\right)dt+t\delta H$$

$$=\Sigma\left(\frac{dT}{d\dot\theta}\delta\theta\right)+t\delta H-\int dt\Sigma\left[\left(\frac{d}{dt}\left(\frac{dT}{d\dot\theta}\right)-\frac{dT}{d\theta}+\frac{dV}{d\theta}\right)\delta\theta\right]\,.$$

But we saw that, for any natural motion, the unintegrated part of δA necessarily vanishes. Thus, as θ, ϕ, ψ . . . . , and, therefore, their variations, are by their very nature independent of one another, the vanishing of the unintegrated part gives us one equation of motion for each degree of freedom, the type being in all of them the same, viz.,

$$\frac{d}{dt}\left(\frac{dT}{d\dot\theta}\right)-\left(\frac{dT}{d\theta}\right)+\left(\frac{dV}{d\theta}\right)=0.$$

To exemplify the use of these equations we will take again a few of the more important cases of constraint already treated, and will then proceed to some others of interest as well as of somewhat greater complexity. Examples.

In the simple pendulum, l being again the length of the string, and θ the inclination to the vertical at time t, we have obviously

$$T=\tfrac{1}{2}ml^2\dot\theta^2,\quad V=C-mgl\cos\theta\,.$$

Hence
$$\left(\frac{dT}{d\dot\theta}\right)=ml^2\dot\theta\,,\quad\left(\frac{dT}{d\theta}\right)=0\,,\quad\left(\frac{dV}{d\theta}\right)=mgl\sin\theta\,.$$

Thus the equation of motion is

$$ml^2\ddot\theta+mgl\sin\theta=0$$

or
$$\ddot\theta+\frac{g}{l}\sin\theta=0\,,$$

as in § 134.

Suppose the same pendulum to be moving anyhow, θ still denoting its inclination to the vertical, and ϕ denoting the azimuth of the plane in which it is displaced, we have

$$T=\tfrac{1}{2}ml^2(\dot\theta^2+\sin^2\theta.\dot\phi^2)\,,\quad V=C-mgl\cos\theta$$

These give at once

$$\left(\frac{dT}{d\dot\theta}\right)=ml^2\dot\theta,\quad\left(\frac{dT}{d\theta}\right)=ml^2\sin\theta\cos\theta.\dot\phi^2,\quad\left(\frac{dV}{d\theta}\right)=mgl\sin\theta\,,$$

$$\left(\frac{dT}{d\dot\phi}\right)=ml^2\sin^2\theta.\dot\phi,\quad\left(\frac{dT}{d\phi}\right)=0,\quad\left(\frac{dV}{d\phi}\right)=0.$$

Hence the two equations are

$$\ddot\theta-\sin\theta\cos\theta.\dot\phi^2+\frac{g}{l}\sin\theta=0\,,$$

$$\frac{d}{dt}(\sin^2\theta.\dot\phi)=0.$$

Pendulum with extensible cord. Still keeping to easy examples, suppose the cord of the ordinary simple pendulum to be extensible, according to Hooke's law. Let λ be its length at time t. Then the tension is $E(\lambda - l)/l$, and the work it can do in contracting is the integral of this with regard to λ from l to λ, *i.e.*,

$$E(\lambda - l)^2/2l .$$

Hence we have
$$V = C + E(\lambda - l)^2/2l - mg\lambda\cos\theta ,$$
$$T = \tfrac{1}{2}m(\lambda^2\dot\theta^2 + \dot\lambda^2) .$$

Thus Lagrange's equations become

$$\frac{d}{dt}(\lambda^2\dot\theta) + g\lambda\sin\theta = 0 ,$$
$$m\ddot\lambda - m\lambda\dot\theta^2 + E(\lambda - l)/l - mg\cos\theta = 0 ;$$

equations which could be obtained immediately from the application of the second law, with the help of the kinematical expressions for acceleration perpendicular to, and along, the radius-vector of a plane curve (§ 47).

Instead of the complex pendulum treated in § 177, we will now take the case of two masses attached at different points to an elastic string, or light helical spring, and consider their *vertical* vibrations.

Let a, b be the unstretched lengths of the parts of the string, M and m the masses. Then if ξ, η be the vertical displacements at time t, we have

$$T = \tfrac{1}{2}(M\dot\xi^2 + m(\dot\xi + \dot\eta)^2) ,$$
$$V = \frac{E}{2}\left(\frac{\xi^2}{a} + \frac{\eta^2}{b}\right) - Mg\xi - mg(\xi + \eta) ;$$

so that Lagrange's equations are

$$\frac{d}{dt}(M\dot\xi + m(\dot\xi + \dot\eta)) + E\frac{\xi}{a} - (M + m)g = 0 ,$$
$$\frac{d}{dt}(m(\dot\xi + \dot\eta)) + E\frac{\eta}{b} - mg = 0 .$$

The equilibrium positions are found by supposing the accelerations to vanish, so that, if we suppose ξ and η to be measured from them, the terms in g will disappear. Hence the solution is of exactly the same nature as that already given for an apparently different problem (§ 178).

Setting a watch. We may mention that equations practically the same as these are obtained when we consider the motions of a watch and its balance-wheel, the watch being supported in a horizontal position by means of a wire, and oscillating in its own plane by the torsion-elasticity of the wire. The reader of § 242 below will have no difficulty in obtaining this result. It suggests a practical method of "setting" a watch to true time, without turning the hands forward or backward, and without letting it run down.

Transference of energy. The following is a simple, but very instructive, example of the transference of energy (back and forward) between two parts of a system. Two bar-magnets of equal mass, length, and strength (fig. 58), are supported horizontally by pairs of parallel strings, so that when at rest they are in one line. One of them is slightly displaced in the direction of its length, find the subsequent motion of both.[1]

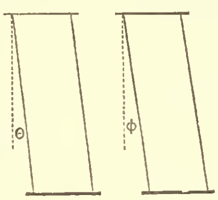


Fig. 58.

If we can, by any process, find two fundamental states of motion which, once established, will be permanent, any other possible motion of the system will be a superposition of these two. The amplitudes and phases in the components may have any values, so long as the whole disturbance is small. This follows from the fact that the system has two degrees of freedom only,—since we are concerned only with motions in the plane of the figure.

(A) Now one obviously possible motion is a simple harmonic vibration of the whole, without change of distance between the magnets. The period of this vibration is obviously the same as that of either magnet if the other were removed.

(B) Another obviously possible motion is that in which the magnets are, at every instant, equally and oppositely deflected. The period of this oscillation will be less or greater than that of the former according as the poles attract or repel one another.

[1] We suppose the bars to be so long, in comparison with the distance between them, that we need take account only of the action of their poles which are turned towards one another.

Now the initial state of motion proposed evidently consists of the superposition of (A) and (B) in such a way that there is, at starting, no displacement of either mass, but a definite velocity of one of them only. This corresponds to simultaneous zero of displacement, with equal velocities, for each of (A) and (B). There is therefore at that instant no displacement of either mass; and one is at rest while the other is moving with double the assigned velocity. If $2\pi/n$, $2\pi/n'$ be the periods of the two motions, it is obvious that after the time $\pi/(n - n')$ the magnets will have interchanged their states so that the arrangement will present exactly the same appearance as at first, *if looked at from the other side.*

Let a be the distance between the ends of the bars when all four strings are vertical. Then, if θ, ϕ be at time t the inclinations of the pairs of strings to the vertical, a becomes

$$D = a + l(\phi - \theta) ,$$

where l is the common length of the strings. The expression for the potential energy due to magnetism is of the form μ/D, where μ is positive if like poles be turned to one another.

Hence

$$T = \tfrac{1}{2}ml^2(\dot\theta^2 + \dot\phi^2) ,$$
$$V = \tfrac{1}{2}mgl(\theta^2 + \phi^2) + \frac{\mu}{a + l(\phi - \theta)} .$$

Forming the equations as usual, and omitting powers of θ and ϕ above the first, we have

$$ml^2\ddot\theta = -mgl\theta + \frac{\mu l}{a^2}\left(1 - \frac{2l}{a}(\phi - \theta)\right) ,$$
$$ml^2\ddot\phi = -mgl\phi - \frac{\mu l}{a^2}\left(1 - \frac{2l}{a}(\phi - \theta)\right) ;$$

from which the results already given may be deduced.

Atwood's machine. Finally, let us take the case of Atwood's machine (§ 173) when the masses are equal, and one of them is vibrating through small arcs.

One mass vibrating. Let r, θ be the polar coordinates of the vibrating mass; then, neglecting powers of θ higher than the second, we have the generalized equations

$$2\ddot r - r\dot\theta^2 = -\tfrac{1}{2}g\theta^2 ,$$
$$\frac{d}{dt}(r^2\dot\theta) = -gr\theta .$$

Put $\tfrac{1}{2}gr$ for r, and $\theta\sqrt{2}$ for θ, and we get

$$\ddot r - r\dot\theta^2 = -\theta^2 ,$$
$$\frac{1}{r}\frac{d}{dt}(r^2\dot\theta) = -2\theta .$$

Transform to rectangular coordinates in the plane of motion, x being vertically downwards; then

$$\ddot x = y^2/x^2 , \qquad \ddot y = -2y/x .$$

This shows that the vertical acceleration of the vibrating particle is very small, but constantly downward. Hence the energy of the vibratory motion is steadily converted into energy of translation of the masses.

When both the equal masses vibrate through small arcs, it is found that the mass whose angular range is the greater has downward acceleration with diminishing angular range. Hence it would appear that, if the string be long enough, the entire motion would be periodic.

§ 216. Before leaving this subject we may form, from the complete value of δA given in last section, the generalized equations corresponding to those of Hamilton's "varying action," as given in § 204.

We have at once

$$\left(\frac{dA}{d\theta}\right) = \left(\frac{dT}{d\dot\theta}\right) , \left(\frac{dA}{d\phi}\right) = \left(\frac{dT}{d\dot\phi}\right) , \ . \ . \ . \ , \left(\frac{dA}{dH}\right) = t .$$

But, by the value of T, we have

$$\left(\frac{dT}{d\dot\theta}\right) = P\dot\theta + Q\dot\phi + \ . \ . \ .$$
$$\left(\frac{dT}{d\dot\phi}\right) = Q\dot\theta + R\dot\phi + \ . \ . \ .$$
$$\&c. = \&c.$$

These equations give θ, ϕ, . . . as homogeneous linear functions of $\left(\frac{dT}{d\dot\theta}\right)$, $\left(\frac{dT}{d\dot\phi}\right)$, . . . that is, of $\left(\frac{dA}{d\theta}\right)$, $\left(\frac{dA}{d\phi}\right)$, . . . Thus, if we substitute these expressions in the equation

$$2T = \Sigma\left[\dot\theta\left(\frac{dT}{d\dot\theta}\right)\right] = \Sigma\left[\dot\theta\left(\frac{dA}{d\theta}\right)\right],$$

which is obviously true, because T is a homogeneous function of $\dot\theta$, $\dot\phi$, . . . of the second degree, we have a partial differential equation of the form

$$p\left(\frac{dA}{d\theta}\right)^2 + 2q\left(\frac{dA}{d\theta}\right)\left(\frac{dA}{d\phi}\right) + r\left(\frac{dA}{d\phi}\right)^2 + \;.\;\;. = 2(H - V),$$

from which A is to be found.

The coefficients p, q, r . . . are, in general, like P, Q, R, . . . functions of θ, ϕ, . . .

As an illustration, take again the example in last section, where two masses are attached to a helical spring, and vibrate in a vertical line. From the value of T there given we have

$$\left(\frac{dA}{d\xi}\right) = \left(\frac{dT}{d\dot\xi}\right) = (M + m)\dot\xi + m\dot\eta,$$

$$\left(\frac{dA}{d\eta}\right) = \left(\frac{dT}{d\dot\eta}\right) = m\dot\xi + m\dot\eta.$$

From these we have the equation for A

$$m\left(\frac{dA}{d\xi}\right)^2 - 2m\left(\frac{dA}{d\xi}\right)\left(\frac{dA}{d\eta}\right) + (M + m)\left(\frac{dA}{d\eta}\right)^2 = 2Mm(H - V).$$

The value of V is given above. This equation is, of course, to be treated according to the process illustrated in § 209.

Statics of a Rigid Solid.

Equilibrium of rigid solid. § 217. A rigid body, as we have already seen, has at the utmost six degrees of freedom, three of translation and three of rotation. According to Newton's scholium, the conditions of equilibrium of such a body, under the action of any system of forces, are that the algebraic sum of the rates of doing work by and against the forces shall be *nil* whatever uniform velocity of translation or of rotation the body may have. For, if this were not so, there would be work done against acceleration, and the body would gain or lose kinetic energy. And this gain or loss would take place even if the body were originally at rest, *i.e.*, it would not be in equilibrium. To ensure equilibrium then, all that is necessary is that the sums of the components of the forces in any three non-coplanar directions shall vanish, along with the sums of their moments about any three non-coplanar lines. For simplicity it is usual to assume for these directions a system of rectangular axes, and for the lines another system parallel to them and passing through some definite point (say the centre of inertia) of the body.

The six conditions. Thus we have at once

$$\Sigma(X) = 0,\ \Sigma(Y) = 0,\ \Sigma(Z) = 0;$$

$$\Sigma(Zy - Yz) = 0,\ \Sigma(Xz - Zx) = 0,\ \Sigma(Yx - Xy) = 0,$$

where X, Y, Z are the components, parallel to the axes, of a force acting at the point x, y, z of the body. If P, with direction cosines λ, μ, ν, represent the force acting at x, y, z, these equations may be written in the form

$$\Sigma(P\lambda) = 0,\ \Sigma(P\mu) = 0,\ \Sigma(P\nu) = 0$$

$$\Sigma[P(\nu y - \mu z)] = 0,\ \Sigma[P(\lambda z - \nu x)] = 0,\ \Sigma[P(\mu x - \lambda y)] = 0.$$

These equations correspond to the six degrees of freedom involved.

It is easy to see that it is a mere matter of convenience through what point of the body we draw the lines about which moments are taken. For, if we shift it by quantities a, b, c respectively, the moments become

$$\Sigma\{Z(y - b) - Y(z - c)\},\ \&c.;$$

but these are $\quad \Sigma(Zy - Yz) - b\Sigma(Z) + c\Sigma(Y),\ \&c.;$

and, by the first three equations, these quantities are seen to reduce themselves to their first terms. Hence, in forming the equations of equilibrium, simplicity will be gained by choosing as origin a point through which the line of action of one or more of the applied forces passes.

Again, the point of application of any one of the forces may be shifted at will anywhere along the line in which the force acts. For the equations of the line in which the force at x, y, z acts are

$$\frac{x' - x}{X} = \frac{y' - y}{Y} = \frac{z' - z}{Z},$$

and these give $\quad Zy' - Yz' = Zy - Yz,\ \&c.,$

so that the expressions for the moments are unaltered if the point of application of the force be shifted to any position along the line in which it acts.

§ 218. In the great majority of treatises on Statics the fundamental propositions of the subject, above given, are deduced from the assumption (as a thing to be proved experimentally) of the result just established, which is designated the "principle of the transmission of force." Along with it are assumed the parallelogram of forces, and the principle of the "superposition of systems of forces in equilibrium." Since the publication of the *Principia*, the continued use of such methods must be looked upon as a retrograde step in science.

§ 219. From this category we cannot quite except (so far Couple. at least as the usual modes of treating it are concerned) the valuable idea of the "couple," due to Poinsot. But the term is in such common use, and the idea in its applications sometimes of such importance, that it cannot be omitted here.

A couple is a pair of equal forces acting on the same body in opposite directions and in parallel lines.

From the general conditions already given we see that a couple produces a definite moment of force about a particular axis, but that the axis is determinate merely as regards direction, and not as regards position in space. The forces of a couple do not appear in the first three of the equations of equilibrium. On the other hand, the left hand members of the other three equations may all be regarded as moments of couples. All the properties of couples are contained in these statements. Thus, for instance, it is obvious that, so far as its effects are concerned—

1. A couple may be shifted by translation to any other Transference of couple. position in its own plane.
2. It may be shifted to any parallel plane.
3. In either of these it may be turned through any angle.
4. Its forces may be increased or diminished in any Arm of couple. ratio, provided the distance between their lines of action (which is called the "arm" of the couple) be proportionately diminished or increased.

A couple is therefore completely determined by means Axis of couple. of its "axis," which is a line drawn perpendicular to its plane, and of length representing its moment. And two couples are obviously to be compounded by treating their axes as if they were forces acting at one point.

§ 220. We will now examine the consequences of the Reduction of a system to a force and a couple. six conditions of equilibrium (§ 217) in some of the more common cases which present themselves. But, before doing so, it may make matters clearer if we restate these conditions in a somewhat different form.

The resultant of any number of forces, acting at any points of a rigid body, may be represented by a single force acting at the origin, and a couple of definite moment about a definite line passing through the origin.

For equilibrium of the body this force and couple must separately vanish.

Thus if, in fig. 59, P, acting at Q, be any one of the forces, and O the origin (chosen at random), we may introduce at O a pair of equal and opposite forces ± P, parallel to P. The original force, taken along with − P at the origin, gives a couple; and in addition there is + P acting at the origin.

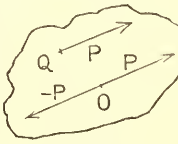


Fig. 59.

§ 221. When only two forces act on a body, the first condition above shows that they must be equal and opposite, and the second that they must act in the same line, if they are to maintain equilibrium. When only three forces act, the first condition shows that their directions must lie in one plane, the second that their lines of action must be parallel or must meet in one point, if they are to maintain equilibrium.

If their directions meet in one point we have again the problem of the equilibrium of a single particle under three forces; for there can be no moment about this point.

When the directions are parallel, one of the forces must obviously be equal to the sum of the other two, and must act in the opposite direction. Also its line of action must lie between those of the other two, for their moments about any point in it must be equal and opposite. Hence it is impossible that any single force should balance a couple, unless we adopt the mathematical fiction of an infinitely small force acting in a line everywhere at an infinite distance; so that its moment may be finite, and equal and opposite to that of the couple.

rallel rces. § 222. When any number of parallel forces act simultaneously on a rigid body, their resultant is a single force equal to their algebraic sum, with a couple whose plane is obviously parallel to the common direction of the forces. The forces of this couple may be made, by lengthening or shortening the arm, equal to the resultant force. One of them will neutralize it, and the other remains the final resultant, which passes through a definite point called the "centre of parallel forces." Thus any set of parallel forces necessarily has a single force as a resultant, excepting in the special case when their algebraic sum is zero.

entre."

avity. § 223. Excellent examples are furnished by heavy bodies of moderate dimensions, where the weights of their parts are forces practically in parallel lines. The single resultant force, in such cases, is the whole weight of the body. Its direction always passes through the centre of inertia (§ 109) because weight (in any one locality) is proportional to mass. For this reason all heavy bodies of moderate dimensions are said to have a "centre of gravity," which coincides with the centre of inertia. But it must be noticed that the two ideas are radically different, and that, while every piece of matter has a true centre of inertia, it is, in general, only approximately that we can predicate of it that it has a centre of gravity. In fact a body has a true centre of gravity only when it attracts, and is attracted by, all other gravitating matter as if its whole mass were concentrated in that point. See POTENTIAL. When there is a centre of gravity in a body, it is necessarily coincident with the centre of inertia. In gravitation cases, where bodies of moderate size are concerned, the resultant is, at least approximately, a single force. But, when we deal with large non-barycentric bodies like the earth, we find that the resultant of the sun's attraction is a force (determining the orbit) and a couple (producing precession, &c.).

ntre of avity.

When a mass is laid on a three-legged table, we find the pressure which each leg supports by simply taking moments about the line joining the upper ends of the other two. The leg is thus seen to support a fraction of the weight of the mass, whose numerator is the distance of the centre of gravity of the mass from this line, and its denominator the distance of the leg from the same line. Thus we have a physical proof of the geometrical proposition that if any point, P, be taken in the plane of a triangle ABC (fig. 60), and perpendiculars be drawn from it and from the angles, we have

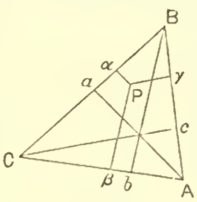


Fig. 60.

$$\frac{P\alpha}{Aa}+\frac{P\beta}{Bb}+\frac{P\gamma}{Cc}=1.$$

If the mass of the table is to be reckoned, P must be taken as the centre of gravity of the system of table and load together. If the table be of uniform material, triangular, and supported by legs at its corners, similar reasoning shows that when it is unloaded (or loaded at its centre of gravity) each leg supports one third of the weight.

§ 224. Examples in which the resultant is a single couple are found in rigidly magnetized bodies placed in a uniform magnetic field. As the amounts of N. and S. magnetism in a body are always equal, there is no force of translation in a uniform field. The resultant couple depends for its magnitude on the orientation of the body, and the positions of equilibrium are those for which its moment vanishes. Resultant a couple.

§ 225. Let P at x, y, z, be one of a system of parallel forces, their direction cosines being λ, μ, ν. Let Q be the resultant force, and R, with direction cosines λ', μ', ν', the axis of the resultant couple. Then our conditions become

$$Q=\Sigma(P),$$

$$\lambda'R=\Sigma[P(\nu y-\mu z)],\quad \mu'R=\Sigma[P(\lambda z-\nu x)],\quad \nu'R=\Sigma[P(\mu x-\lambda y)].$$

The last three equations give the following conditions determining R, λ', μ', ν':—

$$\begin{aligned}\lambda'R\quad &+\mu\Sigma(Pz)-\nu\Sigma(Py)=0,\\ -\lambda\Sigma(Pz)&+\mu'R\quad+\nu\Sigma(Px)=0,\\ +\lambda\Sigma(Py)&-\mu\Sigma(Px)+\nu'R\quad=0.\end{aligned}$$

From these we have the equation of condition

$$\lambda\lambda'+\mu\mu'+\nu\nu'=0,$$

showing that the axis of the couple is at right angles to the common direction of the parallel forces.

We have also

$$R^2=(\Sigma(Px))^2+(\Sigma(Py))^2+(\Sigma(Pz))^2-(\lambda\Sigma(Px)+\mu\Sigma(Py)+\nu\Sigma(Pz))^2.$$

This expression is of the same form as that in § 77, and we therefore conclude that, if λ'', μ'', ν'' be the direction cosines of a line in the body such that

$$\frac{\lambda''}{\Sigma(Px)}=\frac{\mu''}{\Sigma(Py)}=\frac{\nu''}{\Sigma(Pz)},$$

the magnitude of the resultant couple is directly as the sine of the angle between this line and the common direction of the parallel forces. In fact the mere form of the three equations above proves this result.

In the case of a body of moderate dimensions, acted on by gravity, P is the weight of the element at x, y, z, and therefore proportional to its mass, so that if the centre of inertia be taken as the origin we have

$$\Sigma(Px)=0,\quad \Sigma(Py)=0,\quad \Sigma(Pz)=0,$$

and there is no couple. The whole effect is therefore the same as if the mass were condensed at the centre of inertia.

In the case of a magnet,

$$\Sigma(P)=0,$$

and there is no translatory force. The couple, as we have seen, depends upon the orientation of the body as regards the direction of the line of the earth's magnetic force.

§ 226. We have seen that any system of forces acting on a rigid body may be reduced to a force and a couple; also that when the force is in the plane of the couple the resultant can always be put in the form of a single force acting in a definite line in the body. When the force is not in the plane of the couple, we may resolve the couple into two components, the plane of one being parallel, of the other perpendicular, to the force. The first, when compounded with the force, merely shifts the line in which it acts. Thus any system of forces may be reduced to a single force, acting in a definite line called the "central axis," and a couple in a plane perpendicular to it. One of the forces of the couple may now be compounded with the single force, and thus we obtain, as the resultant of any system of forces, a pair of forces in non-intersecting lines not perpendicular to one another. This is only one of an infinite number of ways in which fancy, or convenience, may lead us to represent the equivalent of a group of forces. Many very curious theorems have been met with in investigations on this subject. For instance, by compounding one of the forces of the resultant couple with the resultant force (not Reduction to two forces. Central axis.

now necessarily perpendicular to its plane) we have a system of two forces acting in non-intersecting lines. Then we have the following curious proposition, which may easily be proved from the formulæ already given:—

When a system of forces is reduced in any manner whatever to two, the volume of the tetrahedron of which these are opposite edges is constant.

Symmetrical reduction.

§ 227. The most symmetrical pair of resultant forces is found thus. Take any point P (fig. 61) in the central axis, and draw through it a line APA′, perpendicular to it, and bisected at P. Substitute for the single force at P its halves acting at A and A′ respectively. Combine these respectively with the forces AQ, A′Q′ of the couple when AA′ is made its arm. The system is thus reduced to two equal forces AR, A′R′, whose directions are interchangeable by a rotation of two right angles about the central axis.

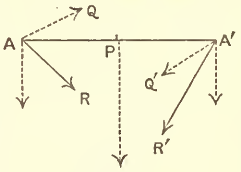


Fig. 61.

General reduction.

Let P with direction cosines λ, μ, ν be one of the forces, and let x, y, z be its point of application. Then

$$X = \Sigma(P\lambda)\,,\quad Y = \Sigma(P\mu)\,,\quad Z = \Sigma(P\nu)$$

are the components of the single force at the origin.

Also

$$\begin{aligned} L &= \Sigma[P(\nu y - \mu z)] \\ M &= \Sigma[P(\lambda z - \nu x)] \\ N &= \Sigma[P(\mu x - \lambda y)] \end{aligned}$$

are the components of the resultant couple.

If we shift the origin to the point a, b, c the first three quantities are unaltered, but the couples become

$$\begin{aligned} L' &= L + cY - bZ \\ M' &= M + aZ - cX \\ N' &= N + bX - aY. \end{aligned}$$

The point a, b, c is on the central axis if the axis of the resultant couple be parallel to the single force, *i.e.*, if

$$\frac{L'}{X} = \frac{M'}{Y} = \frac{N'}{Z} = e, \text{ suppose ;}$$

or

$$\begin{aligned} L &= \quad eX - cY + bZ, \\ M &= \quad cX + eY - aZ, \\ N &= -bX + aY + eZ. \end{aligned}$$

Either of these sets gives the equations of the central axis.

The resultant force and couple are in one plane, and therefore the resultant is a single force in the central axis, when

$$L'X + M'Y + N'Z = 0\,.$$

By the values of L′, M′, N′, above, we see that this is equivalent

$$LX + MY + NZ = 0\,.$$

When this last condition is not satisfied, we see that the value of the left hand member which, from the way in which it occurs, must obviously be an invariant, is

$$e(X^2 + Y^2 + Z^2)\,,$$

where e has the same value as in the three equations above.

Minding's theorem.

§ 228. One of the most remarkable of the many curious theorems connected with the single resultant of a system of forces is that of Minding. We have seen that, in general, the resultant may be put in the form of a single force and a couple in a plane perpendicular to it. If we now suppose the system of forces to be shifted into a new position such that their points of application, their magnitudes, and the angles between their directions two and two, all remain unchanged, the resultant force will be of the same magnitude as before, but the couple will in general be different. Of the infinitely infinite number of possible positions which the forces may assume, an infinite number correspond to a zero couple. Minding has shown that the lines of action of these single resultants consist of all lines passing through each of two curves, fixed in the body, an ellipse and an hyperbola, in planes perpendicular to each other. The proof of the proposition gives an interesting example of the use of Rodrigues's coordinates (§ 83).

The most obvious mode of attacking this question would be to resolve the applied forces into three groups, parallel respectively to three rectangular axes which revolve with them, and to choose those axes so that the sum of the resolved parts does not vanish parallel to any one of the three. Each of these systems of parallel forces has its own "centre" (§ 222),—so that the final resolution gives three forces, each of a given magnitude, acting in any mutually perpendicular directions at three definite points in the body. This, however, is not analytically so simple as the following.

We refer the body to fixed axes Ox, Oy, Oz, to be afterwards specified. As the origin and the directions of these axes are at our disposal, we may impose six conditions. Now suppose the forces to be resolved parallel to a set of rectangular axes Ox', Oy', Oz' which will be considered afterwards to rotate with them. Such a system of axes may, at starting, have any assigned position. This gives us three conditions more. Let then A, B, C be the components, parallel to the second set of axes, of the force applied at the point whose coordinates referred to the first system are a, b, c. Let the direction cosines of the second system in any of its future positions, referred to the first system, be l_1, m_1, n_1; l_2, m_2, n_2; l_3, m_3, n_3 respectively.

Then the force at a, b, c has the following components:—

$$\begin{aligned} &Al_1 + Bl_2 + Cl_3\,, &&\text{parallel to O}x \\ &Am_1 + Bm_2 + Cm_3\,, &&\quad ,, \quad ,, \ \text{O}y \\ &An_1 + Bn_2 + Cn_3\,, &&\quad ,, \quad ,, \ \text{O}z\,. \end{aligned}$$

The expressions for the resultant force and couple at the origin will evidently depend upon the following twelve quantities, besides the direction cosines, viz:—

$$\begin{aligned} &\Sigma A, \quad \Sigma B, \quad \Sigma C, \\ &\Sigma(Aa),\ \Sigma(Ab),\ \Sigma(Ac)\,, \\ &\Sigma(Ba),\ \Sigma(Bb),\ \Sigma(Bc)\,, \\ &\Sigma(Ca),\ \Sigma(Cb),\ \Sigma(Cc)\,. \end{aligned}$$

Assume $\Sigma B = 0$, $\Sigma C = 0$, *i.e.*, let Ox' be always parallel to the direction of the resultant force. Next, let

$$\Sigma(Aa) = 0,\ \Sigma(Ab) = 0,\ \Sigma(Ac) = 0\,,$$

i.e., let the origin be chosen as the "centre" (§ 222) of the forces parallel to the resultant force. As we have still four conditions to impose, we select the following:—

$$\Sigma(Ba) = 0,\ \Sigma(Bc) = 0,\ \Sigma(Ca) = 0,\ \Sigma(Cb) = 0.$$

These express that the plane of the couple due to the forces C passes through Oy, while that of the forces B passes through Oz.

Write now

$$\Sigma(A) = \mathfrak{A}\,,\ \Sigma(Bb) = \mathfrak{A}\beta,\ \Sigma(Cc) = \mathfrak{A}\gamma.$$

The force and couple at the origin are

$$\begin{aligned} &\mathfrak{A}l_1\,, &&\mathfrak{A}m_1\,, &&\mathfrak{A}n_1\,, \\ &\mathfrak{A}(n_2\beta - m_3\gamma), &&\mathfrak{A}l_3\gamma, &&-\mathfrak{A}l_2\beta\,. \end{aligned}$$

These are equivalent to a single force if (§ 227)

$$(l_1n_2 - n_1l_2)\beta - (l_1m_3 - m_1l_3)\gamma = 0\,,$$

or

$$m_3\beta - n_2\gamma = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

This is the required condition. When it is satisfied, the equations of the line in which the single force $\mathfrak{A}$ acts are any two of

$$\left.\begin{aligned} n_1\eta - m_1\zeta &= \quad n_2\beta - m_3\gamma\,, \\ l_1\zeta - n_1\xi &= \quad l_3\gamma\,, \\ m_1\xi - l_1\eta &= -l_2\beta \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

the condition that these three agree being (1).

Eliminate l_1 between the last two, and we get

$$\xi(m_1\zeta - n_1\eta) = l_3\gamma\eta - l_2\beta\zeta\,. \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Now introduce in (1), in the first of (2), and in (3), Rodrigues's values of the cosines (§ 83), and they become respectively

$$\begin{aligned} &(yz - wx)\beta - (yz + wx)\gamma = 0\,, \\ &(xz - wy)\eta - (wz + xy)\zeta = (yz + wx)\beta - (yz - wx)\gamma\,, \\ &\zeta\xi(wz + xy) - \xi\eta(xz - wy) = (xz + wy)\gamma\eta - (xy - wz)\beta\zeta. \end{aligned}$$

Rearranging according to y, z, and yz,

$$\begin{aligned} &(\beta - \gamma)yz - (\beta + \gamma)wx = 0\,, \\ &(\beta - \gamma)yz + (w\eta + x\zeta)y - (x\eta - w\zeta)z + (\beta + \gamma)wx = 0\,, \\ &[\zeta(\xi + \beta)x + \eta(\xi - \gamma)w]y + [\zeta(\xi - \beta)w - \eta(\xi + \gamma)x]z = 0\,, \end{aligned}$$

the second of which may be put, by means of the first, in the form

$$(w\eta + x\zeta)y - (x\eta - w\zeta)z + 2(\beta + \gamma)wx = 0.$$

These three equations involve w, x, y, z in the form of the ratios only of the last three to the first. The last two are linear in $\frac{y}{w}$, $\frac{z}{w}$. Solving them, and substituting in the first we find, finally, a biquadratic in $\frac{x}{w}$.

Hence, if particular values be assigned to ξ, η, ζ, we find four values of $\frac{x}{w}$. Thus, in general, there are four positions of the single resultant force passing through any point.

But, without forming the biquadratic, we may easily obtain Minding's theorem. Suppose we seek the locus of all points in which the plane $\xi\eta$ can be cut by the line of action of the single force. We have $\zeta=0$, and the equations above are reduced to

$$(\beta-\gamma)yz-(\beta+\gamma)wx\ =0\,,$$
$$\eta(wy-xz)+2(\beta+\gamma)wx=0\,,$$
$$(\xi-\gamma)wy-(\xi+\gamma)xz\ =0\,.$$

From the last two we find

$$-\gamma\eta z=(\beta+\gamma)(\xi-\gamma)w\,,$$
$$-\gamma\eta y=(\beta+\gamma)(\xi+\gamma)x\,,$$

so that finally, by the first,

$$(\beta^2-\gamma^2)(\xi^2-\gamma^2)=\gamma^2\eta^2\,,$$

or

$$\frac{\xi^2}{\gamma^2}-\frac{\eta^2}{\beta^2-\gamma^2}=1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4).$$

Had we put $\eta=0$, we should have found, by a similar process,

$$\frac{\xi^2}{\beta^2}+\frac{\zeta^2}{\beta^2-\gamma^2}=1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5).$$

(4) and (5) represent an hyperbola and an ellipse, or an ellipse and an hyperbola, respectively, according as β^2 is greater or less than γ^2. In either case the vertices of the hyperbola coincide with the foci of the ellipse; so that the two curves are linked together.

It is now easy to see that, from any assigned point of space, the two curves will appear to intersect one another in four points. Two, or all, of these may in special cases coincide. Lines drawn to these points give the four positions of the single force which can pass through the assigned point.

Examples of Statical Methods and Theorems.

adder aning gainst a all.

§ 229. Suppose a ladder to be leaning against a vertical wall. If there be no friction, what force, applied at the lower end, will just suffice to support it?

In the treatment of all questions of this kind the student should commence by making a rough sketch of the situation, indicating all the forces concerned, with the directions in which they act. As shown in fig. 62, the wall exerts an outward thrust S on the upper end of the ladder, the ground an upward thrust R on the lower end. The only other force is gravity, which may be supposed to produce a downward force at the middle of the ladder, equal to its whole weight. Unless there be some other horizontal force to balance S, the ladder will obviously slide down. Suppose then a horizontal force F to be applied at the lower end, and let the ladder be inclined at an angle α to the horizon. Then our conditions become

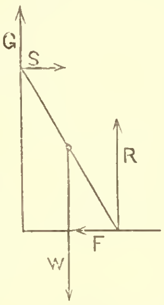


Fig. 62.

horizontally $\quad S-F=0\,,$

vertically $\quad W-R=0\,,$

and for the couple in the plane of the figure, l being the length of the ladder,

$$\tfrac{1}{2}Wl\cos\alpha-Sl\sin\alpha=0\,.$$

[The last equation is obtained by taking moments about the lower end of the ladder, this point being chosen (§ 217) because the directions of two of the forces pass through it.] From these equations we find at once

$$F=S=\tfrac{1}{2}W\cot\alpha\,.$$

It is to be observed that the requisite force F is very small while the ladder is nearly vertical, but increases without limit as it becomes more nearly horizontal.

Jse of riction.

§ 230. Next let us vary the question by supposing the coefficient of friction on the ground to be μ. The equations are precisely the same as before, and the limiting value of α for which equilibrium is possible is now to be found by putting

$$F=\mu R=\mu W\,.$$

Thus

$$2\mu=\cot\alpha$$

gives the smallest value of α for which equilibrium is possible. For any larger value of α less friction is called into play.

§ 231. If next we assume the wall also to be rough, a new friction force, G, comes in. The equations (for any given value of α) are

$$S-F=0\,,$$
$$W-R-G=0\,,$$
$$\tfrac{1}{2}Wl\cos\alpha-Sl\sin\alpha-Gl\cos\alpha=0\,.$$

Here there is a certain amount of indeterminateness which our formulæ cannot escape (although of course it does not exist in nature) so long as we are not dealing with the limiting case in which motion is about to commence. In that case we have the additional conditions

$$G=\mu S\,,\quad F=\mu R\,.$$

Thus, in all, there are five equations. These are requisite and necessary because there are four forces S, G, R, F to be determined, as well as the special value of the angle α. The result of eliminating the four forces is

$$\tan\alpha=\frac{1-\mu^2}{2\mu}\,.$$

§ 232. We may still further vary the question by supposing a man of weight w to ascend the ladder. Let e represent the fraction of the ladder's length which he has ascended. The equations are Man on ladder.

$$S-F=0\,,$$
$$W+w-R-G=0\,,$$
$$(\tfrac{1}{2}W+ew)l\cos\alpha_1-Sl\sin\alpha_1-Gl\cos\alpha_1=0\,.$$

Introducing the condition that slipping is just about to commence, we obtain

$$\frac{\tan\alpha_1}{\tan\alpha}=\frac{1+2\frac{w}{W}\frac{(1+\mu^2)e-\mu^2}{1-\mu^2}}{1+\frac{w}{W}}\,.$$

where α has the value given in § 231. Hence the limiting angle is increased or diminished by the load on the ladder according as

$$2(1+\mu^2)e-2\mu^2\gtrless 1-\mu^2\,,$$

i.e., $\quad 2e\gtrless 1\,.$

The ratio w/W does not appear in this condition. But it shows its importance when e is either greater or less than $\frac{1}{2}$.

Hence, when the ladder is just about to slip, a man makes it more stable if he stands anywhere on the lower half of it, but brings it down if he mounts higher. We conclude that, so far as sliding is concerned, it is advantageous to make the lower half of a ladder more massive than the upper half.

§ 233. Suppose a ladder, with its lower end resting against a wall, to be supported by a horizontal rail parallel to the wall (fig. 63). This case is chosen because it illustrates definite limits within which stability is ensured.

Let a be the half length of the ladder, α its inclination to the horizon, b the distance of the rail from the wall. Suppose the ladder in such a position that if there were no friction it would slip downwards. Then the equations of equilibrium are

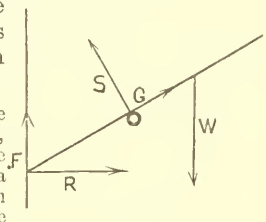


Fig. 63.

$$R+G\cos\alpha-S\sin\alpha=0\,,$$
$$F+S\cos\alpha+G\sin\alpha-W=0\,,$$
$$Sb\sec\alpha-Wa\cos\alpha=0\,.$$

In the third of these equations the lower end of the ladder has been chosen as the point about which moments are taken, because the lines of action of three of the forces pass through it. Here again there is indeterminateness, because there are two places at which friction comes in, and we do not know at which it is most freely exerted. But if the whole be on the point of slipping, we have as before the additional data

$$F=\mu R\,,\quad G=\mu S\,.$$

These lead to the equation

$$(1-\mu^2)\cos\alpha+2\mu\sin\alpha=\frac{b}{a}\sec^2\alpha\,.$$

If we introduce an angle ν, such that

$$\cos\nu=\frac{1-\mu^2}{1+\mu^2}\,,\quad \sin\nu=\frac{2\mu}{1+\mu^2}$$

this equation becomes

$$\cos^2\alpha\cos(\alpha-\nu)=\frac{b}{a(1+\mu^2)}=\frac{b}{a}\cos^2\frac{\nu}{2}\,,$$

the right-hand member of which must necessarily be less than 1.

This determines the lowest position of the lower end consistent with equilibrium, and the mere change of sign of μ, and therefore of ν, alters it into the equation for the highest. The signs of the friction terms are changed when the direction of slipping is supposed to be reversed.

Kinetics of a Rigid Solid.

Rotation of rigid solid.

§ 234. The motion of a rigid body is, as we have seen, completely determined when we know the motion of one of its points and the relative motion of the body about that point. The point usually chosen is the centre of inertia of the body, and the investigation of its motion comes under the kinetics of a particle, which we have already sufficiently discussed. For we are permitted to suppose the whole mass to be concentrated at that point, and to be acted on by all the separate forces, each unaltered in direction and magnitude. Hence we may now confine ourselves to the study of the motion about the centre of inertia which, for the moment, we may look on as fixed.

To illustrate, in a very simple manner, the new conceptions which are required for the study of this question, let us take a uniform circular ring of matter, of radius R, revolving with angular velocity ω about an axis through its centre, and perpendicular to its plane. Its moment of momentum is obviously

$$M\,.\,R\omega\,.\,R\ \text{ or }\ MR^2\,.\,\omega\,.$$

Its kinetic energy is

$$\tfrac{1}{2}M(R\omega)^2\ \text{ or }\ \tfrac{1}{2}MR^2\,.\,\omega^2\,.$$

If it be acted on by a couple C, in its plane, C is the rate of increase of the moment of momentum, or

$$MR^2\,.\,\dot\omega=C\,.$$

The work done by the couple in time δt is

$$C\omega\delta t\,,$$

and the increase of kinetic energy is

$$MR^2\,.\,\omega\dot\omega\delta t\,.$$

By equating these we have (after dividing both sides by ω) the same equation as we obtained from the rate of increase of moment of momentum. It will be observed that these equations are of exactly the same form as those for the motion of a particle parallel to one of the coordinate axes, only that ω takes the place of a velocity (such as $\dot x$) while the expression MR^2 takes the place of M, and the right-hand side is the moment of a force, not a force simply.

Moment of inertia.

§ 235. Hence, generally, we define as follows :—

Def. The "moment of inertia" of a body about any axis is the sum of the products of the mass of each particle of the body into the square of its (least) distance from the axis.

The following theorem enables us at once to find the moment of inertia about any line, as axis, from that about a parallel axis through the centre of inertia.

Let the line be chosen as the axis of z, then the moment of inertia about it is

$$\Sigma m(x^2+y^2)\,.$$

But, if $\bar x$, $\bar y$ be the coordinates of the centre of inertia, ξ, η the coordinates of m with reference to that centre, we have

$$x=\bar x+\xi\,,\ y=\bar y+\eta\,,$$

and the above expression for the moment of inertia becomes

$$\Sigma m(\bar x^2+\bar y^2+2\bar x\xi+2\bar y\eta+\xi^2+\eta^2)\,.$$

By the property of the centre of inertia, § 109,

$$\Sigma(m\xi)=0\,,\quad \Sigma(m\eta)=0\,.$$

Hence the above expression consists of two parts:—

$$\Sigma m(\xi^2+\eta^2)$$

the moment of inertia about a parallel axis through the centre of inertia, and

$$\Sigma(m)\,.\,(\bar x^2+\bar y^2)$$

the moment of inertia of the whole mass supposed concentrated at its centre of inertia.

§ 236. Hence we need study only the moments of inertia about axes passing through the centre of inertia. But we will commence with an origin assumed at hazard.

If the direction cosines of an axis through the origin be λ, μ, ν, the square of the distance of the mass m at x, y, z from it is

$$x^2+y^2+z^2-(\lambda x+\mu y+\nu z)^2\,.$$

Hence the moment of inertia is

$$\mathfrak{I}=\Sigma m(x^2+y^2+z^2-(\lambda x+\mu y+\nu z)^2)$$
$$=\Sigma m((y^2+z^2)\lambda^2+(z^2+x^2)\mu^2+(x^2+y^2)\nu^2-2xy\lambda\mu-2yz\mu\nu-2zx\nu\lambda)\,,$$

which may be written

$$\mathfrak{I}=A\lambda^2+2G_3\lambda\mu+B\mu^2+2G_1\mu\nu+2G_2\nu\lambda+C\nu^2\,.$$

If we measure off, on the axis, a quantity ρ whose square is the reciprocal of $\mathfrak{I}$, and call its terminal coordinates ξ, η, ζ, this equation becomes by multiplying both sides by ρ^2

$$1=A\xi^2+2G_3\xi\eta+B\eta^2+2G_1\eta\zeta+2G_2\zeta\xi+C\zeta^2\,.$$

As the moment of inertia is essentially a positive quantity, this equation represents an ellipsoid. It must of course have three principal axes ; and, when these are taken as the coordinates axes, the terms in $\xi\eta$, $\eta\zeta$, and $\zeta\xi$ in the above expression must disappear.

Princ[ipal] axes [of] inerti[a].

§ 237. Hence at every point of every rigid body there are three "principal axes" of inertia, at right angles to one another. One of them is the axis of absolute maximum moment, another that of absolute minimum.

Our equation now becomes, when referred to these axes,

$$1=A\xi^2+B\eta^2+C\zeta^2\,,$$

or, dividing by ρ^2,

$$\mathfrak{I}=A\lambda^2+B\mu^2+C\nu^2.$$

Thus the moment of inertia about any axis is found from those about the principal axes at that point by multiplying each by the square of the corresponding direction cosine, and adding the results.

For the quantity A was written originally as

$$\Sigma m(y^2+z^2)\,,$$

i.e., it is the moment of inertia about the axis of x. We see also that, at every point of a body, there are three rectangular axes such that the expressions

$$\Sigma(mxy)\,,\ \Sigma(myz)\,,\ \Sigma(mzx)$$

vanish when these are taken as coordinate axes.

Distri[bu]tion o[f] princi[pal] axes. Radiu[s] of gyr[a]tion.

To find how these axes are distributed in a body, let us suppose it referred to the principal axes through its centre of inertia, and let Mk_1^2, Mk_2^2, Mk_3^2 be the moments of inertia about them. The quantities k_1, k_2, k_3 are called the principal "radii of gyration." Then, by the results above, the moment of inertia about a line λ, μ, ν through the point α, β, γ is

$$\mathfrak{I}=M\{\alpha^2+\beta^2+\gamma^2-(\lambda\alpha+\mu\beta+\nu\gamma)^2\}+M(\lambda^2k_1^2+\mu^2k_2^2+\nu^2k_3^2)\,.$$

For a principal axis this is to be a maximum or minimum, with the sole condition

$$\lambda^2+\mu^2+\nu^2=1\,.$$

Hence, if p be an undetermined multiplier, we have

$$(k_1^2+p)\lambda - \alpha(\alpha\lambda+\beta\mu+\gamma\nu)=0\,,$$
$$(k_2^2+p)\mu - \beta(\alpha\lambda+\beta\mu+\gamma\nu)=0\,,$$
$$(k_3^2+p)\nu - \gamma(\alpha\lambda+\beta\mu+\gamma\nu)=0\,.$$

But, if we consider a surface of the second order

$$\frac{x^2}{k_1^2+p}+\frac{y^2}{k_2^2+p}+\frac{z^2}{k_3^2+p}=1\,,$$

confocal with the ellipsoid

$$\frac{x^2}{k_1^2}+\frac{y^2}{k_2^2}+\frac{z^2}{k_3^2}=1\,, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a),$$

the direction cosines of its normal at x, y, z are

$$\lambda:\mu:\nu::\frac{x}{k_1^2+p}:\frac{y}{k_2^2+p}:\frac{z}{k_3^2+p}\,.$$

Hence, if this surface pass through the point α, β, γ, we have

$$(k_1^2+p)\lambda = \mathrm{P}\alpha\,,$$
$$(k_2^2+p)\mu = \mathrm{P}\beta\,,$$
$$(k_3^2+p)\nu = \mathrm{P}\gamma\,,$$

where P is determined by the equation

$$\alpha\lambda+\beta\mu+\gamma\nu=\mathrm{P}\left(\frac{\alpha^2}{k_1^2+p}+\frac{\beta^2}{k_2^2+p}+\frac{\gamma^2}{k_3^2+p}\right)=\mathrm{P}.$$

Substitute this value of P in the preceding equations, and they become identical with those above given for determining the principal axes at α, β, γ. Hence Binet's Theorem :—

The principal axes at any point of a body are normals to the three surfaces of the second order which pass through that point and are confocal with the ellipsoid (a).

ncipal ments iner-

§ 238. We will here tabulate the values of the moments of inertia about principal axes through the centre of inertia, in a few specially useful cases.

1. Plane uniform circular disk.

Divide it into concentric rings, of radius r, of breadth δr. Then the moment of inertia about the axis through the centre, and perpendicular to the plane, of the circle is

$$\rho\int_0^a 2\pi r^3 dr = \tfrac{1}{2}\pi a^4\rho\,,$$

where a is the radius, and ρ the mass of a square unit, of the disk. But the mass is $\pi a^2\rho$,

so that $\qquad k_1^2=\tfrac{1}{2}a^2.$

This of course, applies to a circular cylinder. Obviously, in the disk

$$k_2^2=k_3^2=\tfrac{1}{2}k_1^2=\tfrac{1}{4}a^2.$$

In fact the moment of inertia about an axis drawn perpendicular to any plane figure at any point is equal to the sum of the other two about rectangular axes which lie in the plane. The one is $\Sigma m(x^2+y^2)$, and the others are Σmx^2 and Σmy^2 respectively.

2. Uniform rod of length l, ρ mass per unit length.

$$\mathrm{M}=l\rho\,,\quad \mathrm{M}k_1^2=0\,,\quad \mathrm{M}k_2^2=\mathrm{M}k_3^2=2\rho\int_0^{\frac{1}{2}l}x^2dx=\frac{\rho l^3}{12}\,,$$

so that $\qquad k_2^2=k_3^2=\tfrac{1}{12}l^2.$

3. Uniform rectangular plate, sides a and b, axis parallel to b.

$$\mathrm{M}k^2=2b\rho\int_0^{\frac{a}{2}}x^2dx=\frac{a^3b}{12}\rho\,,$$

so that $\qquad k_1^2=\tfrac{1}{12}a^2,$ and $k_2^2=\tfrac{1}{12}b^2.$

Hence, by the remark above,

$$k_3^2=\tfrac{1}{12}(a^2+b^2)\,.$$

4. Uniform sphere, radius a, ρ mass per unit volume. Here

$$\Sigma(mx^2)=\Sigma(my^2)=\Sigma(mz^2)\,,$$

and therefore the sum of any two is

$$=\tfrac{2}{3}\Sigma m(x^2+y^2+z^2)\,.$$

Thus $\qquad \mathrm{M}k_1^2=\mathrm{M}k_2^2=\mathrm{M}k_3^2=\tfrac{2}{3}4\pi\rho\int_0^a r^4dr=\tfrac{8}{15}\pi\rho a^5\,.$

But $\qquad \mathrm{M}=\tfrac{4}{3}\pi\rho a^3,$

and thus $\qquad k_1^2=k_2^2=k_3^2=\tfrac{2}{5}a^2.$

5. Plane uniform elliptic disk, semiaxes a, b ; ρ mass of unit area. Moment of inertia about a is

$$\mathrm{M}k_1^2=2\rho\int_0^a\frac{y^3}{3}dx=\frac{\pi ab^3\rho}{4}\,,$$

so that $\qquad k_1^2=\tfrac{1}{4}b^2.$

From this follows immediately

6. Ellipsoid, semiaxes a, b, c, and of uniform density :—

$$k_1^2=\tfrac{1}{5}(b^2+c^2),\quad k_2^2=\tfrac{1}{5}(c^2+a^2),\quad k_3^2=\tfrac{1}{5}(a^2+b^2).$$

From these we can, of course, reproduce the result for a sphere.

7. Rectangular parallelepiped, edges a, b, c :—

$$k_1^2=\tfrac{1}{12}(b^2+c^2),\quad k_2^2=\tfrac{1}{12}(c^2+a^2),\quad k_3^2=\tfrac{1}{12}(a^2+b^2).$$

The determination of moments of inertia is, like that of centres of inertia, a purely mathematical matter, the full discussion of which would lead us away from the proper objects of this article.

§ 239. The simplest cases that can present themselves so far as rotation is concerned (for the translational effects on a rigid body are treated precisely as if it were a mere particle,—a process already sufficiently illustrated) are those in which there is one degree of freedom to rotate, *i.e.*, when the body is rigidly attached to a fixed axis. Here the physical condition is simply that the rate of increase of moment of momentum is equal to the moment of the resultant couple about the axis of rotation. Rotation about fixed axis.

§ 240. Let us recur to Atwood's machine as a first example, and suppose the string not to slip on the pulley, so that the pulley must turn. In this case we must observe that the two free parts of the string are now, as it were, separate strings, so that we have no right to assume their tensions to be equal. In fact if they were equal there would be no acceleration of the rotation of the pulley, nor of course of the common velocity of the two masses. We assume that the pulley is symmetrical, and the axis through its centre of inertia. Pulley of Atwood's machine.

Let a be the radius of the pulley, and ω its angular velocity, then $a\omega$ is the linear velocity of either mass. Thus the linear acceleration of each of the masses is equal to a times the angular acceleration of the pulley. But the linear acceleration multiplied by the mass is the measure of the force producing it; while the angular acceleration multiplied by the moment of inertia is the measure of the moment of the couple producing it. Thus we have (M being the mass of the pulley, and k its radius of gyration)

$$\mathrm{M}k^2\times\text{angular acceleration} = (\mathrm{T}'-\mathrm{T})a\,,$$
$$m'\times\text{linear acceleration} = m'g-\mathrm{T}'\,,$$
$$m\times\text{linear acceleration} = \mathrm{T}-mg\,.$$

Eliminating T and T′, and taking account of the above relation between the accelerations, we find at once

$$\text{Linear Acceleration}=\frac{m'-m}{m'+m+\mathrm{M}k^2/a^2}g\,;$$

from which, by the last two of our equations, the separate values of T and T′ may be found.

If we compare this result with that obtained in § 173, on the supposition that the pulley was perfectly smooth, we see that the only difference is in the addition of $\mathrm{M}k^2/a^2$ to the sum of the two masses. Otherwise the nature of the motion remains unaffected.

§ 241. Let us next take the case of a body of any form attached to a horizontal axis which does not pass through its centre of inertia. In such a case gravity is the force producing motion, and we have what is called a "compound pendulum." Draw through the centre of inertia a line parallel to the axis; let h be the distance between these lines, and θ the angle which their plane makes (at a given time) with the vertical. The moment producing angular acceleration is obviously Compound pendulum.

$$-mgh\sin\theta\,.$$

Divide by the moment of inertia about the axis, which by a previous proposition (§ 235) is

$$m(k^2+h^2)$$

(where k is the radius of gyration about the line drawn through the centre of inertia), and we have for the angular acceleration

$$-\frac{gh\sin\theta}{k^2+h^2}\,.$$

In the case of a simple pendulum of length l, we saw that the angular acceleration is

$$-\frac{g\sin\theta}{l}.$$

Hence the motion of the compound pendulum will be identical with that of the simple pendulum when, and only when,

$$l=\frac{k^2+h^2}{h}=2k+\frac{(k-h)^2}{h}.$$

As h and k are necessarily positive (or rather *signless*) quantities, the smallest value of l is evidently when $k=h$. Hence the shortest time in which the mass can vibrate about any axis parallel to the original one corresponds to that of a simple pendulum of length $2k$. When h is made either less or greater than k, the length of the equivalent simple pendulum increases, and for any assigned value of l greater than $2k$ there are two corresponding values of h, one less and the other greater than k. Their sum, however, as we see by the coefficient of the second term in the equation

$$h^2-lh+k^2=0,$$

is always equal to l.

If then we can find two parallel axes in a rigid body, lying in one plane with the centre of inertia, and on opposite sides of that point, such that the time of oscillation is the same for each, the distance between them is the length of the equivalent simple pendulum. Kater made use of this proposition in his determination of the length of the second's pendulum, under the circumstances in which it was defined by Act of Parliament as a datum for restoring, in case of loss, the standard yard.

Complex compound pendulum.

§ 242. Suppose now that a second body is attached to the first by an axis parallel to that about which the first is constrained to move; and, for simplicity, suppose the centre of inertia of the first body to be in the plane containing the two axes. Here we have a *complex compound pendulum*, and it is interesting to compare the motion with that of the complex simple pendulum of §§ 177, 178.

Let m', h', ϕ correspond, for the second body, to m, h, θ for the first, and let a be the distance between the axes. For variety we will adopt Lagrange's method. We have clearly

$$T=\tfrac{1}{2}\,(mk^2\dot\theta^2+mh^2\dot\theta^2+m'k'^2\dot\phi^2+m'(a^2\dot\theta^2+h'^2\dot\phi^2+2ah'\cos(\phi-\theta)\dot\phi\dot\theta),$$
$$V=C-mgh\cos\theta-m'g(a\cos\theta+h'\cos\phi).$$

These would enable us at once to write down the equations of motion, however large be the disturbance, but they are too complex for our present work. Let us then assume ϕ and θ to be very small, and we have

$$\{m(k^2+h^2)+m'a^2\}\ddot\theta+m'ah'\ddot\phi=-(mh+m'a)g\theta,$$
$$m'(k'^2+h'^2)\ddot\phi+m'ah'\ddot\theta=-m'gh'\phi.$$

Combining, as before, by means of an undetermined multiplier, we have

$$(m(k^2+h^2)+m'a^2+\lambda m'ah')\ddot\theta+(m'ah'+\lambda m'(k'^2+h'^2))\ddot\phi$$
$$=-g\{(mh+m'a)\theta+\lambda m'h'\phi\}.$$

Thus the two values of λ are given by the equation

$$\frac{m'ah'+\lambda m'(k'^2+h'^2)}{m(k^2+h^2)+m'a^2+\lambda m'ah'}=\frac{\lambda m'h'}{mh+m'a}.$$

This may be written in the form

$$\frac{A+\lambda}{B+\lambda}=\frac{\lambda}{C},$$

where B is greater than A; and A, B, C are all essentially positive, if the bodies have been only slightly displaced from the position of stable equilibrium. The equation gives

$$\lambda^2+(B-C)\lambda-AC=0,$$

so that the values of λ are essentially real and of opposite signs. If we write $\mu-B$ for λ, this equation becomes

$$\mu^2-(B+C)\mu+(B-A)C=0,$$

so that the values of $\lambda+B$ are both positive, and therefore the motion of either mass is the resultant of two simple harmonic motions.

§ 243. A well-known puzzle in connexion with this subject used to be "How to distinguish between two hollow shells, one of gold the other of silver, if their diameters and masses be alike, and both be painted." If we observe that the volumes of equal masses are inversely as the densities, the volume of the gold shell is seen to be less than that of the silver one, and therefore, on the whole, its mass is farther from the centre, and its moment of inertia greater. Hence any form of experiment in which the moment of inertia comes in will suffice to decide the question. Thus they might be alternately clamped tight to the end of a rod, and the system swung as a pendulum, when the gold sphere would vibrate more slowly than the silver one. Or they might be allowed to *roll*, not *slide*, down a rough plane. In this case the work done by gravity on each is the same when they have fallen through equal spaces. But its equivalent is in the form of kinetic energy, partly translational and partly rotational. The relative amounts of these two depend on the moments of inertia of the spheres, for the ratio of the translational velocity to the angular velocity is the same for each. Hence the gold sphere, having the greater moment of inertia, will have the smaller velocity of translation. Another form of this question was to have a shell with a spherical mass inside, which might be either free to rotate on gimbals, or else be keyed to the outer skin. The keying would of course retard the motion of the whole down a rough plane, for part of the energy due to gravity would then be shared by the internal mass in the form of energy of rotation, from which it would otherwise have been free. Another very instructive form is that of a spherical shell full of fluid. If the fluid be perfect, the moment of inertia is that of the shell alone; if it be infinitely viscous, the moment of inertia is that of shell and fluid as if they constituted one rigid solid; and we may have every intermediate amount. If we suppose the rotation of the outer shell to be suddenly stopped, the infinitely viscous contents would be reduced to rest also. But if they be not infinitely viscous they will not at once be brought to rest, but will be able to put the shell in rotation again if it be at once set free. Thus, in practice, we can tell a raw egg from a hard-boiled egg. The first is with difficulty made to rotate, and sets itself in motion again if it be stopped and at once let go. The second behaves, practically, like a rigid solid.

Rolling of hollow shells.

§ 244. The problem of the rolling of a sphere down a rough inclined plane is solved at once, as above, by applying the conservation of energy. For, if x be the coordinate of its centre parallel to the plane, θ the angle through which it has turned, and a its radius, we have the kinematical condition

$$x=a\theta$$

(due to the perfect roughness of the plane).

Also the potential energy lost is

$$Mgx\sin\alpha,$$

where α is the inclination of the plane to the horizon; and the kinetic energy gained is made up of the two parts,—$\tfrac{1}{2}M\dot x^2$ translational, and $\tfrac{1}{2}Mk^2\dot\theta^2$ rotational.

Hence $$M(k^2+a^2)\dot\theta^2=2Mga\theta\sin\alpha,$$

or $$\dot x^2=2\frac{a^2g}{k^2+a^2}x\sin\alpha.$$

This shows that the motion is the same as that of a particle sliding down a *smooth* plane of the same inclination, under gravity diminished in the ratio $a^2:k^2+a^2$. And it shows how friction may retard motion without producing any dissipation of energy.

§ 245. Suppose one point of a rigid plane sheet be made to move in any manner in the plane of the sheet, what will be the consequent rotation?

Let M be the mass, and ξ, η, given in terms of t, the coordinates v·ying c· s·int o·ne p·rt of a·dy.

of the point of the sheet whose motion is assigned. Let a, θ be the relative polar coordinates of the centre of inertia, then

$$M[\ddot{\xi}+a(\cos\theta)^{\cdot\cdot}]=X\,,\quad M[\ddot{\eta}+a(\sin\theta)^{\cdot\cdot}]=Y\,,$$
$$Mk^2\ddot{\theta}=-Ya\cos\theta+Xa\sin\theta\,;$$

where X and Y are the forces requisite to produce the motion. Eliminating them, we find

$$(k^2+a^2)\ddot{\theta}=-a(\ddot{\eta}\cos\theta-\ddot{\xi}\sin\theta),$$

with which we can do no more until further data are specified.

Suppose ξ, η to move with uniform acceleration p in a direction assigned by α, then

$$\ddot{\xi}=p\cos\alpha\,,\quad \ddot{\eta}=p\sin\alpha\,,\ \text{and}$$
$$(k^2+a^2)\ddot{\theta}=-ap(\sin\alpha\cos\theta-\cos\alpha\sin\theta)=ap\sin(\theta-\alpha)\,.$$

The centre of inertia of the mass therefore moves, relatively to the constrained point, precisely as does a simple pendulum; but the direction of p is reversed.

Again suppose the constrained point to move uniformly in a circle of radius b, with angular velocity ω. We have

$$\xi=b\cos\omega t\,,\quad \eta=b\sin\omega t\,,$$

and
$$(k^2+a^2)\ddot{\theta}=+\omega^2ab(\sin\omega t\cos\theta-\cos\omega t\sin\theta)\,,$$

or
$$(k^2+a^2)\left(\frac{d}{dt}\right)^2(\theta-\omega t)=-\omega^2ab\sin(\theta-\omega t)\,.$$

This is, again, the equation of motion of a simple pendulum, but the angle of displacement $\theta-\omega t$ is no longer measured from a fixed line but from the uniformly rotating radius of the guide circle. Hence the mass oscillates, pendulum-wise, about this uniformly revolving line.

·llistic ·ndu·l·m.

§ 246. Let us take, as an instance of impulse, the case of Robins's "ballistic pendulum,"—a massive block of wood movable about a horizontal axis at a considerable distance above it,—employed to measure the velocity of a cannon or musket shot. The shot is usually fired into the block in a horizontal direction perpendicular to the axis. The impulsive penetration is so nearly instantaneous, and the mass of the block so large compared with that of the shot, that the ball and pendulum are moving on as one mass before the pendulum has been sensibly deflected from the position of equilibrium. This is the essential peculiarity of the ballistic method,—which is used also extensively in electromagnetic researches and in practical electric testing, when the integral quantity of the electricity which has passed in a current of short duration is to be measured. The line of motion of the bullet at impact may be in any direction whatever, but the only part which is effective is the component in a plane perpendicular to the axis. We may therefore, for simplicity, consider the motion to be in a line perpendicular to the axis, though not necessarily horizontal.

Let m be the mass of the bullet, v its velocity, and p the distance of its line of motion from the axis. Let M be the mass of the pendulum with the bullet lodged in it, and k its radius of gyration. Then, if ω be the angular velocity of the pendulum when the impact is complete,

$$mvp=Mk^2\omega\,,$$

from which the solution of the question is easily determined. For the kinetic energy after impact is changed into its equivalent in potential energy when the pendulum reaches its position of greatest deflexion. Let this be given by the angle θ; then the height to which the centre of inertia is raised is $h(1-\cos\theta)$, if h be its distance from the axis. Thus

$$Mgh(1-\cos\theta)=\tfrac{1}{2}Mk^2\omega^2=\tfrac{1}{2}\frac{m^2v^2p^2}{Mk^2}\,,$$

or
$$2\sin\frac{\theta}{2}=\frac{m}{M}\,\frac{p}{k}\,\frac{v}{\sqrt{gh}}\,,$$

an expression for the chord of the angle of deflexion. In practice the chord of the angle θ is measured by means of a light tape or cord attached to a point of the pendulum, and slipping with small friction through a clip fixed close to the position occupied by that point when the pendulum hangs at rest.

§ 247. As another example of impulse let us consider the case of a body moving in any way in a plane perpendicular to one of its principal axes. It is required to find what point of the body must be suddenly fixed in order that the whole may be brought to rest; also, what will be the consequent impulsive pressure at this point. It is easy to see that this is exactly the same question as to find the impulse, and its point of application, so that it may produce a given motion of a body in a plane perpendicular to one of its principal axes.

Impulse required for a given motion.

The impulse must obviously act in a plane passing through the centre of inertia. And the physical conditions are that the change of momentum of translation is equal to, and in the direction of, the impulse, while the change of moment of momentum about the centre of inertia is equal to the moment of the impulse. Let the impulse acting at the point ξ, η have components R, S parallel to rectangular coordinates in the plane of motion, and let ω be the angular velocity, u, v the linear velocities, generated by it. Then the physical conditions are

$$Mu=R\,,\quad Mv=S\,,\quad Mk^2\omega=S\xi-R\eta\,.$$

When u, v, ω are given, R and S are found from the first two equations, and the third is then the equation of the line in which the impulse must act. Similarly, when the impulse and its line of action are given, we have in terms of these data the quantities u, v, ω.

§ 248. As a simple practical example, suppose one strikes a hard object with a stick in such a way that his hand is at rest at the instant of the impact; with what part of the stick must he strike so that there may be no jar on his hand?

Centre of percussion.

Let ξ be measured along the stick from its centre of inertia in the direction which it has at the instant of impact. Then the kinematical condition is

$$v=a\omega\,,$$

where a is the distance from the hand to the centre of inertia of the stick. Thus, as the impulse S is the sole cause of the stick's being brought to rest, we have

$$Mv+S=0\,,\quad Mk^2v/a+S\xi=0\,;$$

so that
$$\xi=k^2/a\,.$$

Hence if the stick be uniform and be held by one end, so that its length is $2a$, and therefore $3k^2=a^2$, we have

$$\xi=\tfrac{1}{3}a\,;$$

and $a+\xi$, the distance of the point of impact from the hand, is

$$a+\tfrac{1}{3}a=\tfrac{2}{3}\,.\,2a\,,$$

i.e., it is at two-thirds of the length of the stick.

If, however, the hand be moving, at the instant of impact, perpendicularly to the stick with velocity V, the kinematical condition is $v-V=a\omega$, which introduces a corresponding change in the result.

§ 249. The reaction of the axis is easily calculated. If the axis about which the body is constrained to rotate be perpendicular to a plane though the centre of inertia about which the body is symmetrical, and if the applied forces act in that plane, it is clear that the reaction of the axis is a single force in that plane. Let its components be Ξ and H. Then

Reaction on axis.

$$\Sigma(m\ddot{x})=\Sigma(X)+\Xi\,,\quad \Sigma(m\ddot{y})=\Sigma(Y)+H\,,$$
$$\Sigma m(x\ddot{y}-y\ddot{x})=\Sigma(xY-yX)\,.$$

Let a, θ, be the polar coordinates of the centre of inertia, then $\dot{\theta}$, $\ddot{\theta}$ are the angular velocity and the angular acceleration for all particles of the mass, and we have

$$-Ma\cos\theta\,.\,\dot{\theta}^2-Ma\sin\theta\,.\,\ddot{\theta}=\Sigma(X)+\Xi\,,$$
$$-Ma\sin\theta\,.\,\dot{\theta}^2+Ma\cos\theta\,.\,\ddot{\theta}=\Sigma(Y)+H\,,$$
$$M(k^2+a^2)\ddot{\theta}=\Sigma(xY-yX)\,.$$

From the third we find θ, and the others give Ξ and H.

When there is no plane of symmetry perpendicular to the axis, there must be two points of it at which reactions are exerted on the revolving body. Let the coordinates of these bearings be c, c', and the reactions there Ξ, H, Z, Ξ', H$'$, Z$'$ respectively.

Then we have the six equations (in which $\ddot{z}=0$)

$$\Sigma(m\ddot{x})=\Sigma(X)+\Xi+\Xi',$$
$$\Sigma(m\ddot{y})=\Sigma(Y)+H+H',$$
$$\Sigma(m\ddot{z})=\Sigma(Z)+Z+Z';$$
$$\Sigma m(x\ddot{y}-y\ddot{x})=\Sigma(xY-yX),$$
$$\Sigma m(y\ddot{z}-z\ddot{y})=\Sigma(yZ-zY)-cH-c'H',$$
$$\Sigma m(z\ddot{x}-x\ddot{z})=\Sigma(zX-xZ)+c\Xi+c'\Xi'.$$

The fourth equation, as before, determines θ, and we have then four equations to determine Ξ, Ξ', H, H'. The remaining equation determines only the sum $Z+Z'$. In fact by more or less perfect *fitting* we can throw more or less of the force parallel to the axis on one or other of the bearings. There is really no indeterminateness in nature, but we cannot get the information required to evaluate separately Z and Z'.

§ 250. When impulsive forces are applied to the body, exactly the same methods may be employed, with the exception that $u'-u$ must be written for $\ddot{x}$, &c., and $\omega'-\omega$ for $\ddot{\theta}$. The quantities X, Y, Z, Ξ, H, Z, Ξ', H', Z' now denote impulses and not forces.

As a single example of the use of these formulæ, take the case of a body rotating, under the action of no force, about an axis through its centre of inertia. Here $\Sigma(mx)=0$, &c., and z is constant. The first two of the six equations last written show that the pairs of forces Ξ, Ξ' and H, H' form couples. The fourth equation gives $\theta=\omega t$; and with this the remaining two become

$$\Sigma(mzy).\omega^2=-cH-c'H'=-(c-c')H,$$
$$\Sigma(mzx).\omega^2=-c\Xi-c'\Xi'=-(c-c')\Xi.$$

The multipliers of ω^2 are each zero if the axis of rotation be a principal axis, and thus, in this case, there is no stress perpendicular to the axis. When the axis is not a principal axis the left hand terms are generally finite but they vary as the body turns. It is easy to see, however, that together these terms constitute a constant couple always in a plane passing through the axis, rotating with the body and dependent directly on the square of the angular velocity. Thus, to analyse the factor $\Sigma(mzy)$, we note that z is constant, and

$$y=r\sin(\omega t+\alpha),$$

where r, α were the polar coordinates of the mass m at time $t=0$.

Hence $\Sigma(mzy)=\sin\omega t\Sigma(mzx_1)+\cos\omega t\Sigma(mzy_1)$,

where $x_1=r\cos\alpha$ and $y_1=r\sin\alpha$ were the coordinates of m at $t=0$.

Similarly we have

$$\Sigma(mzx)=\cos\omega t\Sigma(mzx_1)-\sin\omega t\Sigma(mzy_1).$$

These expressions prove the preceding statements.

One point suddenly stopped.

§ 251. As a final instance of impulse in this branch of the subject, suppose that a rigid plate, moving anyhow in its own plane, has one of its points suddenly fixed, what will be the subsequent motion? Let the position in space at which the point is to be fixed be chosen as origin, and let the axis of x be chosen so as to pass through the centre of inertia at the moment of fixture. Then, if u, v be the velocities of the centre of inertia, ω the angular velocity about it, a its distance from the point to be fixed, the conditions of the impact are

$$u'=u-\Xi/M,$$
$$v'=v-H/M,$$
$$\omega'=\omega+Ha/Mk^2,$$

—three equations with five unknown quantities. But the conditions that the point in question is reduced to rest are evidently

$$u'=0,\quad v'-\omega' a=0.$$

These furnish the requisite additional data, and the solution is complete. If we eliminate H between the two equations which contain it, we have

$$k^2\omega'+av'=k^2\omega+av,$$

whence by the relation between v' and ω' we have

$$(k^2+a^2)\omega'=k^2\omega+av.$$

These equal quantities, each multiplied by M, represent respectively the moment of momentum about the point before and after its fixture.

§ 252. Thus, as a little consideration will show, we might have solved the problem at once, so far as the impulsive change of *motion* is concerned, by noticing that as the impulse is applied at the origin, the moment of momentum about that point will not be altered by it. In fact many problems, which present serious complexity when treated by the direct methods, are solved with comparative ease by such general considerations as the conservation of moment of momentum, or the conservation of energy. The first principle holds good when there is no resultant couple, or impulsive couple, round the origin; the second when no work on the whole is done by or against the forces or impulses.

Combined rolling and sliding.

§ 253. We have given instances of pure sliding, and of pure rolling, in one plane, and will now give a single instance of combined rolling and sliding. A common but instructive case of the problem we propose to consider is that of a hoop thrown forwards and at the same time made to rotate, so that after a time it stops, and finally rolls backwards to the hand. Other cases are furnished by a "following stroke" or a "screw-back" with a billiard ball.

Let the axis of x be parallel to the motion of translation of a sphere or cylinder moving on a horizontal plane. Then we have, if F be the friction, a the radius of the hoop or ball, the rate of change of momentum = F, and that of moment of momentum about the centre = Fa.

So long as sliding continues, F is constant, and equal to the product μMg of the normal pressure and the coefficient of kinetic friction. Hence at time t, if u_0 and ω_0 be the initial velocities of translation and of rotation,

$$u=u_0-\mu gt,$$
$$k^2\omega=k^2\omega_0-\mu gat.$$

These equations cease to be true when the sliding ceases, *i.e.*, when we have pure rolling, of which the geometrical condition is

$$u+a\omega=0.$$

This gives $\quad u_0+a\omega_0-\mu g(a^2/k^2+1)t_0=0,$

or $\quad t_0=\dfrac{k^2(u_0+a\omega_0)}{\mu g(a^2+k^2)}.$

At time t_0 and ever after we have

$$u=u_0-\frac{k^2(u_0+a\omega_0)}{k^2+a^2}=a\frac{au_0-k^2\omega_0}{k^2+a^2},$$

$$\omega=\omega_0-\frac{au_0+a^2\omega_0}{k^2+a^2}=\frac{k^2\omega_0-au_0}{k^2+a^2}.$$

Hence, if the body be projected in the positive direction, its ultimate motion will be in the negative direction if $au_0-k^2\omega_0$ be negative, *i.e.*, if the initial angular velocity be positive, and greater than au_0/k^2; which is $\frac{5}{2}u_0/a$ in the case of a sphere. Thus, at starting, the linear velocity of the point of contact with the plane must bear to that of translation of the ball a ratio of over 7 : 2 if it is to stop and return. In the case of a hoop this ratio must be at least 2 : 1.

Rigid body with point fixed.

§ 254. We pass now to the case of a rigid body one point only of which is fixed. As we have already seen (§ 234) this has only to be compounded with the motion of the whole mass, supposed concentrated at the point, in order to give the most general motion of which a rigid body is capable. The geometrical processes which have been applied to this problem, though in many respects of great power and elegance, cannot be introduced here. We will therefore give the more important results in a brief analytical form, and then geometrically exhibit their application.

Recurring to the general equations

$$\Sigma m(x\ddot{y}-y\ddot{x})=\Sigma(xY-yX)=N,\ \&c.,$$

we may transform the left hand members as follows.

Let ω_x, ω_y, ω_z be the angular velocities of the body about the fixed axes of x, y, z respectively. Then (§ 77) we have

$$\dot{x}=z\omega_y-y\omega_z,\ \&c.$$

From these we have three equations of the type

$$\ddot{x}=z\dot{\omega}_y-y\dot{\omega}_z+\dot{z}\omega_y-\dot{y}\omega_z$$
$$=z\dot{\omega}_y-y\dot{\omega}_z+(y\omega_x-x\omega_y)\omega_y-(x\omega_z-z\omega_x)\omega_z.$$

Thus we have

$$x\ddot{y} - y\ddot{x} = (x^2 + y^2)\dot{\omega}_z - yz\dot{\omega}_y - xz\dot{\omega}_x + xz\omega_y\omega_z - zy\omega_x\omega_z + (x^2 - y^2)\omega_x\omega_y - xy(\omega_x^2 - \omega_y^2) .$$

Now if the fixed axes be taken so as to coincide at a particular instant with the principal axes of the body passing through the point which is regarded as fixed, the terms involving factors of the form $\Sigma(mxy)$, &c., necessarily vanish (§ 237). Also we have

$$\Sigma m(x^2 - y^2) = \Sigma m(x^2 + z^2 - y^2 - z^2) ,$$

so that, if the principal moments of inertia of the body be A, B, C respectively, the dynamical equations become

$$C\dot{\omega}_z + (B - A)\omega_x\omega_y = N , \ \&c.$$

But it was proved in § 79 that when the angular velocities of a rigid body are referred to moving and to fixed axes, which coincide at a particular instant, not only are the angular velocities but also the angular accelerations equal at that instant in the two systems. Thus, if ω_1, ω_2, ω_3 be the angular velocities of the body about its principal axes, the equations just obtained take the form (due to Euler)

$$A\dot{\omega}_1 + (C - B)\omega_2\omega_3 = L ,$$
$$B\dot{\omega}_2 + (A - C)\omega_3\omega_1 = M ,$$
$$C\dot{\omega}_3 + (B - A)\omega_1\omega_2 = N .$$

When ω_1, ω_2, ω_3 are found, in any particular case, from these equations, the actual orientation of the body at any time can be calculated from them by the kinematical processes of § 81. The position in space of the point of the body which has been hitherto treated as fixed is to be calculated separately by the processes already explained for kinetics of a particle, and thus the motion of the body is completely determined—in the sense that the difficulties of the further steps are of a purely mathematical nature.

igid ody nder no rces. When the forces applied to the body have a single resultant, which either vanishes or passes through the origin, the right-hand terms disappear from Euler's equations. Multiply the equations by ω_1, ω_2, ω_3 respectively, and add. We thus obtain

$$A\omega_1\dot{\omega}_1 + B\omega_2\dot{\omega}_2 + C\omega_3\dot{\omega}_3 = 0 ,$$

whence

$$A\omega_1^2 + B\omega_2^2 + C\omega_3^2 = 2T \quad . \quad . \quad . \quad . \quad . \quad (1),$$

—the statement that the kinetic energy is constant. Again, multiply by $A\omega_1$, $B\omega_2$, $C\omega_3$ respectively, and add. Then we have

$$A^2\omega_1\dot{\omega}_1 + B^2\omega_2\dot{\omega}_2 + C^2\omega_3\dot{\omega}_3 = 0 ,$$

whence

$$A^2\omega_1^2 + B^2\omega_2^2 + C^2\omega_3^2 = D^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

expressing the constancy of *amount* of moment of momentum.

But if, in these equations, we now choose to regard ω_1, ω_2, ω_3 as the coordinates, parallel to the principal axes, of the extremity of a line which represents, in magnitude and direction, the instantaneous axis, we see that that axis is a central vector of each of the ellipsoids (1) and (2). Hence the instantaneous axis describes, relatively to the body, a cone of the second order. Since T and D are the only arbitrary coefficients in the equations, all the ellipsoids (1) or (2) are similar and similarly situated. The curve of intersection of (1) and (2) projected on the plane of the axes A and B has the equation

$$A(C - A)\omega_1^2 + B(C - B)\omega_2^2 = 2TC - D^2.$$

This represents an ellipse if the terms on the left have the same sign, *i.e.*, if C is either greater or less than each of A and B. Hence, if the body be originally rotating about an axis nearly coinciding either with the axis of greatest or that of least moment of inertia, it will continue to do so. These two cases are exemplified respectively by a quoit and by an elongated rifle bullet,—at least in so far as the resistance of the air does not interfere with their motion. But if the body be originally rotating about an axis nearly coinciding with the axis of intermediate moment of inertia, the curve indicated by the equation above is an hyperbola or a pair of straight lines through the origin; and the instantaneous axis travels, in general, far away from its first position in the body. We will henceforth look on A, B, C as in descending order of magnitude. It is obvious from the mode in which they are formed that $A = B + C$ only when the body is a plate. Hence, generally, any two of A, B, C are together greater than the third. Also by multiplying (1) by A, and comparing it term by term with (2), we see that $2AT > D^2$; similarly $2CT < D^2$.

To complete the examination of the immediate results of Euler's equations in this case, let us find how the length of the instantaneous axis, considered as a common vector-radius of the ellipsoids (1) and (2), depends on the time.

Let

$$\Omega^2 = \omega_1^2 + \omega_2^2 + \omega_3^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3);$$

$$\Omega\dot{\Omega} = \omega_1\dot{\omega}_1 + \omega_2\dot{\omega}_2 + \omega_3\dot{\omega}_3$$
$$= -\left(\frac{C - B}{A} + \frac{A - C}{B} + \frac{B - A}{C}\right)\omega_1\omega_2\omega_3 = -\frac{\Delta}{ABC}\omega_1\omega_2\omega_3 ,$$

where Δ is the determinant

$$\begin{vmatrix} 1 & 1 & 1 \\ A & B & C \\ A^2 & B^2 & C^2 \end{vmatrix} = -(C - B)(B - A)(A - C) .$$

Now (1), (2), (3) are linear equations in ω_1^2, ω_2^2, ω_3^2, and from them we have three equations like

$$\Delta\omega_1^2 = BC(C - B)\Omega^2 + 2T(B^2 - C^2) + D^2(C - B)$$
$$= BC(C - B)\{\Omega^2 - a\} ,$$

where

$$a = \frac{2T(B + C) - D^2}{BC}$$

is, by the remark above, essentially positive. Hence

$$\Delta^3\omega_1^2\omega_2^2\omega_3^2 = A^2B^2C^2(C - B)(B - A)(A - C)(\Omega^2 - a)(\Omega^2 - b)(\Omega^2 - c)$$
$$= A^2B^2C^2\Delta(a - \Omega^2)(b - \Omega^2)(c - \Omega^2) .$$

Thus

$$\Omega\dot{\Omega} = \sqrt{(a - \Omega^2)(b - \Omega^2)(c - \Omega^2)} ;$$

whence Ω^2 is at once found by elliptic functions. Ω known, we have ω_1, ω_2, ω_3, and then by the method of § 81 we have the complete analytical determination of the position of the body in terms of the time.

§ 255. Such a solution, however, fails to give so clear a conception of the nature of the motion as is afforded by the very elegant geometrical representation discovered by Poinsot. We may arrive at it by considering the tangent plane to (1) at the extremity of the radius Ω. If x, y, z be the current coordinates of that plane, its equation is — Poinsot's rolling ellipsoid.

$$A\omega_1(\omega_1 - x) + B\omega_2(\omega_2 - y) + C\omega_3(\omega_3 - z) = 0 ,$$

so that the perpendicular from the origin upon it is equal, by (2), to $2T/D$, a constant. The direction cosines of this perpendicular are proportional to $A\omega_1$, $B\omega_2$, $C\omega_3$, the component moments of momentum. Hence it is the axis of resultant moment of momentum, and is therefore (§ 166) fixed in direction in space. The tangent plane to (1) at the extremity of the instantaneous axis is therefore a fixed plane, and the ellipsoid (1) rolls upon it as if it were perfectly rough. From this we can of course find the equation of the curve of contact with the plane, and thence that of the cone, fixed in space, on which the cone of instantaneous axes in the body rolls, as in § 75. The latter cone is of course given by the intersection of (1) and (2).

To complete this beautiful representation of the motion, all that is necessary is a method of measuring time, something to show the rate of rolling of the ellipsoid on the fixed plane. Many constructions have been given for this purpose, such as Poinsot's "rolling and sliding cone," &c., but none can compare in elegance with that invented by Sylvester. We can only sketch a particular case—sufficient, however, to completely solve the question. — Sylvester's addition to Poinsot's construction.

Writing l, m, n for the direction cosines of the fixed line referred to the principal axes, we have

$$l = A\omega_1/D, \quad m = B\omega_2/D, \quad n = C\omega_3/D \quad . \quad . \quad . \quad . \quad (4).$$

Our equations (1) and (2) may now be written

$$l^2/A + m^2/B + n^2/C = 2T/D^2 \quad . \quad . \quad . \quad . \quad (1),$$
$$l^2 + m^2 + n^2 = 1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

Introducing a factor p, of dimensions the same as $1/A$, we have from these a third equation

$$l^2(1/A + p) + m^2(1/B + p) + n^2(1/C + p) = 2T/D^2 + p \quad . \quad (5).$$

Now consider an ellipsoid

$$\frac{x^2}{1/A + p} + \frac{y^2}{1/B + p} + \frac{z^2}{1/C + p} = E \quad . \quad . \quad . \quad (6),$$

which is similar, and similarly situated, to one of the ellipsoids confocal with (1) of § 254. Draw to it a tangent plane perpendicular to the line OL, whose direction cosines are (4). We obtain for the determination of the point of contact Q three equations of the form

$$l = \frac{x}{S(1/A + p)} , \quad m = \frac{y}{S(1/B + p)} , \quad n = \frac{z}{S(1/C + p)} \quad . \quad (7),$$

where

$$S^2 = \frac{x^2}{(1/A + p)^2} + \frac{y^2}{(1/B + p)^2} + \frac{z^2}{(1/C + p)^2} .$$

Here x, y, z are the coordinates of Q, and the distance of the tangent plane from the origin is E/S.

Now (6) gives at once by means of (7)

$$S^2[l^2(1/A + p) + m^2(1/B + p) + n^2(1/C + p)] = E ;$$

whence, by (5),
$$S^2 = \frac{E}{2T/D^2 + p}.$$
This is constant, and therefore the new tangent plane is fixed in space.

Let us now find the angular velocity about the fixed line OL of this plane's point of contact Q with the ellipsoid (6).

The direction cosines of the instantaneous axis OP are as $\omega_1, \omega_2, \omega_3$. Those of OQ are as x, y, z.

And we have obviously by (4) and (7)
$$\begin{vmatrix} \omega_1 & \omega_2 & \omega_3 \\ x & y & z \\ A\omega_1 & B\omega_2 & C\omega_3 \end{vmatrix} = 0.$$

Hence the line OQ lies in the plane containing the instantaneous axis OP and the fixed line OL. The motion of ellipsoid (6) is therefore one of combined sliding and rolling along the new tangent plane. To find the sliding, we must find the angular velocity of Q about the line OL. It is to that about OP, which is Ω, in the ratio of the sines of the angles POQ and QOL.

But
$$\sin^2 POQ = 1 - \frac{(x\omega_1 + y\omega_2 + z\omega_3)^2}{(x^2+y^2+z^2)\Omega^2},$$
and
$$\sin^2 QOL = 1 - \frac{(A\omega_1 x + B\omega_2 y + C\omega_3 z)^2}{(x^2+y^2+z^2)D^2}.$$
By means of the equations (1) and (7) above we find easily
$$\frac{\sin^2 POQ}{\sin^2 QOL} = \frac{D^2p^2}{\Omega^2}.$$

Hence the angular velocity of Q about OL is Dp, a constant. Now suppose the plane on which the ellipsoid (6) rolls and slides to become perfectly rough, and to be capable of rotating round OL as an axis, there will no longer be sliding of Q, but the plane will be made to rotate with the constant angular velocity Dp. Thus the time of any portion of the motion of the body will be measured out by the angle of forced rotation of this plane.

Quoit. § 256. As a simple example, let us take the case of a quoit, in which A, the moment of inertia about the axis of figure, is greater than either of the equal quantities B and C, which may be referred to any two perpendicular lines in the plane of the quoit. The equations become
$$A\dot\omega_1 = 0, \text{ so that } \omega_1 \text{ is constant,}$$
$$B\dot\omega_2 + (A-B)\omega_3\omega_1 = 0,$$
$$B\dot\omega_3 + (B-A)\omega_1\omega_2 = 0.$$
Put for a moment $\frac{A-B}{B}\omega_1 = n$, then we have
$$\dot\omega_2 + n\omega_3 = 0, \quad \dot\omega_3 - n\omega_2 = 0.$$
These give by eliminating ω_3
$$\ddot\omega_2 + n^2\omega_2 = 0.$$
Hence
$$\omega_2 = P\cos(nt+Q),$$
$$\omega_3 = -n^{-1}\dot\omega_2 = P\sin(nt+Q).$$

The resultant of these is an angular velocity P, about an axis in the plane of the axes of B and C, and making an angle $nt+Q$ with the axis of B. Hence the instantaneous axis describes in the body a right cone whose axis is that of figure; it moves round it in the *same* direction as that in which the body is rotating, and with angular velocity n. The fixed cone in space is also, obviously, a right cone and the other rolls on it *externally*.

Cylinder. If instead of a quoit the body be a long stick or cylinder, we have $A = B > C$, and the equations become
$$A\dot\omega_1 + (C-A)\omega_2\omega_3 = 0,$$
$$A\dot\omega_2 + (A-C)\omega_3\omega_1 = 0,$$
$$C\dot\omega_3 = 0.$$
The last gives ω_3 = constant, and, if
$$n = \frac{A-C}{A}\omega_3,$$
the first two equations are
$$\dot\omega_1 - n\omega_2 = 0, \quad \dot\omega_2 + n\omega_1 = 0.$$
Thus
$$\ddot\omega_1 + n^2\omega_1 = 0, \quad \omega_1 = P\cos(nt+Q),$$
and
$$\omega_2 = -P\sin(nt+Q).$$
This indicates a rotation of the axis of constant angular velocity P in the *negative* direction. Everything else is as before, but the cone fixed in the body rolls on the *inside* of that fixed in space.

Gyroscopic pendulum. § 257. Next let us take the case of a pendulum bob, supported by a flexible but untwistable wire, and containing a gyroscope whose axis is in the direction of the length of the pendulum. Here we may use, for variety, Lagrange's equations. For simplicity we suppose the centres of inertia of the bob and gyroscope to lie in the axis, and the bob to be symmetrical about the direction of the length of the pendulum.

Let the moment of inertia of the whole about the axis of symmetry be A when the gyroscope is supposed to be prevented from turning relatively to the bob, and let the other two principal moments about the point of suspension be B. Let that of the gyroscope about its axis be C. Then, if θ be the inclination to the vertical, ϕ the azimuth of the pendulum, and ψ a quantity denoting the position of the gyroscope with reference to a definite plane in the bob passing through its axis, we easily find
$$2T = A(1-\cos\theta)^2\dot\phi^2 + B(\dot\theta^2 + \sin^2\theta\dot\phi^2) + C[\dot\psi - (1-\cos\theta)\dot\phi]^2,$$
$$V = Mgl(1-\cos\theta) = V_0(1-\cos\theta), \text{ suppose,}$$
where M is the whole mass, and l the distance from the point of suspension to the centre of inertia of the whole.

The general treatment of this complex problem cannot be attempted here. We may, however, easily obtain useful and characteristic results in some special simple cases, which will enable us to form a general idea of the nature of the motion.

Thus, suppose if possible θ to be constant. This is the *Conical Gyroscopic Pendulum*. We easily find the equations Conical gyroscopic pendulum.
$$\dot\psi - (1-\cos\theta)\dot\phi = \Omega = \text{const.}$$
$$(A(1-\cos\theta) + B\cos\theta)\dot\phi^2 - C\Omega\dot\phi = V_0.$$
For any assigned values of Ω and θ, this shows what will be the corresponding value of $\dot\phi$. But it also shows that if we change simultaneously the signs only of Ω and $\dot\phi$, the value of θ is unaltered. Thus, reversal of the direction of rotation of the gyroscope involves reversal of the direction of motion of the bob, if the time of rotation is to be unaltered. But to any assigned values of θ and Ω two values of $\dot\phi$ correspond. As θ cannot, in the case considered, exceed $\frac{1}{2}\pi$, the multiplier of $\dot\phi^2$ is essentially positive. So is $V_0 = Mgl$. Hence the values of $\dot\phi$ are real; and one is positive, the other negative. Thus the pendulum, with any rate of rotation of the gyroscope, may be made to move in any horizontal circle; but the angular velocity will be greater when it is in the same sense as that of the rotation of the gyroscope than when it is in the opposite sense. When θ is so small that θ^2 may be neglected, we have
$$B\dot\phi^2 - C\Omega\dot\phi = V_0,$$
or
$$2B\dot\phi = C\Omega \pm \sqrt{4BV_0 + C^2\Omega^2}.$$
To give a numerical example, let the mass of the gyroscope be $\frac{n-1}{n}M$; let $B = Ml^2$, $C = \frac{n-1}{n}M\frac{l^2}{c^2}$, then
$$2\dot\phi = \frac{(n-1)\Omega}{nc^2} \pm \sqrt{4\frac{g}{l} + \left(\frac{n-1}{nc^2}\right)^2\Omega^2}.$$
If $n=5$, $c=10$, $g=10l$ (which are fair approximations to the dimensions of the ordinary form of the instrument),
$$\dot\phi = \frac{2\Omega}{500} \pm \sqrt{10 + \frac{4}{(500)^2}\Omega^2}.$$
Suppose the gyroscope to revolve 100 times per second, then $\Omega = 200\pi$ practically, and
$$\dot\phi = \tfrac{4}{5}\pi \pm \sqrt{10 + \tfrac{16}{25}\pi^2} = 2{\cdot}513 \pm 4{\cdot}039$$
$$= 6{\cdot}552 \text{ or } -1{\cdot}526.$$
The angular velocity, when the gyroscope is not rotating, would be that of the corresponding conical pendulum,
$$\sqrt{g/l} = \pm 3{\cdot}162;$$
so that in this case the gyroscopic pendulum would rotate about twice as fast, or only about half as fast, as the ordinary conical pendulum, according as it rotated with or against the gyroscope.

If we had taken $\Omega = 10\pi$ we should have found
$$\dot\phi = 3{\cdot}29 \text{ or } -3{\cdot}04, \text{ nearly.}$$
Thus the slower the gyroscope rotates the slower is the conical pendulum motion in the same direction, and the quicker that in the opposite direction.

Statics of a Chain or Perfectly Flexible Cord.

§ 258. Axiom.—*When a body or system is in equilibrium under the action of any forces, additional constraints will not disturb the equilibrium.* Compare § 193.

This principle is of very great use in forming the fundamental equations of fluid equilibrium, and thence those of motion. And we find it of advantage, as will be presently seen, in reducing to elementary geometry the problem of the equilibrium of a chain, or perfectly flexible cord.

We may treat this problem, called that of a "catenary," Catenary. by any one of the following methods:—(1) by investigating, as a question of statics of a particle, the conditions of equilibrium of a single link; (2) by imagining a finite portion of the chain to become rigid in its equilibrium form,—assuming, by the axiom above, that it will remain in equilibrium, and then treating the question by the methods employed for a rigid body; (3) by employing the energy test of equilibrium as in § 198.

§ 259. We exemplify each of these methods in the specially important case of the ordinary catenary.

Common catenary.

A uniform chain hangs between two fixed points, find the tension at any point and the curve in which the chain hangs.

First Method.—Let μ be the mass of unit length of the chain; T the tension at the point x, y, z; s the length of the chain to x, y, z from some assigned point; and let the axis of y be taken vertically. Then we have for the equilibrium of the element δs, considered as a material particle,

$$T\frac{dx}{ds} - \left(T\frac{dx}{ds} + \frac{d}{ds}\left(T\frac{dx}{ds}\right)\delta s\right) = 0,$$

$$T\frac{dy}{ds} + \mu g \quad - \left(T\frac{dy}{ds} + \frac{d}{ds}\left(T\frac{dy}{ds}\right)\delta s\right) = 0,$$

$$T\frac{dz}{ds} - \left(T\frac{dz}{ds} + \frac{d}{ds}\left(T\frac{dz}{ds}\right)\delta s\right) = 0.$$

Omitting the terms which cancel one another, and dividing by δs, these become

$$\frac{d}{ds}\left(T\frac{dx}{ds}\right) = 0, \quad \frac{d}{ds}\left(T\frac{dy}{ds}\right) = \mu g, \quad \frac{d}{ds}\left(T\frac{dz}{ds}\right) = 0.$$

From the first and third it follows that dz/dx is constant, *i.e.*, the chain hangs in a vertical plane. We may take it as that of xy, and the equations are reduced to the first two.

The first gives

$$T\frac{dx}{ds} = T_0,$$

showing that the horizontal component of the tension is constant throughout the whole length of the chain. Substituting for T in the second, it becomes

$$\frac{d}{ds}\left(\frac{dy}{dx}\right) = \frac{\mu g}{T_0}.$$

The quantity on the right is evidently of $[L^{-1}]$ dimensions, because that on the left is so; and thus we may write

$$\frac{\mu g}{T_0} = \frac{1}{a}, \quad \text{or} \quad T_0 = \mu g a.$$

Hence a is the length of a portion of the chain whose weight is equal to the constant horizontal component of the tension.

The equation now becomes

$$\frac{d^2y}{dx^2} = \frac{1}{a}\frac{ds}{dx} = \frac{1}{a}\sqrt{1 + \left(\frac{dy}{dx}\right)^2}.$$

Integrating, we have

$$\frac{dy}{dx} + \sqrt{1 + \left(\frac{dy}{dx}\right)^2} = C\varepsilon^{\frac{x}{a}}.$$

If we now assume that the axis of y passes through the point at which the chain is horizontal, we have at that point $x = 0, \frac{dy}{dx} = 0$, and therefore $C = 1$. Thus

$$\sqrt{1 + \left(\frac{dy}{dx}\right)^2} + \frac{dy}{dx} = \varepsilon^{\frac{x}{a}}.$$

Taking the reciprocal of each side, we have

$$\sqrt{1 + \left(\frac{dy}{dx}\right)^2} - \frac{dy}{dx} = \varepsilon^{-\frac{x}{a}}.$$

Subtracting,

$$2\frac{dy}{dx} = \varepsilon^{\frac{x}{a}} - \varepsilon^{-\frac{x}{a}},$$

or

$$2\frac{y}{a} = \varepsilon^{\frac{x}{a}} + \varepsilon^{-\frac{x}{a}};$$

no constant being added if we assume the axis of x so that $y = a$, $x = 0$ together. This is the equation of the curve required.

If we take the sum, instead of the difference, of the above equations, we find

$$2\frac{ds}{dx} = \varepsilon^{\frac{x}{a}} + \varepsilon^{-\frac{x}{a}};$$

so that

$$\frac{2s}{a} = \varepsilon^{\frac{x}{a}} - \varepsilon^{-\frac{x}{a}},$$

s being measured from the axis of y.

But the tension at x, y is, as above,

$$T = T_0\frac{ds}{dx} = T_0\frac{y}{a} = \mu g y.$$

Hence the tension at any point of the chain is equal to the weight of a length of the chain equal to the ordinate at that point.

Chain over parallel rails.

Thus if a chain of finite length be laid over two smooth parallel rails, its ends, when the whole is equilibrium, will be in the horizontal line corresponding to the axis of x in the above investigation, the middle part of the chain forming part of the catenary. When a given length $2l$ of chain rests in equilibrium on two smooth parallel rails at the same level, we have therefore $s + y = l$, while $x = b$, the half distance between the rails.

By the above expressions for y and s in terms of x, this leads to the equation

$$a\varepsilon^{\frac{b}{a}} = l,$$

which determines a when b and l are given. From this equation, as the minimum value of the left-hand side occurs when $a = b$, we see that the least length of chain for which equilibrium is possible under the conditions is equal to ε times the distance between the rails.

§ 260. *Second Method.*—The chain being in equilibrium, suppose any finite arc of it, as PQ (fig. 64), to become rigid. The forces acting on PQ are three—the tensions T_1 and T_2 at its ends, and its weight W acting at its centre of inertia. But three forces in equilibrium are in one plane (§ 221). Hence the curve is in one vertical plane. Also, as the two tensions are not parallel to one another, the lines of action of all three forces meet in one point. Hence there is no couple, and the conditions are simply

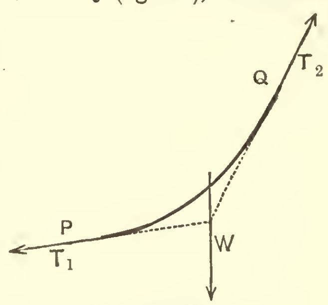


Fig. 64.

$$T_2\cos\theta_2 - T_1\cos\theta_1 = 0,$$
$$T_2\sin\theta_2 - T_1\sin\theta_1 - W = 0;$$

where θ_1, θ_2 are the inclinations to the horizon of the tangents at the ends of the portion solidified. The first asserts that the horizontal part of the tension is the same at P and Q, *i.e.*, all through the chain. The second asserts that the difference of the vertical parts of the tensions at any two points is equal to the weight of the part of the chain between them. By proper mathematical methods these data lead to the results already obtained. In fact the equations we have just obtained are the first integrals of the equations in § 259.

§ 261. *Third Method.*—The potential energy of the chain is

$$\mu g\int y\frac{ds}{dx}dx,$$

with the sole condition

$$\int\frac{ds}{dx}dx = \text{constant},$$

the limits of integration being fixed, and the same for each expression. Hence, by the rules of the calculus of variations, we have the same equations as before.

Mass of chain to hang in given curve.

§ 262. Still supposing gravity to be the only applied force, there are many forms of important questions which can be solved by either of these methods. We will take some simple, but varied, examples.

Find how the mass of unit length of a chain must vary from point to point so that the catenary may be an assigned plane curve.

We have, as before,

$$\frac{d}{ds}\left(T\frac{dx}{ds}\right) = 0;$$

but our second equation is now

$$\frac{d}{ds}\left(T\frac{dy}{ds}\right) = \mu g,$$

where μ is an unknown function of s. The third equation, being of the same form as the first, shows that the curve is in a vertical plane, and is thenceforth unnecessary.

As before, we have

$$T\frac{dx}{ds} = T_0 ,$$

and

$$\frac{d}{ds}\left(\frac{dy}{dx}\right) = \frac{\mu g}{T_0} .$$

Now, from the assigned equation of the catenary, the left-hand member can be expressed as a function of s, and thus we have the solution of the problem. For example, suppose the chain is to hang in an arc of an assigned circle. Referred to the lowest point of the circle, the equation is

$$x^2 = 2ay - y^2,$$

where a is the radius. From this we have

$$\frac{dy}{dx} = \frac{x}{a-y} = \tan\frac{s}{a} ,$$

so that

$$\mu = \frac{T_0}{ag}\sec^2\frac{s}{a} .$$

The tension at the lowest point is thus equal to the weight of a piece of chain like that at the vertex, and of length equal to the radius of the circle; the mass per unit length becomes infinite at the end of a horizontal diameter.

Suspension bridge.

Next *find the form of the chain when the mass of any arc is proportional to its horizontal projection.* This is a rough approximation to the case of a suspension bridge where the roadway is uniform, and much more massive than the chains, to which it is attached throughout by vertical ties. The equations are as before, but the additional condition takes the form

$$\mu\frac{ds}{dx} = \mu_0 , \text{ a constant.}$$

This gives

$$\frac{d^2y}{dx^2} = \frac{\mu_0 g}{T_0} ,$$

and the chain forms a parabola whose vertex is downwards, and whose axis is vertical.

Catenary of uniform strength.

As a final example, we have what is called the *catenary of uniform strength*; that is, *the form in which a chain hangs when the tension at every point is proportional to the breaking stress at that point.* Here we suppose the strength to be proportional to the section, *i.e.*, to the mass per unit length. This gives the condition

$$T = c\mu .$$

Hence

$$\frac{d}{ds}\left(\frac{dy}{dx}\right) = \frac{g}{cT_0}T = \frac{g}{c}\frac{ds}{dx} ,$$

or

$$\frac{d^2y}{dx^2} = \frac{1}{a}\left(\frac{ds}{dx}\right)^2 = \frac{1}{a}\left(1 + \left(\frac{dy}{dx}\right)^2\right) ,$$

where $a = c/g$.

This gives

$$\frac{dy}{dx} = \tan\left(\frac{x}{a} + C\right) ;$$

and the complete integral may be written, by proper selection of origin, in the final form

$$\varepsilon^{\frac{y}{a}} = \sec\frac{x}{a} .$$

Limit of span.

This curve has obviously two vertical asymptotes distant $\pm\frac{1}{2}\pi a$ from the axis of y. The quantity a is directly as the tenacity of the material; and thus we see that there is a limit (even in this simplest case) to the span of a chain, however strong, formed of any known kind of matter.

It is a very curious fact that, if we write the equation of this catenary in terms of the arc and the radius of curvature, it becomes identical with that of the common catenary in terms of Cartesian coordinates, horizontal and vertical. For we see at once that

$$\frac{ds}{dx} = \sec\frac{x}{a} ,$$

so that

$$\varepsilon^{\frac{s}{a}} = \sqrt{\left(1 + \sin\frac{x}{a}\right)\left(1 - \sin\frac{x}{a}\right)} ;$$

while by the previous equations

$$\frac{1}{\rho} = \frac{\frac{d^2y}{dx^2}}{\left(\frac{ds}{dx}\right)^3} = \frac{1}{a\frac{ds}{dx}} = \frac{\cos\frac{x}{a}}{a} .$$

Thus finally,

$$\frac{2\rho}{a} = \varepsilon^{\frac{s}{a}} + \varepsilon^{-\frac{s}{a}} . \quad \text{Compare § 259.}$$

Catenary general.

§ 263. When the chain is not uniform, and when it is subject to the action of other forces than, or besides, gravity, the equations are

$$\frac{d}{ds}\left(T\frac{dx}{ds}\right) = -\mu X , \quad \frac{d}{ds}\left(T\frac{dy}{ds}\right) = -\mu Y , \quad \frac{d}{ds}\left(T\frac{dz}{ds}\right) = -\mu Z ,$$

where X, Y, Z are the component forces on unit mass. These three equations involve the unknown quantities T, x, y, z, and s only; for μ is supposed to be given in terms of s. Two relations only among x, y, and z are wanted (for s is known in terms of x, y, z); so that the equations are necessary and sufficient to give these relations and the remaining unknown T.

The first members of these equations consist each of two terms:—

$$\frac{dT}{ds} \text{ multiplied respectively by } \frac{dx}{ds} , \frac{dy}{ds} , \frac{dz}{ds} ,$$

and

$$\frac{T}{\rho} \text{ multiplied by } \rho\frac{d^2x}{ds^2} , \quad \rho\frac{d^2y}{ds^2} , \quad \rho\frac{d^2z}{ds^2} ;$$

ρ being the radius of curvature of the chain. Hence (§ 22) we conclude that, so far as the tension alone is concerned, the forces on an elementary unit of length of the chain are dT/ds in the direction of the tangent, and T/ρ in the direction of the radius of absolute curvature. These must balance the corresponding components of the external forces on the element. Hence we see that the resultant of the applied forces lies, at every point, in the osculating plane. Thus we have

$$\frac{dT}{ds} = -\mu\left(X\frac{dx}{ds} + Y\frac{dy}{ds} + Z\frac{dz}{ds}\right) = -S ,$$

$$\frac{T}{\rho} = -\mu\left(X\rho\frac{d^2x}{ds^2} + Y\rho\frac{d^2y}{ds^2} + Z\rho\frac{d^2z}{ds^2}\right) = -N .$$

Here S and N are the tangential and normal components of the applied forces per unit length of the chain.

Catenary as path of particle.

But when a unit particle moves in a curve, we have always

$$\frac{dv}{dt} = v\frac{dv}{ds} = S', \text{ and } \frac{v^2}{\rho} = N',$$

where S′ and N′ are the normal and tangential components of the requisite force. If we write these in the form

$$\frac{dv}{ds} = \frac{S'}{v} , \quad \frac{v}{\rho} = \frac{N'}{v} ,$$

and suppose that the curve in which the particle moves is the same as the catenary above, while the speed at each point has the same numerical value as the tension, we see that we must have

$$\frac{S'}{v} = \frac{S'}{T} = -S , \quad \frac{N'}{v} = \frac{N'}{T} = -N ;$$

or

$$S' = -ST , \quad N' = -NT .$$

Thus the catenary will be the free path of the particle provided the force applied at any point is equal to the reverse of the product of that acting on the chain by the numerical value of the tension of the chain at that point.

Conversely, if we take any case of free motion of a particle, a uniform chain will hang in the corresponding orbit under the action of the same forces each reversed, and divided by the numerical value of the speed at the corresponding point of the orbit. Thus we can at once pass from particle kinetics to corresponding cases of catenaries.

Parabolic catenary.

In the case of a projectile, the path is a parabola, the force is constant and parallel to the axis, and the speed is as the square-root of the distance from the directrix. Hence, that the parabola may be a catenary under gravity, it must be turned vertex downwards; and the mass of the chain per unit length at any point must be inversely as the square root of the distance from the directrix. It is easily found from this that the mass of any arc of the chain must be proportional to the length of its horizontal projection, as in the second problem solved in § 262.

Elliptic catenary.

In the case of a planet we have

$$v^2 = \mu(2/r - 1/a) .$$

Hence a chain will hang in an ellipse if it be *repelled* from one focus by a force varying inversely as the square of the distance, the mass per unit length of the chain being directly as the square root of the distance from that focus and inversely as the square root of the distance from the other. If the chain be uniform, the law of the repulsive force from the first focus must be $1/\sqrt{r^3r'}$ instead of $1/r^2$, where r, r' are the distances from the two foci.

Pressure of cord on surface.

§ 264. When a chain or string is stretched over a curved surface, the surface must exert a reaction on it to keep it in its curved form. The preceding investigation has shown that the force normal to a chain per unit length at any point is balanced by T/ρ per unit of length, which must therefore be the magnitude of the reaction. We may establish this, however, in a very simple manner, as follows:—

Let AB (fig. 65) be a small portion of the cord, and AC, CB the tangents at its extremities; and let the (small) exterior angle at C be θ. Then, p being the pressure per unit length of the string, we have at once

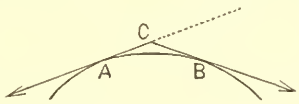


Fig. 65.

$$p.\text{AB} = 2\text{T}\sin\tfrac{1}{2}\theta = \text{T}\theta$$

ultimately. But $\text{AB} = \rho\theta$, so that

$$p = \text{T}/\rho\,.$$

Rope coiled on rough cylinder.

If there be friction, and if the element of the rope be just about to slip, in consequence of the difference of the tensions at its ends, we have

$$\text{T}' - \text{T} = \mu p.\text{AB} = \mu\text{T}\theta\,,$$

so that

$$\text{T}' = \text{T}(1 + \mu\theta)\,.$$

This leads to the formula for the growth of a sum at compound interest at μ per cent. payable every instant. Hence for a *finite* angle a we have

$$\text{T}_a = \varepsilon^{\mu a}\text{T}_0\,.$$

It is to be remarked here that neither the dimensions nor the form of the curve on which the cord is stretched, provided only it be plane, have any influence on this result, which involves only the coefficient of friction and the angle between the two free portions of the cord.

Kinetics of a Chain or Perfectly Flexible Cord.

§ 265. The equations of motion of a chain, under the action of any finite forces, are at once formed from those of equilibrium by introducing the forces of resistance to acceleration according to Newton's principle. Here we enter on a subject of extreme importance, but also (at least in the majority of cases) of great mathematical difficulty. One valuable result, however, can be obtained by very simple means.

Wave-velocity on stretched cord.

A uniformly heavy and perfectly flexible cord, placed in the interior of a smooth tube in the form of any curve, and subject to no external forces, will exert no pressure on the tube if it have everywhere the same tension, and move with a certain definite speed.

For, as in § 264, the statical pressure due to the curvature of the rope is $\text{T}\theta/\sigma$ per unit of length (where σ is the length of the arc AB in that figure) directed inwards to the centre of curvature. Now, the element σ, whose mass is $m\sigma$ (if m be the mass per unit of length), is moving in a curve whose curvature is θ/σ, with speed v (suppose). The requisite force is $\frac{mv^2\sigma\theta}{\sigma} = mv^2\theta$, and for unit of length $mv^2\theta/\sigma$. Hence if $\text{T} = mv^2$ the theorem is true. If we suppose a portion of the tube to be straight, and the whole to be moving with speed v parallel to this line, and against the motion of the cord, we shall have the straight part of the cord reduced to rest, and an undulation, of any, but unvarying, form and dimensions, running along it with linear speed $\sqrt{\text{T}/m}$.

Suppose the tension of the cord to be equal to the weight of W pounds, and suppose its length l feet and its own mass w pounds. Then $\text{T} = \text{W}g$, $lm = w$, and the speed of the undulation is $\sqrt{\text{W}lg/w}$ feet per second.

Reflected wave.

266. As will be shown later, when such an undulation reaches a fixed point of the cord or chain, it is *reflected*, and runs back along the cord with the same definite speed. But the reflected form differs from the incident form in being turned about in its own plane through two right angles. When the string is fixed at both ends any disturbance runs along it, backwards and forwards, with this speed, and thus (in a piano or harp) administers periodic shocks to the sounding board, causing it to give out a musical note. The interval between these periodic shocks is of course the time taken by the disturbance in running from end to end of the string. Dividing the length l of the string by the speed above reckoned, we find for this interval the value

$$\sqrt{wl/\text{W}g} = l\,\sqrt{m/\text{W}g}\,,$$

the reciprocal of which is the number of impulses per second. It is thus seen to be directly as the square-root of the tension of the string, inversely as the square-root of its mass per unit of length, and also inversely as its length. These are well-known facts in Acoustics. It is to be observed that there is no necessity for limiting the proposition above to a plane curve, though we have treated the question as if it were such. The demonstration applies even to a knot of any form.

Vibrati[ons] of musi[cal] string.

267. We will now consider more particularly the vibrations of a musical string, whose tension is great and its own mass small.

Forming the equations of motion as above hinted, we have three of the type

$$\frac{d}{ds}\left(\text{T}\frac{dx}{ds}\right) = -\mu(\text{X} - \ddot{x})\,.$$

In the special case of a tightly stretched inextensible string, performing very small transverse oscillations, we may greatly simplify these by assuming that no external forces act. This practically means that the weight of the string is negligible in comparison with the tension. If the axis of x be taken to coincide with the undisturbed position of the string, we have to the second order of small quantities

$$s = x\,.$$

With this the equation above written becomes

$$\frac{d\text{T}}{ds} = 0\,,$$

or the tension is the same throughout. The second and third equations now become

$$\text{T}\frac{d^2y}{dx^2} = \mu\ddot{y}\,, \qquad \text{T}\frac{d^2z}{dx^2} = \mu\ddot{z}\,.$$

The y and z disturbances are therefore of the same general character, and perfectly independent of one another. We will therefore confine our attention to one of them. From the equations we see that T/μ must be of two linear dimensions, and we will therefore write for it a^2. As this quantity must also be of two negative dimensions in time, a represents a speed. What speed will be seen immediately.

The equation in y is now

$$a^2\frac{d^2y}{dx^2} = \ddot{y}\,;$$

whose integral is known to be

$$y = f(at - x) + \text{F}(at + x)\,,$$

where f and F are arbitrary functions. As we have already seen (§ 53), the first part of the value of y expresses a wave running with speed a along the axis of x in the positive direction; the second part a wave in the negative direction with the same speed. Thus we see that any small disturbance whatever, of a stretched string, gives rise to two series of waves propagated in opposite directions with equal speeds. Also, as the equation is linear, the sum of any two or more particular integrals is also an integral.

One en[d] fixed.

If we suppose one extremity of the string to be fixed at the origin, we have the condition $x = 0$, $y = 0$, and therefore

$$0 = f(at) + \text{F}(at)\,.$$

As this holds for all values of t, the function F is simply the negative of f, so that

$$y = f(at - x) - f(at + x)\,.$$

To investigate what becomes of a disturbance which runs along the cord to the fixed end, let us suppose that $f(r)$ (which, by the remark above, may represent any *part* of a disturbance of the string) is a function which vanishes for all values of r which do not lie between the positive limits p and q, but which for values of r between these limits takes definite values. Then at time $t = 0$ we have

$$y = -f(x)\,,$$

for, by hypothesis, $f(r)$ vanishes for all negative values of r. This denotes a disturbance of the string originally extending from $x = p$

to $x=q$, which runs up to the origin. After the lapse of any interval greater than q/a we have

$$y=f(at-x)\,,$$

for $at+x$ has now become greater than q. This is a wave of exactly the same form as before, but the sign of the disturbance and the direction of its propagation are both reversed. Every portion of a wave is therefore reflected, with simple *reversal* of the displacement, as soon as it reaches the fixed end. For we may take the limits p and q as close together as we choose.

Both ends fixed.

Now suppose the string to have another fixed point at $x=l$. Then we have

$$0=f(at-l)-f(at+l)\,.$$

Thus f is (§ 67) a periodic function, of period $2l/a$, and can therefore be expressed as a series of simple harmonic terms of the full period, half period, one-third period, &c. Hence we may write, the coefficient $\frac{1}{2}$ being put in for convenience,

$$y=\tfrac{1}{2}\Sigma_1^\infty \mathrm{A}_m\cos\pi ml^{-1}(at-x)+\tfrac{1}{2}\Sigma_1^\infty \mathrm{B}_m\sin\pi ml^{-1}(at-x)$$
$$-\tfrac{1}{2}\Sigma_1^\infty \mathrm{A}_m\cos\pi ml^{-1}(at+x)-\tfrac{1}{2}\Sigma_1^\infty \mathrm{B}_m\sin\pi ml^{-1}(at+x)$$
$$=\Sigma_1^\infty \mathrm{A}_m\sin\pi ml^{-1}at\sin\pi ml^{-1}x-\Sigma_1^\infty \mathrm{B}_m\cos\pi ml^{-1}at\sin\pi ml^{-1}x\,.$$

This expression contains the complete solution of the problem. To adapt it to any particular case, we must know at some definite time (say $t=0$) the value of y in terms of x, *i.e.*, the initial disturbance; also the corresponding value of $\dot{y}$. We have then

$$y_0=-\Sigma_1^\infty \mathrm{B}_m\sin\pi ml^{-1}x\,,$$

$$\dot{y}_0=\frac{\pi a}{l}\Sigma_1^\infty m\mathrm{A}_m\sin\pi ml^{-1}x\,.$$

As y_0, $\dot{y}_0$ are given in terms of x, we can find, by the process of § 67, the values of A_m and B_m, and thence the required value of y.

Oscillations of a chain fixed at one end.

268. As another example, suppose a uniform chain to be suspended by one end, and to make small oscillations in a vertical plane.

We cannot enter here into details; so we simply assume that elementary persistent harmonic solutions are possible, or, what comes to the same thing, that there are *permanent* forms in which the chain can rotate about the vertical from the point of suspension.

If the axis of x be vertical, the equations of motion are

$$\frac{d}{ds}\left(\mathrm{T}\frac{dx}{ds}\right)=-\mu(g-\ddot{x})\,,\qquad \frac{d}{ds}\left(\mathrm{T}\frac{dy}{ds}\right)=\mu\ddot{y}\,;$$

where μ is the mass of unit length of the chain. As the oscillations are supposed to be small, we may neglect the change in the vertical ordinate of any point of the chain, because it must be of the second order of small quantities if the horizontal displacement is of the first order. Hence we may put everywhere x for s, and therefore consider x to be independent of t. Thus the first equation becomes

$$\frac{d\mathrm{T}}{dx}=-\mu g\,;$$

whence $\mathrm{T}=\mu g(l-x)\,,$

where l is the length of the chain. The second equation then becomes

$$(l-x)\frac{d^2y}{dx^2}-\frac{dy}{dx}=\frac{1}{g}\ddot{y}\,;$$

or, if we measure x from the lower end of the chain upwards,

$$x\frac{d^2y}{dx^2}+\frac{dy}{dx}=\frac{1}{g}\ddot{y}\,.$$

The complete integral of this equation would be much more general than we require, for it would express every possible small motion of the chain, however apparently irregular. What we seek are the fundamental modes of simple harmonic oscillation, any number of which, as in the case of a musical string, may be superposed. Hence we may write

$$y=\eta\sin(nt+\alpha)\,,$$

where n is a numerical quantity as yet undetermined, but which is confined to one or other of a series of definite values; η, on the other hand, is a function of x only. With this value of y the equation becomes

$$x\frac{d^2\eta}{dx^2}+\frac{d\eta}{dx}+\frac{n^2}{g}\eta=0\,.$$

By the usual method of undetermined coefficients we easily find the particular integral

$$\eta_0=\mathrm{A}\left(1-\frac{n^2x}{g}+\frac{n^4x^2}{2^2g^2}-\frac{n^6x^3}{2^23^2g^3}+\&\mathrm{c.}\right)\,. \qquad (1).$$

This series is obviously convergent for all finite values of n^2x/g.

The general integral is of the form

$$\eta=\mathrm{B}(\eta_1+\eta_0\log x)+\mathrm{A}\eta_0\,;$$

where η_1 is a function of x, finite for all values of x, but which we need not determine. For it is clear that, to suit our present purpose, we must put $\mathrm{B}=0$; otherwise we should have η infinite at $x=0$. Thus (1) is the expression we require under the limitations above imposed.

The quantity A represents the semi-amplitude of oscillation of the lower extremity of the chain. The condition that the upper end is fixed gives $\eta_0=0$ for $x=l$, *i.e.*,

$$0=1-\frac{n^2l}{g}+\frac{n^4l^2}{2^2g^2}-\frac{n^6l^3}{2^23^2g^3}+\&\mathrm{c.}$$

The roots of this equation (which are all real and positive) give the values of n for the several fundamental modes of vibration.

We have $\eta_0=0$ for the following values of n^2l/g: 1·454, 7·62, 18·74, 34·79, &c.

From these we find for the periods of the various simple disturbances the following multiples of the period of a simple pendulum equal in length to the chain, viz., 0·83, 0·36, 0·23, 0·17, &c. When n^2l/g has the least of the above values, the chain is always entirely on one side of the vertical, and the time of a complete oscillation is to that of a simple pendulum of the same length as 5 : 6 nearly.

Impulsive tension.

269. When a free chain, at rest, has an impulsive tension applied at one end, the calculation of the consequent impulsive tension at different parts of the chain and the velocities generated is very simple.

For, calling the instantaneous speeds along the tangent and along the radius of absolute curvature v_s and v_ρ respectively, we have

$$\delta\mathrm{T}=\mu v_s\delta s\,,\qquad \mathrm{T}/\rho=\mu v_\rho\,,$$

where μ is the mass of unit length of chain at s. It is obvious that there can be no impulsive speed perpendicular to the osculating plane. The kinematical condition is simply that an elementary arc δs is not altered in length. But the tangential increment of speed alone would imply an increase of the length of δs in the ratio $1+\frac{dv_s}{ds}\delta t:1$ in time δt. Also the impulsive speed v_ρ would imply a diminution of its length in the ratio $1-v_\rho\delta t/\rho:1$ by virtually making it an arc of a circle of smaller radius, but subtending the same angle at the centre. Hence, neglecting the square of δt as compared with its first power, we find for the kinematical condition

$$\frac{dv_s}{ds}-\frac{v_\rho}{\rho}=0\,.$$

This gives, by eliminating the impulsive velocities,

$$\frac{d}{ds}\left(\frac{1}{\mu}\,\frac{d\mathrm{T}}{ds}\right)-\frac{1}{\mu}\,\frac{\mathrm{T}}{\rho^2}=0\,.$$

If the chain be uniform, this becomes

$$\frac{d^2\mathrm{T}}{ds^2}-\frac{\mathrm{T}}{\rho^2}=0\,.$$

The whole kinetic energy generated in the chain by the impulse is

$$\tfrac{1}{2}\int\frac{ds}{\mu}\left(\left(\frac{d\mathrm{T}}{ds}\right)^2+\frac{\mathrm{T}^2}{\rho^2}\right)\,;$$

and the condition that this shall be a maximum is the differential equation above. This is a particular case of a general theorem due to Sir W. Thomson, viz.:—

A material system of any kind, given at rest, and subjected to an impulse in any specified direction and of any given magnitude, moves off so as to take the greatest amount of kinetic energy which the specified impulse can give it.

The direction in which an element of the chain begins to move is inclined to the tangent at an angle ϕ where

$$\tan\phi=\frac{v_\rho}{v_s}=\frac{\mathrm{T}}{\rho\frac{d\mathrm{T}}{ds}}\,.$$

Waves of extension of a string.

270. It is to be observed that, in such questions as those just treated, the possibility of an impact's being propagated instantaneously along the whole length of a chain depends upon its assumed inextensibility. When a wire (such as that employed for a distance-signal on railways) is regarded as *extensible*, there is a definite speed with which a disturbance of the nature of extension is transmitted along it.

Thus, recurring to the equations of § 267, we see that for the motion of a stretched elastic string in the direction of its length we have

$$\frac{d\mathrm{T}}{ds}=-\mu(\mathrm{X}-\ddot{x})\,.$$

If there be no applied forces, $\mathrm{X}=0$. Also, if we use x instead of s to characterize a particular point of the string, we must put $x+\xi$ for x and x for s, ξ being a function of x and t which denotes at any instant the displacement of that point.

The physical condition is expressed by Hooke's Law in the form

$$E\frac{d\xi}{dx}=T.$$

Hence

$$E\frac{d^2\xi}{dx^2}=\mu\ddot{\xi}.$$

This expresses (as in § 267) the passage of simultaneous waves. They are now waves of condensation and extension, not of transverse displacement. The nature of the interpretation of the equation is of the same general character as before, the speed being $\sqrt{E/\mu}$.

Dynamics of an Elastic Solid.

§ 271. This subject, which is a very extensive and difficult one, and in its generality quite unsuitable for discussion here, has already been to some extent treated of under Elasticity. We therefore content ourselves with one or two examples, whose treatment is comparatively simple, while their applications are frequent and considerable practical importance.

Cylindrical or prismatic wire, originally straight. § 272. Even so restricted a problem as that of determining the form assumed by a wire or thin rod of homogeneous isotropic elastic material, under the action of given forces and couples, presents somewhat formidable difficulties unless in its unstrained state the wire be straight and truly cylindrical or prismatic. And, even with these limitations, the problem again becomes formidable if we introduce the consideration of non-isotropic material; while, in any case, if the radius of curvature at each point is not very large in proportion to the thickness of the rod in the plane of bending, the problem is to no appreciable extent simplified by the limitation of form of the body. We will therefore give the comparatively simple case of the mere bending and twist of a homogeneous isotropic wire whose natural form is cylindrical or prismatic, the amounts of these from various sources being so small as to be superposable. Bending. Bending lengthens one set of lines of particles originally parallel to the axis of the wire and shortens others. Twist. Twist lengthens all but one such line, forming them into helices. The more detailed investigation, which we cannot give here, shows that there is one line of particles (the "elastic central line") which passes through the centre of inertia of each transverse section, and which may be treated (under our present limitations) as rigorously unchanged in length. The mutual molecular action of the parts of the wire on opposite sides of any transverse section may of course be reduced to a force and a couple, and the force may be conveniently treated as passing through the centre of inertia of the section. Also the twist and curvature of the wire near this section obviously depend on the couple and not on the force. For the moment of the couple is in general finite, while that of the force (about any point in the corresponding element of the wire) is infinitesimal.

§ 273. Let any two planes, at right angles to one another, be drawn through the elastic central line before distortion; and let them be cut in lines PR and PS by a transverse section through a point P of the central line. Also let PT be a tangent to that line. Suppose a similar construction to be carried out for every point P of the central line. Then it is clear that the form of the distorted wire will be completely determined if we know the form assumed by the central line, and the positions taken by the lines PR and PS drawn from each point in it. In their new positions P′T′, P′R′, and P′S′ will still form (in consequence of the limitations we have imposed) a rectangular system; and the nature of the distortion will be clearly indicated by the change of position of this rectangular system as it passes from point to point of the distorted central line. The plane of rotation of P′T′ is the osculating plane of the bending; its rate of rotation in that plane per unit length of the central line is the amount of bending; and the rate of rotation of the system P′R′, P′S′, about P′T′, per unit length of the central line, is the rate of twist. Suppose P′ to move with unit velocity along the distorted central line, and let ρ, σ, τ be the angular velocities of the system about P′R′, P′S′, P′T′ respectively, then ρ represents the curvature (or bending) resolved in the plane S′P′T′, σ that in R′P′T′, while τ represents the twist.

Expressions for force and couple in terms of bending and twist. Now, if the elastic forces constitute a conservative system, the amount of work done on an element of the body corresponding to a length δs of the central line is to be calculated entirely from its change of form. It must therefore be expressible in the form

$$w\delta s$$

where w is a function of ρ, σ, τ; which must be such that the couples producing the bending are

$$\frac{dw}{d\rho} \text{ and } \frac{dw}{d\sigma},$$

while that producing the twist is

$$\frac{dw}{d\tau}.$$

These again, are functions of ρ, σ, τ, and they must, on account of the principle of superposition, be linear and homogeneous. For, within the limits to which we have restricted ourselves, the doubling alike of bending and twist must involve the doubling of each of the couples. Thus w must be a homogeneous function of ρ, σ, τ of the second degree. Hence we may assume

$$w=\tfrac{1}{2}(A\rho^2+B\sigma^2+C\tau^2+2D\rho\sigma+2E\sigma\tau+2F\tau\rho),$$

where A, B, C, D, E, F are quantities depending on the form of the section of the wire and the nature of its material at each point. This gives

$$\frac{dw}{d\rho}=A\rho+D\sigma+F\tau,\quad \frac{dw}{d\sigma}=D\rho+B\sigma+E\tau,\quad \frac{dw}{d\tau}=F\rho+E\sigma+C\tau.$$

Hence, when the couples are assigned, the amounts of bending and twist are at once calculated from them. But the expression above is much more general than we require for the limited case we are considering. For, if the only couples applied to a portion of the prism or cylinder considered be in planes perpendicular to its length, twist only will be produced. Thus, for $\frac{dw}{d\rho}=0$, $\frac{dw}{d\sigma}=0$, we ought to have also $\rho=0$, $\sigma=0$. Hence E and F both vanish and we have simply

$$w=\tfrac{1}{2}(A\rho^2+2D\rho\sigma+B\sigma^2+C\tau^2).$$

This may be reduced, by properly selecting the planes originally drawn through the elastic central line, to the form

$$w=\tfrac{1}{2}(A\rho^2+B\sigma^2+C\tau^2).$$

Now we see that

$$\frac{dw}{d\rho}=A\rho,\quad \frac{dw}{d\sigma}=B\sigma,\quad \frac{dw}{d\tau}=C\tau.$$

§ 274. In a prismatic or cylindrical wire of homogeneous isotropic material, the elastic central line is thus a torsion axis simply. Equal and opposite couples, applied to the ends of such a wire, in planes perpendicular to its length, produce twist in direct proportion to the moments of the couples. There are two planes perpendicular to one another, and passing through this line, such that, if equal and opposite couples in either of these planes be applied at any parts of the wire, the portion between is bent into a circular arc in that plane. These are the principal planes of flexure. The quantities A and B which, when multiplied by the amount of bending in either of these planes, give the moment of the corresponding couple are called the principal "flexure rigidities" of the wire. Flexure rigidity. When they are equal (as in the case of a wire of circular, square, equilateral triangular, &c., section) any plane through the axis is a principal plane of flexure. Torsional rigidity. C is the torsional rigidity of the wire. In general, when the wire is fixed at one end and a couple applied at the other, the wire assumes the form of a circular helix. The exceptions (or rather particular cases) are:—(*a*) when the plane of the couple contains the elastic central line, and there is mere flexure, without twist; (*b*) when the plane of the couple is perpendicular to the wire, and there is twist simply.

§ 275. As an example of the preceding theory, take first

Flexure of plank by its own weight.

the case of a uniform plank clamped horizontally at one end, and otherwise unsupported. This is obviously the same as the case of a plank of double the length, supported by a trestle placed under its middle. We assume as before that the radius of curvature is always very large compared with the thickness of the plank.

In all such cases we may at once apply the principle of § 258, and suppose one portion of the plank up to a section P to be fixed in its equilibrium position. The curvature immediately contiguous to P will then be simply proportional to the moment about P of the forces acting on the unfixed portion. Hence at the free end there will be no curvature, and the curvature at points near that end will be of the second order of infinitesimals; *i.e.*, its rate of increase at the end vanishes.

Let x be the length of the fixed portion, l the whole length of the plank. Then, as the deflexion y from the horizontal is always very small, the curvature is expressed (§ 22) by

$$\frac{d^2y}{dx^2},$$

so that we have at once

$$E\frac{d^2y}{dx^2} = -\mu g\int_0^{l-x} x'dx' = -\tfrac{1}{2}\mu g(l-x)^2,$$

where E is the "flexural rigidity" of the plank, and μ its mass per unit of length.

Successive integrations give

$$E\frac{dy}{dx} = B + \tfrac{1}{6}\mu g(l-x)^3,$$

and

$$Ey = A - B(l-x) - \tfrac{1}{24}\mu g(l-x)^4.$$

The terminal conditions are

for $x=0$, $\quad y=0, \quad \frac{dy}{dx}=0;$

and for $x=l$, $\quad \frac{d^2y}{dx^2}=0, \quad \frac{d^3y}{dx^3}=0.$

The last two are obviously satisfied.

The two former give

$$B = -\frac{\mu g l^3}{6}, \quad A = Bl + \tfrac{1}{24}\mu g l^4 = -\tfrac{1}{8}\mu g l^4.$$

Hence

$$Ey = -\tfrac{1}{24}\mu g(3l^4 - 4l^3(l-x) + (l-x)^4).$$

Thus the droop of the free extremity ($x=l$) is

$$\frac{\mu g}{8}\frac{l^4}{E} = \frac{Wl^3}{8E},$$

where W is the whole weight.

If the plank had been weightless, but loaded at the free end with a weight W, our equation would have been

$$E\frac{d^2y}{dx^2} = -W(l-x),$$

and we should have had

$$E\frac{dy}{dx} = B' + \tfrac{1}{2}W(l-x)^2,$$

$$Ey = A' - B'(l-x) - \tfrac{1}{6}W(l-x)^3.$$

The terminal conditions at $x=0$ are as before, so that

$$B' = -\tfrac{1}{2}Wl^2, \quad A' = -\tfrac{1}{2}Wl^3 + \tfrac{1}{6}Wl^3 = -\tfrac{1}{3}Wl^3,$$

and the droop of the free end is $\frac{Wl^3}{3E}$, greater than before in the ratio of 8 : 3.

If the plank be again looked on as heavy, but its free end be supported on a trestle which is pressed upwards till it acts with a force W, we find directly

$$E\frac{d^2y}{dx^2} = W(l-x) - \tfrac{1}{2}\mu g(l-x)^2,$$

$$E\frac{dy}{dx} = B'' - \tfrac{1}{2}W(l-x)^2 + \tfrac{1}{6}\mu g(l-x)^3,$$

$$Ey = A'' - B''(l-x) + \tfrac{1}{6}W(l-x)^3 - \tfrac{1}{24}\mu g(l-x)^4.$$

The terminal conditions, at $x=0$, are still as in the first case, and they give

$$B'' = \tfrac{1}{2}Wl^2 - \tfrac{1}{6}\mu g l^3,$$

when the amount by which the free end is raised is

$$\frac{A''}{E} = [l(\tfrac{1}{2}Wl^2 - \tfrac{1}{6}\mu g l^3) - \tfrac{1}{6}Wl^3 + \tfrac{1}{24}\mu g l^4]/E = \frac{5Wl^3}{24E}.$$

This is obviously the same as the amount of depression of the middle of a plank of length $2l$ supported by trestles at each end.

§ 276. Hence the droop of the middle of a plank resting on trestles at its ends is to that of the ends when the plank rests on a single trestle at the middle in the ratio of 5 : 3.

If the equation expressing the curvature in the first or third cases above be twice differentiated, the common result is

$$E\frac{d^4y}{dx^4} = -\mu g.$$

Horizontal plank under any vertical forces.

The simplicity of this expression leads us to seek for the most general form. Suppose the plank to be exposed to any system of forces in lines perpendicular to its length and breadth. Then, if any transverse section be made, the stress between the two portions of the plank will consist of forces ($\pm$G) and couples ($\pm$H) in the plane of length and thickness. Let the applied forces be N per unit of length. Suppose also, as before, that the radius of curvature is very great compared with the thickness. Then the equations of equilibrium of an element are

$$\frac{dG}{dx} + N = 0, \quad \frac{dH}{dx} + G = 0.$$

We have also the condition of bending, viz.,

$$E \times \text{curvature} = E\frac{d^2y}{dx^2} = H.$$

Eliminating H and G among these equations, we have

$$E\frac{d^4y}{dx^4} = \frac{d^2H}{dx^2} = -\frac{dG}{dx} = N,$$

which of course includes all the previous particular cases. We may now determine (under the limits imposed) the form of a uniform plank of any length, supported in a nearly horizontal position at different points in its length, and loaded at any assigned points with any weights. The importance of this in practice is obvious.

Vibration of plank or flat spring.

§ 277. But we may easily take a further step, and investigate the oscillatory motion, so long at least as the acceleration parallel to the length of the plank and its rotation are negligible. For in such a case, if μ be the mass per unit of length, the equation of motion is (§ 199)

$$E\frac{d^4y}{dx^4} = N - \mu\ddot{y}.$$

We will consider only the case in which the applied force N may be neglected. This is practically the case of a uniform wire or flat rectangular spring. Suppose, further, that it is fixed at one end and free at the other, like Wheatstone's "kalcidophone," or like the tongue of a reed organ-pipe.

Then, writing n^4 for the fraction μ/E, we have

$$\frac{d^4y}{dx^4} + n^4\ddot{y} = 0.$$

A particular integral may obviously be found in the form

$$y = \eta\cos(i^2t/n^2 + \alpha) \quad \ldots\ldots \quad (1),$$

where η (a function of x) and i/n (a constant number) have to be found; α is any constant. The substitution of this value of y leads to

$$\frac{d^4\eta}{dx^4} - i^4\eta = 0,$$

the complete integral of which is

$$\eta = A\varepsilon^{ix} + B\varepsilon^{-ix} + C\cos(ix + D).$$

Now, provided the value of i be properly determined, the motion represented by (1), with the above value of η, can exist by itself; and the most general motion of which the spring is capable (under the limits imposed) consists of superposition of a number of separate motions of a similar character. Hence this may be treated by itself. Our limiting conditions in the present case are

$x=0$, $\quad \eta=0, \ \frac{d\eta}{dx}=0$ at the fixed end;

and $\quad x=l$, $\quad \frac{d^2\eta}{dx^2}=0, \ \frac{d^3\eta}{dx^3}=0$ at the free end.

Now, from the value of η above, we have

$$\frac{1}{i}\frac{d\eta}{dx}=\mathrm{A}\varepsilon^{ix}-\mathrm{B}\varepsilon^{-ix}-\mathrm{C}\sin(ix+\mathrm{D}),$$

$$\frac{1}{i^2}\frac{d^2\eta}{dx^2}=\mathrm{A}\varepsilon^{ix}+\mathrm{B}\varepsilon^{-ix}-\mathrm{C}\cos(ix+\mathrm{D}),$$

$$\frac{1}{i^3}\frac{d^3\eta}{dx^3}=\mathrm{A}\varepsilon^{ix}-\mathrm{B}\varepsilon^{-ix}+\mathrm{C}\sin(ix+\mathrm{D}).$$

Hence we have

$$\begin{aligned}0&=\mathrm{A}+\mathrm{B}+\mathrm{C}\cos\mathrm{D},\\0&=\mathrm{A}-\mathrm{B}-\mathrm{C}\sin\mathrm{D},\\0&=\mathrm{A}\varepsilon^{il}+\mathrm{B}\varepsilon^{-il}-\mathrm{C}\cos(il+\mathrm{D}),\\0&=\mathrm{A}\varepsilon^{il}-\mathrm{B}\varepsilon^{-il}+\mathrm{C}\sin(il+\mathrm{D}).\end{aligned}$$

Eliminating C and D, we have

$$\begin{aligned}0&=\mathrm{A}\varepsilon^{il}+\mathrm{B}\varepsilon^{-il}+(\mathrm{A}+\mathrm{B})\cos il+(\mathrm{A}-\mathrm{B})\sin il,\\0&=\mathrm{A}\varepsilon^{il}-\mathrm{B}\varepsilon^{-il}-(\mathrm{A}+\mathrm{B})\sin il+(\mathrm{A}-\mathrm{B})\cos il.\end{aligned}$$

Eliminate the ratio A/B, which is all that these equations furnish, and we have

$$(\varepsilon^{il}+\varepsilon^{-il})\cos il+2=0.$$

From this equation the values of i must be determined. It is clear that the multiplier of $\cos il$ is always greater than 2, except in the special case of $i=0$, which we obviously need not consider, as it gives $y=0$, and therefore belongs to the statical problem already considered. Hence as, to make $\cos il$ negative, il must be greater than $\frac{1}{2}\pi$; and, as $\varepsilon^{\frac{1}{2}\pi}+\varepsilon^{-\frac{1}{2}\pi}=5$ nearly, it is clear that the excess of the first value of il over $\frac{1}{2}\pi$ is somewhere about 0·3. The next value falls short of $\frac{3}{2}\pi$ by a quantity of the order $\frac{1}{100}$, the next exceeds $\frac{5}{2}\pi$ by a quantity of the order $\frac{1}{2500}$, &c. The required values arrange themselves in two groups, one of either group being taken alternately. The first group involves arcs a little greater than but rapidly approaching to the values of $(4m+1)\frac{1}{2}\pi$; the second consists of arcs a little less than but rapidly approaching to those of $(4m+3)\frac{1}{2}\pi$.

Effects of pressure on tubes and spherical shells.

§ 278. Some of the simplest, but at the same time most practically useful, of questions connected with elasticity of solids relate to the changes of form or volume experienced by circular cylindrical tubes or spherical shells exposed to hydrostatic pressure. A steam-boiler, the cylinders and tubes of an hydraulic press, a fowling-piece or cannon and (on a much smaller scale) Örsted's piezometer, deep-sea thermometers, &c., afford common instances. All that is necessary for attacking such questions is given in §§ 45, 46 of the article ELASTICITY. For it is there shown that, if a homogeneous isotropic elastic solid be subjected to a simple longitudinal stress P, uniform and in a definite direction throughout its whole substance, the result will be linear extension $=\mathrm{P}\left(\frac{1}{3n}+\frac{1}{9k}\right)$ in the direction of P, and linear contraction $=\mathrm{P}\left(\frac{1}{6n}-\frac{1}{9k}\right)$ in all directions perpendicular to P. The quantities n and k, as explained in the article referred to, are respectively the "rigidity" and the reciprocal of the "compressibility" of the solid operated on.

Equal pressures within and without piezometer.

§ 279. The case of the piezometer, in which the vessel holding the liquid whose compression is to be measured is exposed both inside and outside to the same hydrostatic pressure, is seen to correspond to three equal stresses in directions at right angles to one another. These directions may be any whatever, and in each of them the linear extension is obviously

$$\mathrm{P}\left\{\left(\frac{1}{3n}+\frac{1}{9k}\right)-2\left(\frac{1}{6n}-\frac{1}{9k}\right)\right\}=\frac{\mathrm{P}}{3k}.$$

P is negative, as the stress is a pressure. Hence the strain consists in a simple alteration of volume measured by P/k. Every part of the walls of the vessel, as well as its external bulk, and its interior content, is altered to the same extent.

Cylinder under internal pressure.

§ 280. In the case of a cylinder, when the internal and external pressures are different, it is clear from symmetry that the stresses may be resolved at any point of the walls into three at right angles to one another, the first (P_1) parallel to, the second (P_2) at right angles to, the axis, and the third (P_3) perpendicular to each of the other two. In a transverse section of the cylinder, the second of these is radial and the third is tangential to a coaxal cylinder passing through the element considered. We suppose the cylinder closed at both ends, and we make the further assumption (quite exact enough for practical applications, and most important from the point of view of simplicity of calculation) that all transverse sections of the cylinder remain, after distortion, transverse sections. This is equivalent to assuming P_1 to be constant throughout the walls of the cylinder. Hence, if there be interior pressure only, the value of this stress must be

$$\mathrm{P}_1=\frac{\text{pressure on end of interior of cylinder}}{\text{area of transverse section of walls of cylinder}}=\frac{\Pi a_0^2}{a_1^2-a_0^2},$$

where Π is the interior hydrostatic pressure, and a_0, a_1 are the internal and external radii. This stress represents a longitudinal *tension* of the walls of the cylinder.

Let us consider an element of the cylindrical wall, defined as follows in the unstrained state:—

Draw two transverse sections at distances x and $x+\delta x$ from one end, two planes through the axis making an (infinitesimal) angle θ with one another, and two cylinders of radii r and $r+\delta r$ about the common axis. In the strained state θ is unchanged, but x becomes $x+\xi$, and r becomes $r+\rho$. The distance between the transverse sections was δx; it becomes $\delta x+\frac{d\xi}{dx}\delta x$, so that the linear extension parallel to the axis is $\frac{d\xi}{dx}$. The distance between the cylinders was δr; it becomes $\delta r+\frac{d\rho}{dr}\delta r$, so that the radial extension is $\frac{d\rho}{dr}$. The breadth of the base of the wedge-shaped element was $r\theta$; it becomes $(r+\rho)\theta$, so that the linear extension perpendicular alike to the radial line and to the axis is $\frac{\rho}{r}$.

If we now write, for simplicity,

$$e=\frac{1}{3n}+\frac{1}{9k},\quad f=\frac{1}{6n}-\frac{1}{9k},$$

the three requisite equations between stresses and strains are at once obvious in the form

$$\frac{d\xi}{dx}=e\mathrm{P}_1-f\mathrm{P}_2-f\mathrm{P}_3,$$

$$\frac{d\rho}{dr}=-f\mathrm{P}_1+e\mathrm{P}_2-f\mathrm{P}_3,$$

$$\frac{\rho}{r}=-f\mathrm{P}_1-f\mathrm{P}_2+e\mathrm{P}_3.$$

We have, however, four unknown quantities ξ, ρ, P_2, and P_3, so that another equation is required. This must be supplied by one of the statical conditions of equilibrium of the element above defined, when in its strained state. There is obviously equilibrium in the axial direction, and also parallel to the base of the element; but radially we have a case resembling that of an element of a cord as in § 264. Neglecting small quantities of a higher order than those retained, this consideration gives

$$\mathrm{P}_3\delta\theta\delta x\delta r=\frac{d}{dr}(\mathrm{P}_2r\delta\theta\delta x)\delta r,\quad\text{or}\quad\mathrm{P}_3=\frac{d}{dr}(\mathrm{P}_2r).$$

Solving the four equations, and taking account of the boundary conditions

$$\mathrm{P}_2=-\Pi\text{ when }r=a_0,\text{ and }\mathrm{P}_2=0\text{ when }r=a_1,$$

we obtain the following values:—

$$\frac{d\xi}{dx}=\Pi\frac{a_0^2}{a_1^2-a_0^2}(e-2f),$$

$$\frac{\rho}{r}=\Pi\frac{a_0^2}{a_1^2-a_0^2}\left[(e-2f)+\frac{a_1^2}{r^2}(e+f)\right],$$

$$\frac{d\rho}{dr}=\Pi\frac{a_0^2}{a_1^2-a_0^2}\left[(e-2f)-\frac{a_1^2}{r^2}(e+f)\right]:$$

or, reintroducing the values of e and f,

$$\frac{d\xi}{dx}=\frac{\Pi a_0^2}{a_1^2-a_0^2}\frac{1}{3k},$$

$$\frac{\rho}{r}=\frac{\Pi a_0^2}{a_1^2-a_0^2}\left(\frac{1}{3k}+\frac{a_1^2}{r^2}\frac{1}{2n}\right).$$

$$\frac{d\rho}{dr}=\frac{\Pi a}{a_1^2-a_0^2}\left(\frac{1}{3k}-\frac{a_1^2}{r^2}\frac{1}{2n}\right).$$

§ 281. Thus the nature of the distortion produced in the walls of a cylindrical tube by internal pressure may be described as made up of a uniform dilatation, whose linear measure in every direction is $\frac{\Pi a_0^2}{a_1^2 - a_0^2}\frac{1}{3k}$, combined with a shear in each transverse section, whose measure is $1 \pm \frac{\Pi a_0^2 a_1^2}{(a_1^2 - a_0^2)r^2}\frac{1}{2n}$. § 91.

The shorter axis of this shear is radial, and the magnitude of the shear is obviously greater for smaller values of r. The inner layer of the walls is thus the most distorted. The amount of the distortion is directly as the pressure, and inversely as the area of the section of the walls.

When the walls are very thin the shear is practically the same throughout their thickness. When they are very thick, the shear near the inner surface is nearly $1 \pm \frac{\Pi}{2n}$, however fine be the bore. That near the outer surface is nearly $1 \pm \frac{a_0^2}{a_1^2}\frac{\Pi}{2n}$, which vanishes when the bore is very fine. Thus it appears that, if a stout tube bursts by the shear produced by internal pressure, little is gained either by making it of extremely great thickness or by making it of very small bore.

The diagrams A and B in fig. 66 show, necessarily on a greatly exaggerated scale, the nature of the distortion produced at different

A B C D

Fig. 66.

parts of the wall of the tube. They represent transverse sections of small, originally spherical, elements made by planes at right angles to the axis. The radial diameters are horizontal. A is an element close to the external surface, B an element near the inner surface. The increase per unit volume of the interior of the tube is

$$\frac{\Pi a_0^2}{a_1^2 - a_0^2}\left(\frac{1}{k} + \frac{a_1^2}{a_0^2}\frac{1}{n}\right);$$

so that, if the tube be very thick in comparison with its bore, the increase is nearly Π/n. In flint glass this is approximately about $\frac{1}{1000}$, when Π is a ton-weight per square inch.

Cylinder under external pressure.

§ 282. The reader who has followed the above investigation will find no difficulty in obtaining the corresponding results for a cylindrical tube, closed at both ends and exposed to external pressure Π, in the form

$$\frac{d\xi}{dx} = -\frac{\Pi a_1^2}{a_1^2 - a_0^2}\frac{1}{3k},$$

$$\frac{\rho}{r} = -\frac{\Pi a}{a_1^2 - a_0^2}\left(\frac{1}{3k} + \frac{a_0^2}{r^2}\frac{1}{2n}\right),$$

$$\frac{d\rho}{dr} = -\frac{\Pi a_1^2}{a_1^2 - a_0^2}\left(\frac{1}{3k} - \frac{a_0^2}{r^2}\frac{1}{2n}\right).$$

The only comments we need make are (1) that the signs of these distortions are now negative; (2) that they are (so far as change of volume is concerned) greater than for the internal pressure, as a_1^2 has taken the place of a_0^2 as a factor in each term involving k; (3) that the terms involving the rigidity are, except as regards sign, unchanged.

The change of volume of every part of the walls is

$$-\frac{\Pi a_1^2}{a_1^2 - a_0^2}\frac{1}{k},$$

and the change of volume of the interior is

$$-\frac{\Pi a_1^2}{a_1^2 - a_0^2}\left(\frac{1}{k} + \frac{1}{n}\right).$$

The numerical value of the factor $\Pi\left(\frac{1}{k} + \frac{1}{n}\right)$ is about $\frac{1}{1000}$ for flint glass and about $\frac{1}{4000}$ for steel, when Π is a ton-weight per square inch. There is, however, a peculiarity which (when the walls are thick enough) distinguishes this from the preceding case. For k is usually considerably greater than n, so that *a fortiori* $3k$ is greater than $2n$. Hence, in the value of $d\rho/dr$, the term in n is always greater than that in k so long as the pressure is internal. Thus the radial effect is compression at all parts of the walls. But, when the pressure is external, we may (if the walls be thick enough) find a value of r for which

$$\frac{1}{3k} = \frac{a_0^2}{r^2}\frac{1}{2n}.$$

In glass, this occurs when $r = 1{\cdot}6a_0$ nearly. At this distance from the axis there is no radial change of length; at greater distances there is radial compression, and at smaller radial extension. This is indicated in the diagrams C and D in fig. 66, which like the former are greatly exaggerated. They represent the distortion of small spherical elements of a thick tube,—the first at the inner wall, the second at the outer surface. As before, these are sections made by a plane perpendicular to the axis of the cylinder.

Spher[ical] shell under exter[nal] press[ure].

§ 283. In a spherical shell of internal and external radii a_0 and a_1, the equations become a little more simple on account of the more complete symmetry.

Using the same notation, so far as it is now applicable, we have

$$\frac{d\rho}{dr} = -2f\text{P}_1 + e\text{P}_2, \qquad \frac{\rho}{r} = (e-f)\text{P}_1 - f\text{P}_2.$$

The statical equation is

$$2r\text{P}_1 = \frac{d}{dr}(r^2\text{P}_2).$$

With these we obtain, for external pressure Π, the result

$$\frac{\rho}{r} = -\Pi\frac{a_1^3}{a_1^3 - a_0^3}\left(\frac{1}{3k} + \frac{a_0^3}{r^3}\frac{1}{4n}\right),$$

from which the other equation may be derived by differentiation.

§ 284. The propagation of plane waves in an elastic solid has been discussed in Elasticity, and the mechanics of fluids is discussed under Hydromechanics.

General Considerations.

Gener[al] considerations.

§ 285. The preceding view of the subject of Abstract Dynamics has been based entirely upon Newton's Laws of Motion, which were adopted without discussion, as a complete and perfectly definite foundation; and the terms employed, as well as the mode of treatment in general, have somewhat closely followed Newton's system. The only considerable apparent departure from that system is connected with the development of the idea of energy, and its application to the simplification of many of the methods and results. This also was, as we have seen, really introduced by Newton; but it has been immensely extended since his time both by mathematical and by experimental processes. It is time that we should now return to the laws of motion, and examine more closely, in the light of what we have learned, one or two of the more prominent ideas which they embody. To do so fairly we must go back to Newton's own definitions of the terms which he employs. About many of these, which have already been quoted in §§ 97–113, there is no difference of opinion But it is otherwise when we come to the definition of "force" (§§ 5, 104).

Force

There can be no doubt that the proper use of the term "force" in modern science is that which is implied in the statement of the first law of motion, as we rendered it in § 1 from Newton's Latin. It is thus seen to be the English equivalent of the term *vis impressa*. Newton uses the word *vis* in other connexions, and with a certain vagueness inevitable at a time when the terminology of science was still only shaping itself; but his idea of "force" was perfectly definite, and when *this* is in his mind the vague word *vis* is (when necessary) always qualified and rendered precise, either by the addition of *impressa* or in some equally unambiguous way. To render *vis* by "force," wherever it stands without the *impressa* or its equivalents, is to introduce a quite gratuitous confusion for which Newton is not responsible. We have only to think of the multitude of terms, such as *vis insita* (inertia), *vis acceleratrix* (acceleration), *vis viva* (kinetic energy), &c., &c., to see that all such complex expressions must be regarded as *wholes*, and that *vis* does not mean "force" in any one of them.

§ 286. Thus in Newton's view *force is whatever changes* (but not "*or tends to change*") *a body's state of rest or of uniform motion in a straight line.*

He mentions, as instances, percussion, pressure, and central force.[1] Under the last of these heads he expressly includes magnetic as well as gravitational force. Thus

[1] *Vis centripeta.* It has been already explained that such words as *centripeta* include *impressa*, so that the above rendering of Newton's phrase is the obvious one.

force may have different origins, but it is always one and the same; and it produces, in any body to which it is applied, a change of momentum in its own direction, and in amount proportional to its magnitude and to the time during which it acts.

Equilibrium.

§ 287. Thus, from Newton's point of view, equilibrium is not a balancing of forces, but a balancing of the effects of forces. When a mass rests on a table, gravity produces in it a vertically downward velocity which is continually neutralized by the equal upward velocity produced by the reaction of the table; and these forces, whose origins and places of application are alike so widely different, are (as forces), in every respect except direction, similar and equal. And they are so because they produce, in equal times, equal and opposite quantities of motion.

Origin of the idea of force.

§ 288. The idea of "force" was undoubtedly suggested by the "muscular sense"; and there can be no question as to the vividness of the sensation of effort we experience when we try to lift a heavy weight or to open a massive gate. In this, as in other cases, it is the business of science to find what objective fact corresponds to the subjective data of sensation. It is very difficult to realize the fact, certain as it is, that light (in the sense of *brightness*) is a mere sensation or subjective impression, and has no objective existence. Yet we know that, beside those radiations which give us the sensation of light, there are others, in endless series both higher and lower in their refrangibility, to which our eyes are absolutely blind. And the only difference between these and the former is one of mere wave-length or of period of vibration. Similarly, it is very hard to realize the fact that sound (in the sense of *noise*) is only a sensation; and that outside us there is merely a series of alternate compressions and dilatations of the air, the great majority of which produce no sensible effect upon our ears. Thus because we know that we should seek in vain for brightness or noise in the external world, familiar as our senses have rendered us with these conceptions, we are driven to inquire whether the idea of *force* may not also be a mere suggestion of sense, corresponding (no doubt) to some process going on outside us, but quite as different from the sensation which suggests it as is a periodic shearing of the ether from brightness, or a periodic change of density of air from noise.

Stress.

§ 289. So far, we have treated of force as acting on a body without inquiring whence or why; we have referred to the first and second laws of motion only, and have thus seen only one half of the phenomenon. As soon, however, as we turn to the third law, we find a new light cast on the question. Force is always dual. To *every* action there is *always* an equal and contrary reaction. Thus the weight which we lift or try to lift, and the massive gate which we open or try to open, both as truly exert force upon our hands as we do upon them. This looking to the other side of the account, as it were, puts matters in a very different aspect. "Do you mean to tell me," said a medical man of the old school, "that, if I pull a 'subject' by the hand, it will pull me with an equal and opposite force?" When he was convinced of the truth of this statement, he gave up the objectivity of force at once.

Tension and pressure.

§ 290. The third law, in modern phraseology, is merely this:—

Every action between two bodies is a stress.

When we pull one end of a string, the other end being fixed, we produce what is called *tension* in the string. When we push one end of a beam, of which the other end is fixed, we produce what is called *pressure* throughout the beam. Leaving out of account, for the moment, the effects of gravity, this merely amounts to saying that there is stress across every transverse section of the string or beam. But, in the case of the string, the part of the stress which every portion exerts on the adjoining portion is a *pull*; in the case of the beam it is a *push*. And all this distribution of stress, though exerted across every one of the infinitely numerous cross sections of the string or beam, disappears the moment we let go the end. We can thus, by a touch, call into action at will an infinite number of stresses, and put them out of existence again as easily. This, of itself, is a very strong argument against the supposition that force, in any form, can have objective reality.

Objective physical realities.

§ 291. We must now say a word or two on the question of the objective realities in the physical world. If we inquire carefully into the grounds we have for believing that matter (whatever it may be) has objective existence, we find that by far the most convincing of them is what may be called the "conservation of matter." This means that, do what we will, we cannot alter the mass or quantity of a portion of matter. We may change its form, dimensions, state of aggregation, &c., or (by chemical processes) we may entirely alter its appearance and properties, but its quantity remains unchanged. It is this experimental result which has led, by the aid of the balance, to the immense developments of modern chemistry. If we receive this as evidence of the objective reality of matter, we must allow objective reality to anything else which we find to be conserved *in the same sense* as matter is conserved. Now there is no such thing as negative mass; mass is, in mathematical language, a signless quantity. Hence the conservation of matter does not contemplate the simultaneous production of equal quantities of positive and negative mass, thus leaving the (algebraic) sum unchanged. But this is the nature of conservation of momentum (§ 165) and of moment of momentum. The only other known thing in the physical universe, which is conserved in the same sense as matter is conserved, is energy. Hence we naturally consider energy as the other objective reality in the physical universe, and look to it for information as to the true nature of what we call force.

True nature of force.

§ 292. When we do so, the answer is easily obtained, and in a completely satisfactory form. We give only a very simple instance. When a stone, whose mass is M and weight W, has fallen through a space h towards the earth, it has acquired a speed v, which (§ 28) is given by the equation

$$\tfrac{1}{2}Mv^2 = Wh.$$

This is a particular case of the conservation of energy, but the terms in which it is expressed are those suggested by Newton's laws of motion, and are therefore based on the recognition of "force." The first member of the equation represents the kinetic energy acquired; the second the potential energy lost, or the work done by gravity upon the stone during its fall. Both members therefore express real things, having objective existence.

Space-rate of transformation of energy.

But the "force" (so-called) which is said to have produced the motion, has the value

$$W = \tfrac{1}{2}Mv^2/h,$$

i.e., it is the *rate per unit of length*, at which potential energy is converted into kinetic energy during the fall. In other words, it is merely an expression for the *space-rate at which energy is transformed.*

§ 293. Another mode of presenting the case will make this still more clear. The average speed with which the stone falls is (§ 28) $v/2$. Divide both sides of the equation above by this quantity, remembering that $2h/v$ is the time of falling, which we call t. We have thus, as another perfectly legitimate deduction from our premises,

Time-rate of change of momentum.

$$W = Mv/t.$$

Here the (so-called) force appears in a new light. It is now the *time-rate at which momentum is generated* in the falling stone.

§ 294. The statements in the last two sections are, in fact, merely particular cases of Newton's two interpretations of action in the third law, which have already been discussed (§§ 165, 167).

Analytically, the whole affair is merely this: if s be the space described, v the speed of a particle,

$$\ddot{s}=\dot{v}=\frac{dv}{dt}=\frac{dv}{ds}\cdot\frac{ds}{dt}=v\frac{dv}{ds}.$$

Hence the equation of motion (formed by the second law)

$$m\ddot{s}=m\dot{v}=f,$$

which gives f as the time-rate of increase of momentum, may be written in the new form

$$mv\frac{dv}{ds}=\frac{d}{ds}(\tfrac{1}{2}mv^2)=f,$$

giving f as the space-rate of increase of kinetic energy.

Rate. § 295. But a mere *rate*, be it a space-rate or a time-rate, is not a thing which has objective existence. No one would confound the bank rate of interest with a sum of money, nor the birth or death rate of a country with a group of individual human beings. These rates are, in fact, mere abstract numbers, by the help of which a man may compute interest per annum from the amount of capital, or the number of infants per annum from the amount of the population. The gradient of temperature, in an irregularly heated body, is a mere vector-rate, by the help of which we can calculate how much energy (in the form of heat) passes in a given time across any assigned surface in the body. To attribute objectivity to a rate is even more ridiculous than it would be to attribute it to a sensation, or to a thought, or to a word or phrase which we find useful in characterizing some material object.

§ 296. On the other hand, all these different kinds of rates have been introduced and continue to be employed, because they have been found to be useful. There is no harm done by retaining them, provided those who use them know that they are introduced for convenience of expression, and not because there are objective realities corresponding to them. Even such a term as "centrifugal force" is sometimes useful; but always under the proviso that he who employs it shall remember that it is only one side of the stress under which a particle of matter is compelled, in spite of its inertia, to move in a curved line. But the term must be taken, like "algebra," "theodolite," "Abracadabra," or any other combination of letters whose derivation is uncertain or unknown, as one and indivisible, to which a certain definite meaning is attached, and as having nothing whatever to do with the meaning or derivation of the word centrifugal, whose embodiment in it is a perennial monument to the memory of an old error.

Potential energy kinetic. § 297. The main characteristics of energy, especially from the experimental point of view, have already been discussed under Dynamics (*q.v.*) and Energy (*q.v.*). But there is one point of importance connected with it which comes more naturally here than in either of the articles referred to.

When two measurable quantities, of any kind, are equivalent to one another, their numerical expressions must involve the same fundamental units, and in the same manner. This is obvious from the fact that an alteration of any unit alters in the inverse ratio the numerical measure of any quantity which is a mere multiple of it. And equivalent quantities must always be expressed by equal numbers when both are measured in terms of the same system of units. It appears, therefore, from the conservation of energy directly, as well as from the special data in §§ 111, 113, that potential energy must, like kinetic energy, be of dimensions $[ML^2T^{-2}]$.

Now it is impossible to conceive of a truly dormant form of energy whose magnitude should depend in any way on the unit of time; and we are therefore forced to the conclusion that potential energy, like kinetic energy, depends (in some as yet unexplained, or rather unimagined, way) upon motion. For the immediate purposes of this article the question is not one of importance. We have been dealing with the more direct consequences of a very compact set of laws, exceedingly simple in themselves, originally based upon observation and experiment, and, most certainly, true. But reason cannot content itself with the mere consequences of a series of observed facts, however elegantly and concisely these may be stated by the help of new terms and their definitions. We are forced to inquire into what may underlie these definitions, and the laws which are observed to regulate the things signified by them. And the conclusion which appears inevitable is that, whatever matter may be, the other reality in the physical universe, energy, which is never found unassociated with matter, depends in all its widely varied forms upon motion of matter. In some cases we are sure, in others we can as yet only suspect, that it depends upon motions in a medium which, unlike ordinary matter, has not yet been subjected to the scrutiny of the chemist. But the question, in its generality, is one of the most obscure in the whole range of physics. In the articles Atom, Attraction, Ether, will be found nearly all that is yet known on this profoundly difficult subject. But to what is there said must be added the remark that a state of strain of the ether, whether associated with the propagation of light and radiant heat or with a statical distribution of electricity, represents so much "potential" energy, and must in its turn in some way depend on motion.

§ 298. The remarks of Clerk Maxwell on the nature of the evidence for Newton's *first* law of motion raise a question, in some respects novel, but in all respects well worthy of careful study. He says:— Maxwell on inertia.

"Our conviction of the truth of this law may be greatly strengthened by considering what is involved in a denial of it. Given a body in motion. At a given instant let it be left to itself and not acted on by any force. What will happen? According to Newton's law it will persevere in moving uniformly in a straight line; that is, its velocity will remain constant both in direction and magnitude.

"If the velocity does not remain constant let us suppose it to vary. The change of velocity must have a definite direction and magnitude. By the maxim that *the same causes will always produce the same effects*, this variation must be the same whatever be the time or place of the experiment. The direction of the change of motion must therefore be determined either by the direction of the motion itself, or by some direction fixed in the body. Let us, in the first place, suppose the law to be that the velocity diminishes at a certain rate, which, for the sake of the argument, we may suppose so slow that by no experiments on moving bodies could we have detected the diminution of velocity in hundreds of years. The velocity referred to in this hypothetical law can only be the velocity referred to a point absolutely at rest. For if it is a relative velocity, its direction as well as its magnitude depends on the velocity of the point of reference. If, when referred to a certain point, the body appears to be moving northward with diminishing velocity, we have only to refer it to another point moving northward with a uniform velocity greater than that of the body, and it will appear to be moving southward with increasing velocity. Hence the hypothetical law is without meaning, unless we admit the possibility of defining absolute rest and absolute velocity. . . . .

"It may thus be shown that the denial of Newton's law is in contradiction to the only system of consistent doctrine about space and time which the human mind has been able to form."

This is a good example of a valuable application of a principle which, in its widest scope, is inconsistent with the true foundations of physical science. It is, in fact, the exceedingly dangerous "principle of sufficient reason"—which requires for its legitimate use the utmost talent and knowledge on the part of the user. Principle of sufficient reason.

§ 299. But in all methods and systems which involve the idea of force there is the leaven of artificiality. *The* true laws of motion, based entirely on experiments of the most extensive and most varied kinds, are those of the conservation and of the transformation of energy. With the help True laws of motion.

of kinematical ideas, it is easy to base the whole science of dynamics on these principles; and there is no necessity for the introduction of the word "force" nor of the sense-suggested ideas on which it was originally based.

§ 300. Nothing beyond a mere mention has been made above of virtual velocities, and of the so-called elementary machines. These belong to the subject of Applied Mechanics, separately treated below.

§ 301. The references which have been made to various grand theories, such as action, impulse in general, &c., have been illustrated by simple cases only. For a detailed examination of these theories the reader is referred to Thomson and Tait's *Natural Philosophy*, chap. ii. To the same work he is referred for the general "theory of small oscillations," the "dissipative function," the "ignoration of coordinates," the treatment of "gyrostatic systems" and of "kinetic stability." All of these have been exhibited, though in mere particular instances, in the preceding pages.

Treatises on Mechanics.

§ 302. The following works on Mechanics are indispensable:—

1. Newton's *Principia* (1st ed., 1687; latest ed., Glasgow, 1871). Here, for the first time, the fundamental principles were systematized, extended (as we have seen) in a most vital particular, and applied, by the aid of a new mathematical method of immense power (based entirely on kinematical considerations), to many of the most important questions of cosmical and terrestrial dynamics.

Newton's system was first *taught* in the university of Edinburgh; and, with brief intervals, his methods also have been habitually kept before the students there. From the time of Maclaurin to that of Forbes the value of the quasi-geometrical methods in giving a clear insight into the problems treated has rarely been overlooked. In Cambridge these methods were of later introduction, but they still deservedly figure as a necessary part of the reading of candidates for "mathematical honours." It is to be feared, however, that in some other British universities the study of Newton's methods is not prosecuted to anything like the same extent. But the very reverse seems to be the case in America, where, probably to a considerable extent on this account, mathematical physics is advancing in a most remarkable manner.

2. Lagrange's *Mécanique Analytique* (1st ed., 1788). Though objections may fairly be taken to the fundamental method of this work, there can be no question as to the immense power and originality of its author. His "generalized coordinates," and the equations of motion of a system in terms of these, form one of the most important contributions to the science since the days of Newton. The method of Lagrange, though he was not aware of the fact, is really based upon the consideration of energy; and when, in quite recent times, experiment had shown what are the grand laws of energy, Lagrange's magnificent mathematical methods and results were ready for translation into the new language of science.

3. Hamilton's papers in the *Philosophical Transactions* for 1833 and 1834. Here the principle of varying action, and the characteristic function, were first applied to mechanics;—though they had been given, some years before, to the Royal Irish Academy, in their optical applications. Grand as have been the extensions of these new ideas made by Hamilton himself, and by many others, among whom Jacobi and Liouville may be especially mentioned, they have been mainly in a purely mathematical direction. We wait for what cannot now be long delayed, the coming of the philosopher who is to tell us the true *dynamical* bearings of varying action and of the characteristic function.

4. If to these we add some of the works of Galileo, Huygens, Euler, Maclaurin, and D'Alembert, we have the great landmarks in the history of the subject, as distinguished from its development.

5. The mere enumeration of the more important developments which the subject has received, as distinguished from the absolutely new grand ideas and methods introduced, would require a long article. Brilliant examples of what may be done in this direction are furnished by Stokes's "Report on Recent Researches in Hydrodynamics" and by Cayley's "Reports on Theoretical Dynamics" (printed in the *British Association Reports* for 1846, and for 1857 and 1862). These should be consulted by every student who desires to trace the growth of the subject. They have been succeeded, in the same *Reports* (1880, 1881) by two excellent summaries, by Hicks, of "Recent Progress in Hydrodynamics."

But Laplace's *Mécanique Celeste*, Poisson's *Mécanique*, Poinsot's *Théorie Nouvelle de la Rotation*, &c., more or less parts of the immediate outcome of the period when France intellectually dwarfed the rest of the world, are still of far more than mere historic value.

For the English-reading student of modern times, the work of Thomson and Tait will be found suitable. The authors of this work claim the position of "restorers," not of innovators; and they have (since 1863, when the first short sketch of their work was published) striven with success to re-establish in Britain Newton's grand yet simple foundations of the subject. But these foundations, as stated above, are only temporarily the best. We have not, *as yet*, anything nearly so good.

Other modern works of value are the *Analytic Mechanics* of the late Professor Peirce (Boston, 1855) and Kirchhoff's *Vorlesungen über Mathematische Physik* (Leipsic, 1876). Both are rather of the nature of collections of short treatises on special questions than organized wholes, but both will well repay careful reading. This, in the case of Peirce's work, is rendered extremely puzzling and laborious by the peculiar notations and modes of reference adopted by the author. It is particularly interesting to study the ways in which the fundamental principles are introduced in these works, and to compare them with the corresponding parts of the works of Newton and Lagrange. Lagrange, Peirce, and Kirchhoff construct each a system as free from anything but analysis as possible. In fact Lagrange prefaces his work by the characteristic statement, "On ne trouvera point de Figures dans cet ouvrage. Les méthodes que j'y expose ne demandent ni constructions, ni raisonnemens géométriques ou méchaniques, mais seulement des opérations algébriques, assujetties à une marche réguliere et uniforme. Ceux qui aiment l'Analyse verront avec plaisir la Méchanique en devenir une nouvelle branche." . . . . How far we have considered it expedient to differ from such an authority, a glance at the preceding pages will show.

A part of the detailed work of several of the examples above given in *Dynamics of a Particle* has been taken from the elementary treatise (with that title) of Tait and Steele. The English reader who wishes to pursue elementary Statics may profitably consult the treatise of Minchin. The higher parts are discussed in the work of Somoff, *Theoretische Mechanik* (Leipsic, 1879). An excellent introduction to the use of Generalized Coordinates has been published by Watson and Burbury (1879). On Lagrange's Generalized Equations the student should also read in Maxwell's *Treatise on Electricity and Magnetism*, part iv. chap. v. And Maxwell's brief treatise on *Matter and Motion* should be in the hands of every one commencing the subject.

Analysis of the Preceding Article.

(P. G. T.)

APPLIED MECHANICS.

1. The practical applications of mechanics may be divided into two classes, according as the assemblages of material objects to which they relate are intended to remain fixed or to move relatively to each other,—the former class being comprehended under the term "Theory of Structures," and the latter under the term "Theory of Machines." As the details of the theory of structures are dealt with in other articles, it will be treated of here to such extent only as may be necessary in order to state certain general principles applicable to all these subjects. The greater part of the article will relate to machines.

PART I. OUTLINE OF THE THEORY OF STRUCTURES.

2. *Support of Structures.*—Every structure, as a whole, is maintained in equilibrium by the joint action of its own *weight*, of the *external load* or pressure applied to it from without and tending to displace it, and of the *resistance* of the material which supports it. A structure is supported either by resting on the solid crust of the earth, as buildings do, or by floating in a fluid, as ships do in water and balloons in air. The principles of the support of a floating structure form an important part of HYDROMECHANICS (*q.v.*). The principles of the support, as a whole, of a structure resting on the land, are so far identical with those which regulate the equilibrium and stability of the several parts of that structure, and of which a summary will presently be given, that the only principle which seems to require special mention here is one which comprehends in one statement the power both of liquids and of loose earth to support structures, and which was first demonstrated in a paper "On the Stability of Loose Earth," read to the Royal Society on the 19th of June 1856, and published in the *Philosophical Transactions* for that year, viz. :—

Let E represent the weight of the portion of a horizontal stratum of earth which is displaced by the foundation of a structure, S the utmost weight of that structure consistently with the power of the earth to resist displacement, ϕ the angle of repose of the earth; then

$$\frac{S}{E}=\left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2.$$

To apply this to liquids, ϕ must be made $=0$, and then $\frac{S}{E}=1$, as is well known.

3. *Composition of a Structure, and Connexion of its Pieces.*—A structure is composed of *pieces*,—such as the stones of a building in masonry, the beams of a timber frame-work, the bars, plates, and bolts of an iron bridge. Those pieces are connected at their *joints* or surfaces of mutual contact, either by simple pressure and friction (as in masonry with moist mortar or without mortar), by pressure and adhesion (as in masonry with cement or with hardened mortar, and timber with glue), or by the resistance of *fastenings* of different kinds, whether made by means of the form of the joint (as dovetails, notches, mortises, and tenons) or by separate fastening pieces (as trenails, pins, spikes, nails, holdfasts, screws, bolts, rivets, hoops, straps, and sockets).

4. *Stability, Stiffness, and Strength.*—A structure may be damaged or destroyed in three ways :—first, by *displacement* of its pieces from their proper positions relatively to each other or to the earth; secondly, by *disfigurement* of one or more of those pieces, owing to their being unable to preserve their proper shapes under the pressures to which they are subjected; thirdly, by *breaking* of one or more of those pieces. The power of resisting displacement constitutes *stability*; the power of each piece to resist disfigurement is its *stiffness*; and its power to resist breaking, its *strength.*

5. *Conditions of Stability.*—The principles of the stability of a structure can be to a certain extent investigated independently of the stiffness and strength, by assuming, in the first instance, that each piece has strength sufficient to be safe against being broken, and stiffness sufficient to prevent its being disfigured to an extent inconsistent with the purposes of the structure, by the greatest forces which are to be applied to it. The condition that each piece of the structure is to be maintained in equilibrium by having its gross load, consisting of its own weight and of the external pressure applied to it, balanced by the *resistances* or pressures exerted between it and the contiguous pieces, furnishes the means of determining the magnitude, position, and direction of the resistances required at each joint in order to produce equilibrium; and the *conditions of stability* are, first, that the *position*, and, secondly, that the *direction*, of the resistance required at each joint shall, under all the variations to which the load is subject, be such as the joint is capable of exerting,—conditions which are fulfilled by suitably adjusting the figures and positions of the joints, and the *ratios* of the gross loads of the pieces. As for the *magnitude* of the resistance, it is limited by conditions, not of stability, but of strength and stiffness.

6. *Principle of Least Resistance.*—Where more than one system of resistances are alike capable of balancing the same system of loads applied to a given structure, it has been demonstrated by Moseley that the *smallest* of those alternative systems is that which will actually be exerted,—because the resistances to displacement are the effect of a strained state of the pieces, which strained state is the effect of the load, and when the load is applied the strained state and the resistances produced by it increase until the resistances acquire just those magnitudes which are sufficient to balance the load, after which they increase no further.

This principle of least resistance renders determinate many problems in the statics of structures which were formerly considered indeterminate.

7. *Relations between Polygons of Loads and of Resistances.*—In a structure in which each piece is supported at two joints only, the well-known laws of statics show that the directions of the gross load on each piece and of the two resistances by which it is supported must lie in one plane, must either be parallel or meet in one point, and must bear to each other, if not parallel, the proportions of the sides of a triangle respectively parallel to their directions, and, if parallel, such proportions that each of the three forces shall be proportional to the distance between the other two,—all the three distances being measured along one direction.

Considering, in the first place, the case in which the load and the two resistances by which each piece is balanced meet in one point, which may be called the *centre of load*, there will be as many such points of intersection, or centres of load, as there are pieces in the structure; and the directions and positions of the resistances or mutual pressures exerted between the pieces will be represented by the sides of a polygon joining those points, as in fig. 1, where P_1, P_2, P_3, P_4 represent the centres of load in a structure of four pieces, and the sides of the *polygon of resistances* $P_1P_2P_3P_4$ represent respectively the directions and positions of the resistances exerted at the joints.

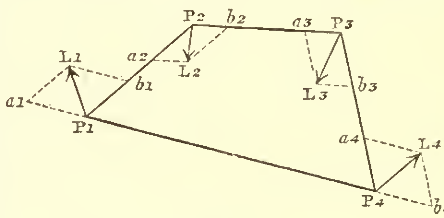


Fig. 1.

Further, at any one of the centres of load let PL represent the magnitude and direction of the gross load, and P*a*, P*b* the two resistances by which the piece to which that load is applied is supported; then will those three lines be respectively the diagonal and sides of a parallelogram; or, what is the same thing, they will be equal to the three sides of a triangle; and they must be in the same plane, although the sides of the polygon of resistances may be in different planes.

According to a well-known principle of statics, because the loads or external pressures P_1L_1, &c., balance each other, they must be proportional to the sides of a closed polygon drawn respectively parallel to their directions. In fig. 2 construct such a *polygon of loads* by drawing the lines L_1, &c., parallel and proportional to, and joined end to end in the order of, the gross loads on the pieces of the structure. Then from the proportionality and parallelism of the load and the two resistances applied to each piece of the structure to the three sides of a triangle, there results the following theorem [originally due to Rankine] :—

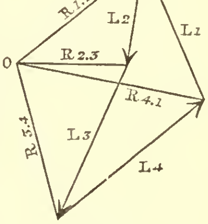


Fig. 2.

If from the angles of the polygon of loads there be drawn lines (R_1, R_2, &c.), *each of which is parallel to the resistance* (*as* P_1P_2, &c.) *exerted at the joint between the pieces to which the two loads represented by the contiguous sides of the polygon of loads* (*such as* L_1, L_2, &c.) *are applied; then will all those lines meet in one point* (O), *and their lengths, measured from that point to the angles of the polygon, will represent the magnitudes of the resistances to which they are respectively parallel.*

When the load on one of the pieces is parallel to the resistances which balance it, the polygon of resistances ceases to be closed, two of the sides becoming parallel to each other and to the load in question, and extending indefinitely. In the polygon of loads the direction of a load sustained by parallel resistances traverses the point O.

8. *How the Earth's Resistance is to be treated.*—When the pressure exerted by a structure on the earth (to which the earth's resistance is equal and opposite) consists either of one pressure, which is necessarily the resultant of the weight of the structure and of all the other forces applied to it, or of two or more parallel vertical forces, whose amount can be determined at the outset of the

investigation, the resistance of the earth can be treated as one or more *upward loads* applied to the structure. But in other cases the earth is to be treated as *one of the pieces of the structure*, loaded with a force equal and opposite in direction and position to the resultant of the weight of the structure and of the other pressures applied to it.

9. *Partial Polygons of Resistance.*—In a structure in which there are pieces supported at more than two joints, let a polygon be constructed of lines connecting the centres of load of any continuous series of pieces. This may be called a *partial polygon of resistances.* In considering its properties, the *load* at each centre of load is to be held to *include* the resistances of those joints which are *not* comprehended in the partial polygon of resistances, to which the theorem of section 7 will then apply in every respect. By constructing several partial polygons, and computing the relations between the loads and resistances which are determined by the application of that theorem to each of them, with the aid, if necessary, of Moseley's principle of the least resistance, the whole of the relations amongst the loads and resistances may be found.

10. *Line of Pressures—Centres and Line of Resistance.*—The *line of pressures* is a line to which the directions of all the resistances in one polygon are tangents. The *centre of resistance* at any joint is the point where the line representing the total resistance exerted at that joint intersects the joint. The *line of resistance* is a line traversing all the centres of resistance of a series of joints,—its form, in the positions intermediate between the actual joints of the structure, being determined by supposing the pieces and their loads to be subdivided by the introduction of intermediate joints *ad infinitum*, and finding the continuous line, curved or straight, in which the intermediate centres of resistance are all situated, however great their number. The difference between the line of resistance and the line of pressures was first pointed out by Moseley.

11. *Stability of Position, and Stability of Friction.*—The resistances at the several joints having been determined by the principles set forth in sections 6, 7, 8, 9, and 10, not only under the ordinary load of the structure, but under all the variations to which the load is subject as to amount and distribution, the joints are now to be placed and shaped so that the pieces shall not suffer relative displacement under any of those loads. The relative displacement of the two pieces which abut against each other at a joint may take place either by turning or by sliding. Safety against displacement by turning is called *stability of position*; safety against displacement by sliding, *stability of friction.*

12. *Condition of Stability of Position.*—If the materials of a structure were infinitely stiff and strong, stability of position at any joint would be insured simply by making the centre of resistance fall within the joint under all possible variations of load. In order to allow for the finite stiffness and strength of materials, the least distance of the centre of resistance inward from the nearest edge of the joint is made to bear a definite proportion to the depth of the joint measured in the same direction, which proportion is fixed, sometimes empirically, sometimes by theoretical deduction from the laws of the strength of materials. That least distance is called by Moseley the *modulus of stability.* The following are some of the ratios of the modulus of stability to the depth of the joint which occur in practice :—

Retaining walls, as designed by British engineers	1 : 8
Retaining walls, as designed by French engineers	1 : 5
Rectangular piers of bridges and other buildings, and arch-stones	1 : 3
Rectangular foundations, firm ground	1 : 3
Rectangular foundations, very soft ground	1 : 2
Rectangular foundations, intermediate kinds of ground	1 : 3 to 1 : 2
Thin, hollow towers (such as furnace chimneys exposed to high winds), square	1 : 6
Thin, hollow towers, circular	1 : 4
Frames of timber or metal, under their ordinary or average distribution of load	1 : 3
Frames of timber or metal, under the greatest irregularities of load	1 : 3

In the case of the towers, the *depth of the joint* is to be understood to mean the *diameter of the tower.*

13. *Condition of Stability of Friction.*—If the resistance to be exerted at a joint is always perpendicular to the surfaces which abut at and form that joint, there is no tendency of the pieces to be displaced by sliding. If the resistance be oblique, let JK (fig. 3) be the joint, C its centre of resistance, CR a line representing the resistance, CN a perpendicular to the joint at the centre of resistance. The angle NCR is the *obliquity* of the resistance. From R draw RP parallel and RQ perpendicular to the joint; then, by the principles of statics, the component of the resistance *normal* to the joint is—

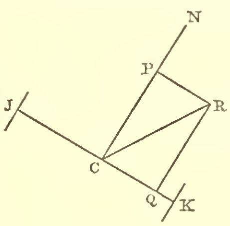


Fig. 3.

$$CP = CR \cdot \cos \angle PRC \,;$$

and the component *tangential* to the joint is—

$$CQ = CR \cdot \sin \angle PCR = CP \cdot \tan \angle PCR \,.$$

If the joint be provided either with projections and recesses, such as mortises and tenons, or with fastenings, such as pins or bolts, so as to resist displacement by sliding, the question of the utmost amount of the tangential resistance CQ which it is capable of exerting depends on the *strength* of such projections, recesses, or fastenings, and belongs to the subject of strength, and not to that of stability. In other cases the safety of the joint against displacement by sliding depends on its power of exerting friction, and that power depends on the law, known by experiment, that the friction between two surfaces bears a constant ratio, depending on the nature of the surfaces, to the force by which they are pressed together. In order that the surfaces which abut at the joint JK may be pressed together, the resistance required by the conditions of equilibrium, CR, must be a *thrust* and not a *pull*; and in that case the force by which the surfaces are pressed together is equal and opposite to the normal component CP of the resistance. The condition of stability of friction is that the tangential component CQ of the resistance required shall not exceed the friction due to the normal component; that is, that

$$CQ \not> f \cdot CP,$$

where f denotes the *coefficient of friction* for the surfaces in question. The angle whose tangent is the coefficient of friction is called *the angle of repose*, and is expressed symbolically by—

$$\phi = \tan^{-1} f.$$

$$\text{Now } CQ = CP \cdot \tan \angle PCR \,;$$

consequently the condition of stability of friction is fulfilled if

$$\angle PCR \not> \phi \,;$$

that is to say, if *the obliquity of the resistance required at the joint does not exceed the angle of repose*; and this condition ought to be fulfilled under all possible variations of the load.

It is chiefly in masonry and earthwork that stability of friction is relied on.

14. *Stability of Friction in Earth.*—The grains of a mass of loose earth are to be regarded as so many separate pieces abutting against each other at joints in all possible positions, and depending for their stability on friction. To determine whether a mass of earth is stable at a given point, conceive that point to be traversed by planes in all possible positions, and determine which position gives the greatest obliquity to the total pressure exerted between the portions of the mass which abut against each other at the plane. The condition of stability is that this obliquity shall not exceed the angle of repose of the earth. The consequences of this principle are developed in a paper "On the Stability of Loose Earth," already cited in sect. 2.

15. *Parallel Projections of Figures.*—If any figure be referred to a system of coordinates, rectangular or oblique, and if a second figure be constructed by means of a second system of coordinates, rectangular or oblique, and either agreeing with or differing from the first system in rectangularity or obliquity, but so related to the coordinates of the first figure that for each point in the first figure there shall be a corresponding point in the second figure, the lengths of whose coordinates shall bear respectively to the three corresponding coordinates of the corresponding point in the first figure three ratios which are the same for every pair of corresponding points in the two figures, these corresponding figures are called *parallel projections* of each other. The properties of parallel projections of most importance to the subject of the present article are the following :—

(1) A parallel projection of a straight line is a straight line.

(2) A parallel projection of a plane is a plane.

(3) A parallel projection of a straight line or a plane surface divided in a given ratio is a straight line or a plane surface divided in the same ratio.

(4) A parallel projection of a pair of equal and parallel straight lines, or plain surfaces, is a pair of equal and parallel straight lines, or plane surfaces; whence it follows

(5) That a parallel projection of a parallelogram is a parallelogram, and

(6) That a parallel projection of a parallelepiped is a parallelepiped.

(7) A parallel projection of a pair of solids having a given ratio is a pair of solids having the same ratio.

Though not essential for the purposes of the present article, the following consequence will serve to illustrate the principle of parallel projections :—

(8) A parallel projection of a curve, or of a surface of a given algebraical order, is a curve or a surface of the same order.

For example, all ellipsoids referred to coordinates parallel to any three conjugate diameters are parallel projections of each other and of a sphere referred to rectangular coordinates.

16. *Parallel Projections of Systems of Forces.*—If a balanced system of forces be represented by a system of lines, then will every parallel projection of that system of lines represent a balanced system of forces.

For the condition of equilibrium of forces not parallel is that they shall be represented in direction and magnitude by the sides and diagonals of certain parallelograms, and of parallel forces that they shall divide certain straight lines in certain ratios; and the parallel projection of a parallelogram is a parallelogram, and that of a straight line divided in a given ratio is a straight line divided in the same ratio.

The resultant of a parallel projection of any system of forces is the projection of their resultant; and the centre of gravity of a parallel projection of a solid is the projection of the centre of gravity of the first solid.

17. *Principle of the Transformation of Structures.*—Here we have the following theorem:—If a structure of a given figure have stability of position under a system of forces represented by a given system of lines, then will any structure whose figure is a parallel projection of that of the first structure have stability of position under a system of forces represented by the corresponding projection of the first system of lines.

For in the second structure the weights, external pressures, and resistances will balance each other as in the first structure; the weights of the pieces and all other parallel systems of forces will have the same ratios as in the first structure; and the several centres of resistance will divide the depths of the joints in the same proportions as in the first structure.

If the first structure have stability of friction, the second structure will have stability of friction also, so long as the effect of the projection is not to increase the obliquity of the resistance at any joint beyond the angle of repose.

The lines representing the forces in the second figure show their *relative* directions and magnitudes. To find their *absolute* directions and magnitudes, a vertical line is to be drawn in the first figure, of such a length as to represent the weight of a particular portion of the structure. Then will the projection of that line in the projected figure indicate the vertical direction, and represent the weight of the part of the second structure corresponding to the before-mentioned portion of the first structure.

The foregoing "principle of the transformation of structures" was first announced, though in a somewhat less comprehensive form, to the Royal Society on the 6th of March 1856. It is useful in practice, by enabling the engineer easily to deduce the conditions of equilibrium and stability of structures of complex and unsymmetrical figures from those of structures of simple and symmetrical figures. By its aid, for example, the whole of the properties of elliptical arches, whether square or skew, whether level or sloping in their span, are at once deduced by projection from those of symmetrical circular arches, and the properties of ellipsoidal and elliptic-conoidal domes from those of hemispherical and circular-conoidal domes; and the figures of arches fitted to resist the thrust of earth, which is less horizontally than vertically in a certain given ratio, can be deduced by a projection from those of arches fitted to resist the thrust of a liquid, which is of equal intensity, horizontally and vertically.

18. *Conditions of Stiffness and Strength.*—After the arrangement of the pieces of a structure and the size and figure of their joints or surfaces of contact have been determined so as to fulfil the conditions of *stability*,—conditions which depend mainly on the position and direction of the *resultant* or *total* load on each piece, and the *relative* magnitude of the loads on the different pieces,—the dimensions of each piece singly have to be adjusted so as to fulfil the conditions of *stiffness* and *strength*,—conditions which depend not only on the *absolute* magnitude of the load on each piece, and of the resistances by which it is balanced, but also on the *mode of distribution* of the load over the piece, and of the resistances over the joints.

The effect of the pressures applied to a piece, consisting of the load and the supporting resistances, is to force the piece into a state of *strain* or disfigurement, which increases until the elasticity, or resistance to strain, of the material causes it to exert a *stress*, or effort to recover its figure, equal and opposite to the system of applied pressures. The condition of *stiffness* is that the strain or disfigurement shall not be greater than is consistent with the purposes of the structure; and the condition of *strength* is that the stress shall be within the limits of that which the material can bear with safety against breaking. The ratio in which the utmost stress before breaking exceeds the safe working stress is called the *factor of safety*, and is determined empirically. It varies from three to twelve for various materials and structures.

The Strength of Materials forms the subject of a special article, to which the reader is referred.

PART II. THEORY OF MACHINES.

19. *Parts of a Machine—Frame and Mechanism.*—The parts of a machine may be distinguished into two principal divisions,—the *frame*, or fixed parts, and the *mechanism*, or moving parts. The frame is a structure which supports the pieces of the mechanism, and to a certain extent determines the nature of their motions. The form and arrangement of the pieces of the frame depend upon the arrangement and the motions of the mechanism; the dimensions of the pieces of the frame required in order to give it stability and strength are determined from the pressures applied to it by means of the mechanism. It appears therefore that in general the mechanism is to be designed first and the frame afterwards, and that the designing of the frame is regulated by the principles of the stability of structures and of the strength and stiffness of materials,—care being taken to adapt the frame to the most severe load which can be thrown upon it at any period of the action of the mechanism.

Each independent piece of the mechanism also is a structure, and its dimensions are to be adapted, according to the principles of the strength and stiffness of materials, to the most severe load to which it can be subjected during the action of the machine.

20. *Definition and Division of the Theory of Machines.*—From what has been said in the last section it appears that the department of the art of designing machines which has reference to the stability of the frame and to the stiffness and strength of the frame and mechanism is a branch of the art of construction. It is therefore to be separated from the *theory of machines*, properly speaking, which has reference to the action of machines considered as moving. In the action of a machine the following three things take place:—

First, Some natural source of energy communicates motion and force to a piece or pieces of the mechanism, called the *receiver of power* or *prime mover*.

Secondly, The motion and force are transmitted from the prime mover through the *train of mechanism* to the *working piece* or *pieces*, and during that transmission the motion and force are modified in amount and direction, so as to be rendered suitable for the purpose to which they are to be applied.

Thirdly, The working piece or pieces by their motion, or by their motion and force combined, produce some useful effect.

Such are the phenomena of the action of a machine, arranged in the order of *causation*. But in studying or treating of the theory of machines, the order of *simplicity* is the best; and in this order the first branch of the subject is the modification of motion and force by the train of mechanism; the next is the effect or purpose of the machine; and the last, or most complex, is the action of the prime mover.

The modification of motion and the modification of force take place together, and are connected by certain laws; but in the study of the theory of machines, as well as in that of pure mechanics, much advantage has been gained in point of clearness and simplicity by first considering alone the principles of the modification of motion, which are founded upon what is now known as Kinematics, and afterwards considering the principles of the combined modification of motion and force, which are founded both on geometry and on the laws of dynamics. The separation of kinematics from dynamics is due mainly to Monge, Ampère, and Willis.

The theory of machines in the present article will be considered under the following four heads:—

I. Pure Mechanism, or Applied Kinematics; being the theory of machines considered simply as modifying motion.
II. Applied Dynamics; being the theory of machines considered as modifying both motion and force.
III. Purposes and Effects of Machines.
IV. Applied Energetics; being the theory of prime movers and sources of power.

Chap. I. On Pure Mechanism.

21. *Division of the Subject.*—Proceeding in the order of simplicity, the subject of Pure Mechanism, or Applied Kinematics, may be thus divided:—

Division 1.—Motion of a point.
Division 2.—Motion of the surface of a fluid.
Division 3.—Motion of a rigid solid.
Division 4.—Motions of a pair of connected pieces, or of an "elementary combination" in mechanism.
Division 5.—Motions of trains of pieces of mechanism.
Division 6.—Motions of sets of more than two connected pieces, or of "aggregate combinations."

A point is the boundary of a line, which is the boundary of a surface, which is the boundary of a volume. Points, lines, and surfaces have no independent existence, and consequently those divisions of this chapter which relate to their motions are only preliminary to the subsequent divisions, which relate to the motions of bodies.

Division 1. *Motion of a Point.*

22. *Path and Direction.*—See above, p. 679, § 21.
23. *Uniform Velocity.*—See p. 680, § 25.
24. *Varied Velocity.*—See p. 680, § 25.
25. *Direct Deviation, or Acceleration and Retardation.*—See pp. 680, 681, §§ 27–29.

26. *Lateral Deviation or Deflexion—Angular Velocity of Deviation—Revolution.*—See pp. 681, 682, §§ 31–38.

27. *Comparative Motion.*—The comparative motion of two points is the relation which exists between their motions, without having regard to their absolute amounts. It consists of two elements,—the *velocity ratio*, which is the ratio of any two magnitudes bearing to each other the proportions of the respective velocities of the two points at a given instant, and the *directional relation*, which is the relation borne to each other by the respective directions of the motions of the two points at the same given instant.

It is obvious that the motions of a pair of points may be varied in any manner, whether by direct or by lateral deviation, and yet that their *comparative motion* may remain constant, in consequence of the deviations taking place in the same proportions, in the same directions, and at the same instants for both points.

Willis has the merit of having been the first to simplify considerably the theory of pure mechanism, by pointing out that that branch of mechanics relates wholly to comparative motions.

The comparative motion of two points at a given instant is capable of being completely expressed by one of Sir William Hamilton's Quaternions,—the "tensor" expressing the velocity ratio, and the "versor" the directional relation.

28. *Resolution and Composition of Motion.*—See p. 681, §§ 30, 31.

29. *Rectangular Projection, Resolution, and Composition.*—See p. 681, § 31.

30. *Resolution and Composition of Deviations.*—See p. 681, § 31.

Division 2. Motion of the Surface of a Fluid Mass.

31. *General Principle.*—A mass of fluid is used in mechanism to transmit motion and force between two or more movable portions (called *pistons* or *plungers*) of the solid envelope or vessel in which the fluid is contained; and, when such transmission is the sole action, or the only appreciable action of the fluid mass, its volume is either absolutely constant, by reason of its temperature and pressure being maintained constant, or not sensibly varied.

Let a represent the area of the section of a piston made by a plane perpendicular to its direction of motion, and v its velocity, which is to be considered as positive when outward, and negative when inward. Then the variation of the cubic contents of the vessel in a unit of time by reason of the motion of one piston is va. The condition that the volume of the fluid mass shall remain unchanged requires that there shall be more than one piston, and that the velocities and areas of the pistons shall be connected by the equation—

$$\Sigma \,.\, va = 0 \quad \ldots\ldots\ldots \quad (1).$$

32. *Comparative Motion of two Pistons.*—If there be but two pistons, whose areas are a_1 and a_2, and their velocities v_1 and v_2, their comparative motion is expressed by the equation—

$$\frac{v_2}{v_1} = -\frac{a_1}{a_2} \quad \ldots\ldots\ldots \quad (2);$$

that is to say, their velocities are opposite as to inwardness and outwardness, and inversely proportional to their areas.

33. *Applications—Hydraulic Press—Pneumatic Power-Transmitter.*—In the hydraulic press the vessel consists of two cylinders, viz., the pump-barrel and the press-barrel, each having its piston, and of a passage connecting them having a valve opening towards the press-barrel. The action of the enclosed water in transmitting motion takes place during the inward stroke of the pump-plunger, when the above-mentioned valve is open; and at that time the press-plunger moves outwards with a velocity which is less than the inward velocity of the pump-plunger, in the same ratio that the area of the pump-plunger is less than the area of the press-plunger. (See HYDROMECHANICS.)

In the pneumatic power-transmitter the motion of one piston is transmitted to another at a distance by means of a mass of air contained in two cylinders and an intervening tube. When the pressure and temperature of the air can be maintained constant, this machine fulfils equation 2, like the hydraulic press. The amount and effect of the variations of pressure and temperature undergone by the air depend on the principles of the mechanical action of heat, or THERMODYNAMICS (*q.v.*), and are foreign to the subject of pure mechanism.

Division 3. Motion of a Rigid Solid.

34. *Motions Classed.*—In problems of mechanism, each solid piece of the machine is supposed to be so stiff and strong as not to undergo any sensible change of figure or dimensions by the forces applied to it,—a supposition which is realized in practice if the machine is skilfully designed.

This being the case, the various possible motions of a rigid solid body may all be classed under the following heads:—(1) *Shifting or Translation*; (2) *Turning or Rotation*; (3) *Motions compounded of Shifting and Turning.*

The most common forms for the paths of the points of a piece of mechanism, whose motion is simple shifting, are the straight line and the circle.

Shifting in a straight line is regulated either by straight fixed guides, in contact with which the moving piece slides, or by combinations of link-work, called *parallel motions*, which will be described in the sequel. Shifting in a straight line is usually *reciprocating*; that is to say, the piece, after shifting through a certain distance, returns to its original position by reversing its motion.

Circular shifting is regulated by attaching two or more points of the shifting piece to ends of equal and parallel rotating cranks, or by combinations of wheel-work to be afterwards described. As an example of circular shifting may be cited the motion of the coupling rod, by which the parallel and equal cranks upon two or more axles of a locomotive engine are connected and made to rotate simultaneously. The coupling rod remains always parallel to itself, and all its points describe equal and similar circles relatively to the frame of the engine, and move in parallel directions with equal velocities at the same instant.

35. *Rotation about a Fixed Axis—Lever, Wheel, and Axle.*—The fixed axis of a turning body is a line fixed relatively to the body and relatively to the fixed space in which the body turns. In mechanism it is usually the central line either of a rotating shaft or axle having journals, gudgeons, or pivots turning in fixed bearings, or of a fixed spindle or dead centre round which a rotating bush turns; but it may sometimes be entirely beyond the limits of the turning body. For example, if a sliding piece moves in circular fixed guides, that piece rotates about an ideal fixed axis traversing the centre of those guides.

Let the angular velocity of the rotation be denoted by $a = \frac{d\theta}{dt}$, then the linear velocity of any point A at the distance r from the axis is ar; and the path of that point is a circle of the radius r described about the axis.

This is the principle of the modification of motion by the lever, which consists of a rigid body turning about a fixed axis called a fulcrum, and having two points at the same or different distances from that axis, and in the same or different directions, one of which receives motion and the other transmits motion, modified in direction and velocity according to the above law.

In the wheel and axle, motion is received and transmitted by two cylindrical surfaces of different radii described about their common fixed axis of turning, their velocity-ratio being that of their radii.

36. *Velocity Ratio of Components of Motion.*—As the distance between any two points in a rigid body is invariable, the projections of their velocities upon the line joining them must be equal. Hence it follows that, if A in fig. 4 be a point in a rigid body CD, rotating round the fixed axis F, the component of the velocity of A in any direction AP parallel to the plane of rotation is equal to the total velocity of the point m, found by letting fall Fm perpendicular to AP; that is to say, is equal to

$$a \,.\, \mathrm{F}m.$$

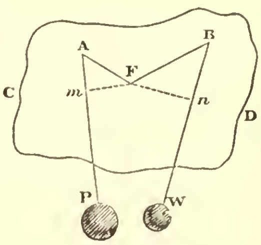


Fig. 4.

Hence also the ratio of the components of the velocities of two points A and B in the directions AP and BW respectively, both in the plane of rotation, is equal to the ratio of the perpendiculars Fm and Fn.

37. *Instantaneous Axis of a Cylinder rolling on a Cylinder.*—Let a cylinder bbb, whose axis of figure is B and angular velocity γ, roll on a fixed cylinder aaa, whose axis of figure is A, either outside (as in fig. 5), when the rolling will be towards the same hand as the

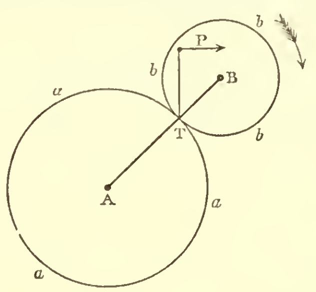


Fig. 5.

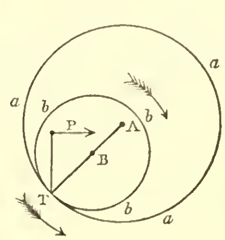


Fig. 6.

rotation, or inside (as in fig. 6), when the rolling will be towards the opposite hand; and at a given instant let T be the line of contact of the two cylindrical surfaces, which is at their common intersection with the plane AB traversing the two axes of figure.

The line T on the surface bbb has for the instant no velocity in a direction perpendicular to AB; because for the instant it touches, without sliding, the line T on the fixed surface *aaa*.

The line T on the surface *bbb* has also for the instant no velocity in the plane AB; for it has just ceased to move towards the fixed surface *aaa*, and is just about to begin to move away from that surface.

The line of contact T, therefore, on the surface of the cylinder *bbb*, is *for the instant* at rest, and is the "instantaneous axis" about which the cylinder *bbb* turns, together with any body rigidly attached to that cylinder.

To find, then, the direction and velocity at the given instant of any point P, either in or rigidly attached to the rolling cylinder T, draw the plane PT; the direction of motion of P will be perpendicular to that plane, and towards the right or left hand according to the direction of the rotation of *bbb*; and the velocity of P will be

$$v_P = \gamma \cdot PT \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3),$$

PT denoting the perpendicular distance of P from T. The path of P is a curve of the kind called *epitrochoids*. If P is in the circumference of *bbb*, that path becomes an *epicycloid*.

The velocity of any point in the axis of figure B is

$$v_B = \gamma \cdot TB \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 4);$$

and the path of such a point is a circle described about A with the radius AB, being for outside rolling the sum, and for inside rolling the difference, of the radii of the cylinders.

Let α denote the angular velocity with which the *plane of axes* AB rotates about the fixed axis A. Then it is evident that

$$v_B = \alpha \cdot AB \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5),$$

and consequently that $\alpha = \gamma \cdot \frac{TB}{AB}$ . . . . (6).

For internal rolling, as in fig. 6, AB is to be treated as negative, which will give a negative value to α, indicating that in this case the rotation of AB round A is contrary to that of the cylinder *bbb*.

The angular velocity of the rolling cylinder, *relatively to the plane of axes* AB, is obviously given by the equation—

$$\left.\begin{aligned} \beta &= \gamma - \alpha ; \\ \text{whence } \beta &= \gamma \cdot \frac{TA}{AB} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7);$$

care being taken to attend to the sign of α, so that when that is negative the arithmetical values of γ and α are to be added in order to give that of β.

The whole of the foregoing reasonings are applicable, not merely when *aaa* and *bbb* are actual cylinders, but also when they are the osculating cylinders of a pair of cylindroidal surfaces of varying curvature, A and B being the axes of curvature of the parts of those surfaces which are in contact for the instant under consideration.

38. *Composition and Resolution of Rotations about Parallel Axes.*—See above, p. 691, § 73.

39. *Instantaneous Axis of a Cone rolling on a Cone.*—Let O*aa* (fig. 7) be a fixed cone, OA its axis, O*bb* a cone rolling on it, OB the axis of the rolling cone, OT the line of contact of the two cones at the instant under consideration. By reasoning similar to that of sect. 37, it appears that OT is the instantaneous axis of rotation of the rolling cone.

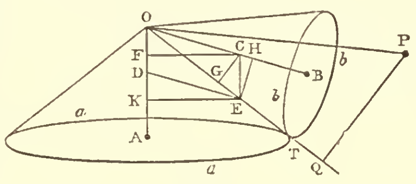


Fig. 7.

Let γ denote the total angular velocity of the rotation of the cone B about the instantaneous axis, β its angular velocity about the axis OB *relatively* to the plane AOB, and α the angular velocity with which the plane AOB turns round the axis OA. It is required to find the ratios of those angular velocities.

Solution.—In OT take any point E, from which draw EC parallel to OA, and ED parallel to OB, so as to construct the parallelogram OCED. Then

$$\left.\begin{matrix} OD : OC : OE \\ :: \alpha : \beta : \gamma \end{matrix}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8).$$

Or because of the proportionality of the sides of triangles to the sines of the opposite angles,

$$\left.\begin{matrix} \sin\angle TOB : \sin\angle TOA : \sin\angle AOB \\ :: \quad \alpha \quad : \quad \beta \quad : \quad \gamma \end{matrix}\right\} \quad . \quad . \quad . \quad (8, \text{A});$$

that is to say, the angular velocity about each axis is proportional to the sine of the angle between the other two.

Demonstration.—From C draw CF perpendicular to OA, and CG perpendicular to OE.

$$\text{Then } CF = 2 \times \frac{\text{area ECO}}{CE},$$

$$\text{and } CG = 2 \times \frac{\text{area ECO}}{OE};$$

$$\therefore CG : CF :: CE = OD : OE.$$

Let v_C denote the linear velocity of the point C. Then

$$v_C = \alpha \cdot CF = \gamma \cdot CG$$

$$\therefore \gamma : \alpha :: CF : CG :: OE : OD;$$

which is one part of the solution above stated. From E draw EH perpendicular to OB, and EK to OA. Then it can be shown as before that

$$EK : EH :: OC : OD.$$

Let v_E be the linear velocity of the point E *fixed in the plane of axes* AOB. Then

$$v_E = \alpha \cdot EK.$$

Now, as the line of contact OT is for the instant at rest on the rolling cone as well as on the fixed cone, the linear velocity of the point E fixed to the plane AOB relatively to the rolling cone is the same with its velocity relatively to the fixed cone. That is to say,

$$\beta \cdot EH = v_E = \alpha \cdot EK;$$

therefore $\alpha : \beta :: EH : EK :: OD : OC$,

which is the remainder of the solution.

The path of a point P in or attached to the rolling cone is a spherical epitrochoid traced on the surface of a sphere of the radius OP. From P draw PQ perpendicular to the instantaneous axis. Then the motion of P is perpendicular to the plane OPQ, and its velocity is

$$v_P = \gamma \cdot PQ \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9).$$

The whole of the foregoing reasonings are applicable, not merely when A and B are actual regular cones, but also when they are the osculating regular cones of a pair of irregular conical surfaces, having a common apex at O.

40. *Composition of Rotations about Two Axes meeting in a Point.*—See p. 691, § 76.

41. *Screw-like or Helical Motion.*—Since (see p. 690, §§ 71, 72) any displacement in a plane can be represented in general by a rotation, it follows that the only combination of translation and rotation, in which a complex movement which is not a mere rotation is produced, occurs when there is a translation *perpendicular to the plane and parallel to the axis* of rotation.

Such a complex motion is called *screw-like* or *helical* motion; for each point in the body describes a *helix* or *screw* round the axis of rotation, fixed or instantaneous as the case may be. To cause a body to move in this manner it is usually made of a helical or screw-like figure, and moves in a guide of a corresponding figure. Helical motion and screws adapted to it are said to be right- or left-handed according to the appearance presented by the rotation to an observer looking towards the direction of the translation. Thus the screw G in fig. 8 is right-handed.

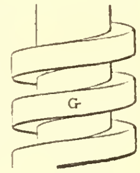


Fig. 8.

The translation of a body in helical motion is called its *advance*. Let v_x denote the velocity of advance at a given instant, which of course is common to all the particles of the body; α the angular velocity of the rotation at the same instant; $2\pi = 6{\cdot}2832$ nearly, the circumference of a circle of the radius unity. Then

$$T = \frac{2\pi}{\alpha} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

is the time of one turn at the rate α; and

$$p = v_x T = \frac{2\pi v_x}{\alpha} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

is the *pitch* or *advance per turn*,—a length which expresses the *comparative motion* of the translation and the rotation.

The pitch of a screw is the distance, measured parallel to its axis, between two successive turns of the same *thread* or helical projection.

Let r denote the perpendicular distance of a point in a body moving helically from the axis. Then

$$v_r = \alpha r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

is the component of the velocity of that point in a plane perpendicular to the axis, and its total velocity is

$$v = \sqrt{\{v_x^2 + v_r^2\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13).$$

The ratio of the two components of that velocity is

$$\frac{v_x}{v_r} = \frac{p}{2\pi r} = \tan\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14);$$

where θ denotes the angle made by the helical path of the point with a plane perpendicular to the axis.

42. *To find the Motion of a Rigid Body from the Motions of Three Points in it.*—See p. 690, § 71, and p. 692, § 78.

Division 4. Elementary Combinations in Mechanism.

43. *Definitions.*—An *elementary combination* in mechanism consists of two pieces whose kinds of motion are determined by their connexion with the frame, and their comparative motion by their connexion with each other,—that connexion being effected either by direct contact of the pieces, or by a connecting piece, which is not connected with the frame, and whose motion depends entirely on the motions of the pieces which it connects.

The piece whose motion is the cause is called the *driver*; the piece whose motion is the effect, the *follower*.

The connexion of each of those two pieces with the frame is in general such as to determine the path of every point in it. In the investigation, therefore, of the comparative motion of the driver and follower, in an elementary combination, it is unnecessary to consider relations of angular direction, which are already fixed by the connexion of each piece with the frame; so that the inquiry is confined to the determination of the velocity ratio, and of the directional relation, so far only as it expresses the connexion between *forward* and *backward* movements of the driver and follower. When a continuous motion of the driver produces a continuous motion of the follower, forward or backward, and a reciprocating motion a motion reciprocating at the same instant, the directional relation is said to be *constant.* When a continuous motion produces a reciprocating motion, or *vice versa*, or when a reciprocating motion produces a motion not reciprocating at the same instant, the directional relation is said to be *variable.*

The *line of action* or *of connexion* of the driver and follower is a line traversing a pair of points in the driver and follower respectively, which are so connected that the component of their velocity relatively to each other, resolved along the line of connexion, is null. There may be several or an indefinite number of lines of connexion, or there may be but one; and a line of connexion may connect either the same pair of points or a succession of different pairs.

44. *General Principle.*—From the definition of a line of connexion it follows that *the components of the velocities of a pair of connected points along their line of connexion are equal.* And from this, and from the property of a rigid body, already stated in sect. 36, it follows, that *the components along a line of connexion of all the points traversed by that line, whether in the driver or in the follower, are equal*; and consequently, *that the velocities of any pair of points traversed by a line of connexion are to each other inversely as the cosines, or directly as the secants, of the angles made by the paths of those points with the line of connexion.*

The general principle stated above in different forms serves to solve every problem in which—the mode of connexion of a pair of pieces being given—it is required to find their comparative motion at a given instant, or *vice versa.*

45. *Application to a Pair of Shifting Pieces.*—In fig. 9, let P_1P_2 be the line of connexion of a pair of pieces, each of which has a motion of translation or shifting. Through any point T in that line draw TV_1, TV_2, respectively parallel to the simultaneous direction of motion of the pieces; through any other point A in the line of connexion draw a plane perpendicular to that line, cutting TV_1, TV_2 in V_1, V_2; then, velocity of piece 1 : velocity of piece 2 :: $TV_1 : TV_2$. Also TA represents the equal components of the velocities of the pieces parallel to their line of connexion, and the line V_1V_2 represents their velocity relatively to each other.

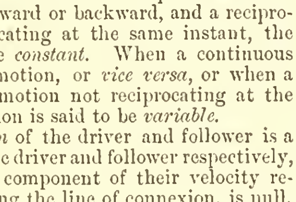


Fig. 9.

46. *Application to a Pair of Turning Pieces.*—Let α_1, α_2 be the angular velocities of a pair of turning pieces; θ_1, θ_2 the angles which their line of connexion makes with their respective planes of rotation; r_1, r_2 the common perpendiculars let fall from the line of connexion upon the respective axes of rotation of the pieces. Then the equal components, along the line of connexion, of the velocities of the points where those perpendiculars meet that line are—

$$\alpha_1 r_1 \cos\theta_1 = \alpha_2 r_2 \cos\theta_2 ;$$

consequently, the comparative motion of the pieces is given by the equation

$$\frac{\alpha_2}{\alpha_1} = \frac{r_1 \cos\theta_1}{r_2 \cos\theta_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15).$$

47. *Application to a Shifting Piece and a Turning Piece.*—Let a shifting piece be connected with a turning piece, and at a given instant let α_1 be the angular velocity of the turning peice, r_1 the common perpendicular of its axis of rotation and the line of connexion, θ_1 the angle made by the line of connexion with the plane of rotation, θ_2 the angle made by the line of connexion with the direction of motion of the shifting piece, v_2 the linear velocity of that piece. Then

$$\alpha_1 r_1 \cos\theta_1 = v_2 \cos\theta_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16);$$

which equation expresses the comparative motion of the two pieces.

48. *Classification of Elementary Combinations in Mechanism.*—The first systematic classification of elementary combinations in mechanism was that founded by Monge, and fully developed by Lanz and Bétancourt, which has been generally received, and has been adopted in most treatises on applied mechanics. But that classification is founded on the absolute instead of the comparative motions of the pieces, and is, for that reason, defective, as Willis has pointed out in his admirable treatise *On the Principles of Mechanism.*

Willis's classification is founded, in the first place, on comparative motion, as expressed by velocity ratio and directional relation, and in the second place, on the mode of connexion of the driver and follower. He divides the elementary combinations in mechanism into three classes, of which the characters are as follows:—

Class A: Directional relation constant; velocity ratio constant.
Class B: Directional relation constant; velocity ratio varying.
Class C: Directional relation changing periodically; velocity ratio constant or varying.

Each of those classes is subdivided by Willis into five divisions, of which the characters are as follows:—

Division A:	Connexion	by	rolling contact.
,, B:	,,	,,	sliding contact.
,, C:	,,	,,	wrapping connectors.
,, D:	,,	,,	link-work.
,, E:	,,	,,	reduplication.

In the present article the principle of Willis's classification is followed; but the arrangement is modified by taking the *mode of connexion* as the basis of the primary classification, and by removing the subject of connexion by reduplication to the section of aggregate combinations. This modified arrangement is adopted as being better suited than the original arrangement to the limits of an article in an encyclopædia; but it is not disputed that the original arrangement may be the best for a separate treatise.

49. *Rolling Contact—Smooth Wheels and Racks.*—In order that two pieces may move in *rolling contact*, it is necessary that each pair of points in the two pieces which touch each other should at the instant of contact be moving in the same direction with the same velocity. In the case of two *shifting* pieces this would involve equal and parallel velocities for all the points of each piece, so that there could be no rolling, and, in fact, the two pieces would move like one; hence, in the case of rolling contact, either one or both of the pieces must rotate.

The direction of motion of a point in a turning piece being perpendicular to a plane passing through its axis, the condition that each pair of points in contact with each other must move in the same direction leads to the following consequences:—

I. That, when both pieces rotate, their axes, and all their points of contact, lie in the same plane.

II. That, when one piece rotates and the other shifts, the axis of the rotating piece, and all the points of contact, lie in a plane perpendicular to the direction of motion of the shifting piece.

The condition that the velocity of each pair of points of contact must be equal leads to the following consequences:—

III. That the angular velocities of a pair of turning pieces in rolling contact must be inversely as the perpendicular distances of any pair of points of contact from the respective axes.

IV. That the linear velocity of a shifting piece in rolling contact with a turning piece is equal to the product of the angular velocity of the turning piece by the perpendicular distance from its axis to a pair of points of contact.

The *line of contact* is that line in which the points of contact are all situated. Respecting this line, the above principles III. and IV. lead to the following conclusions:—

V. That for a pair of turning pieces with parallel axes, and for a turning piece and a shifting piece, the line of contact is straight, and parallel to the axes or axis; and hence that the rolling surfaces are either plane or cylindrical (the term "cylindrical" including all surfaces generated by the motion of a straight line parallel to itself).

VI. That for a pair of turning pieces with intersecting axes the line of contact is also straight, and traverses the point of intersection of the axes; and hence that the rolling surfaces are conical, with a common apex (the term "conical" including all surfaces generated by the motion of a straight line which traverses a fixed point).

Turning pieces in rolling contact are called *smooth* or *toothless wheels.* Shifting pieces in rolling contact with turning pieces may be called *smooth* or *toothless racks.*

VII. In a pair of pieces in rolling contact every straight line traversing the line of contact is a line of connexion.

50. *Cylindrical Wheels and Smooth Racks.*—In designing cylindrical wheels and smooth racks, and determining their comparative motion, it is sufficient to consider a section of the pair of pieces made by a plane perpendicular to the axis or axes.

The points where axes intersect the plane of section are called *centres*; the point where the line of contact intersects it, the *point of contact*, or *pitch-point*; and the wheels are described as *circular*, *elliptical*, &c., according to the forms of their sections made by that plane.

When the point of contact of two wheels lies between their centres, they are said to be in *outside gearing*; when beyond their centres, in *inside gearing*, because the rolling surface of the larger wheel must in this case be turned inward or towards its centre.

From Principle III. of sect. 49 it appears that the angular velocity-ratio of a pair of wheels is the inverse ratio of the distances of the point of contact from the centres respectively.

For outside gearing that ratio is *negative*, because the wheels turn contrary ways; for inside gearing it is *positive*, because they turn the same way.

If the velocity ratio is to be constant, as in Willis's Class A, the wheels must be circular; and this is the most common form for wheels.

If the velocity ratio is to be variable, as in Willis's Class B, the figures of the wheels are a pair of *rolling curves*, subject to the condition that the distance between their *poles* (which are the centres of rotation) shall be constant.

The following is the geometrical relation which must exist between such a pair of curves. See fig. 10.

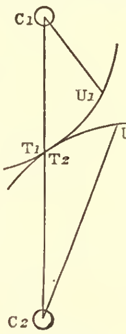


Fig. 10.

Let C_1, C_2 be the poles of a pair of rolling curves; T_1, T_2 any pair of points of contact; U_1, U_2 any other pair of points of contact. Then, for every possible pair of points of contact, the two following equations must be simultaneously fulfilled:—

$$\text{Sum of radii, } C_1U_1 + C_2U_2 = C_1T_1 + C_2T_2 = \text{constant};$$
$$\text{arc, } T_2U_2 = T_1U_1 \quad \ldots\ldots\ldots \quad (17).$$

A condition equivalent to the above, and necessarily connected with it, is, that at each pair of points of contact the inclinations of the curves to their radii-vectores shall be equal and contrary; or, denoting by r_1, r_2 the radii-vectores at any given pair of points of contact, and s the length of the equal arcs measured from a certain fixed pair of points of contact—

$$\frac{dr_2}{ds} = -\frac{dr_1}{ds} \quad \ldots\ldots\ldots \quad (18);$$

which is the differential equation of a pair of rolling curves whose poles are at a constant distance apart.

For full details as to rolling curves, see Willis's work, already mentioned, and Clerk Maxwell's paper on Rolling Curves in the *Transactions of the Royal Society of Edinburgh*, 1849.

A rack, to work with a circular wheel, must be straight. To work with a wheel of any other figure, its section must be a rolling curve, subject to the condition that the perpendicular distance from the pole or centre of the wheel to a straight line parallel to the direction of the motion of the rack shall be constant. Let r_1 be the radius-vector of a point of contact on the wheel, x_2 the ordinate from the straight line before mentioned to the corresponding point of contact on the rack. Then

$$\frac{dx_2}{ds} = -\frac{dr_1}{ds} \quad \ldots\ldots\ldots \quad (19)$$

is the differential equation of the pair of rolling curves.

To illustrate this subject, it may be mentioned that an ellipse rotating about one focus rolls completely round in outside gearing with an equal and similar ellipse also rotating about one focus, the distance between the axes of rotation being equal to the major axis of the ellipses, and the velocity ratio varying from $\frac{1 + \text{eccentricity}}{1 - \text{eccentricity}}$ to $\frac{1 - \text{eccentricity}}{1 + \text{eccentricity}}$; an hyperbola rotating about its further focus rolls in inside gearing, through a limited arc, with an equal and similar hyperbola rotating about its nearer focus, the distance between the axes of rotation being equal to the axis of the hyperbolas, and the velocity ratio varying between $\frac{\text{eccentricity} + 1}{\text{eccentricity} - 1}$ and unity; and a parabola rotating about its focus rolls with an equal and similar parabola, shifting parallel to its directrix.

51. *Conical or Bevel and Disk Wheels.*—From Principles III. and VI. of sect. 49 it appears that the angular velocities of a pair of wheels whose axes meet in a point are to each other inversely as the sines of the angles which the axes of the wheels make with the line of contact. Hence follows the following construction (figs. 11 and 12).—Let O be the apex or point of meeting of the two axes OC_1, OC_2. The angular velocity ratio being given, it is required to find the line of contact. On OC_1, OC_2 take lengths OA_1, OA_2, respectively proportional to the angular velocities of the pieces on whose axes they are taken. Complete the parallelogram OA_1EA_2; the diagonal OET will be the line of contact required.

When the velocity ratio is variable, the line of contact will shift its position in the plane C_1OC_2, and the wheels will be cones, with eccentric or irregular bases. In every case which occurs in practice, however, the velocity ratio is constant; the line of contact is constant in position, and the rolling surfaces of the wheels are regular circular cones (when they are called *bevel wheels*); or one of a pair of wheels may have a flat disk for its rolling surface, as W_2 in fig. 12, in which case it is a *disk wheel*. The rolling surfaces of actual wheels consist of frusta or zones of the complete cones or disks, as shown by W_1, W_2 in figs. 11 and 12.

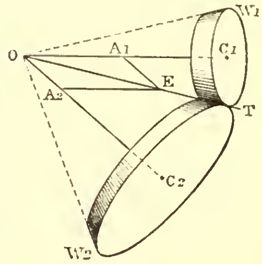


Fig. 11.

52. *Sliding Contact (lateral): Skew-Bevel Wheels.*—An hyperboloid of revolution is a surface resembling a sheaf or a dice box, generated by the rotation of a straight line round an axis from which it is at a constant distance, and to which it is inclined at a constant angle. If two such hyperboloids, equal or unequal, be placed in the closest possible contact, as in fig. 13, they will touch each other along one of the generating straight lines of each, which will form their line of contact, and will be inclined to the axes AG, BH in opposite directions. The axes will not be parallel, nor will they intersect each other.

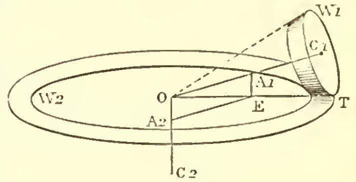


Fig. 12.

The motion of two such hyperboloids, turning in contact with each other, has hitherto been classed amongst cases of rolling contact; but that classification is not strictly correct, for, although the component velocities of a pair of points of contact in a direction at right angles to the line of contact are equal, still, as the axes are neither parallel to each other nor to the line of contact, the velocities of a pair of points of contact have components along the line of contact which are unequal, and their difference constitutes a *lateral sliding*.

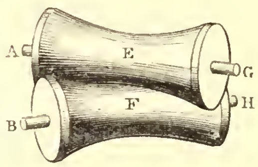


Fig. 13.

The directions and positions of the axes being given, and the required angular velocity ratio, the following construction serves to determine the line of contact, by whose rotation round the two axes respectively the hyperboloids are generated:—

In fig. 14, let B_1C_1, B_2C_2 be the two axes; B_1B_2 their common perpendicular. Through any point O in this common perpendicular draw OA_1 parallel to B_1C_1 and OA_2 parallel to B_2C_2; make those lines proportional to the angular velocities about the axes to which they are respectively parallel; complete the parallelogram OA_1EA_2, and draw the diagonal OE; divide B_1B_2 in D into two parts, *inversely* proportional to the angular velocities about the axes which they respectively adjoin; through D parallel to OE draw DT. This will be the line of contact.

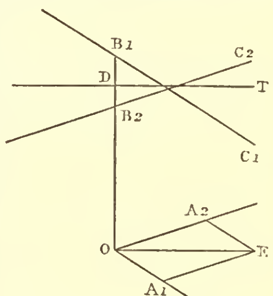


Fig. 14.

A pair of thin frusta of a pair of hyperboloids are used in practice to communicate motion between a pair of axes neither parallel nor intersecting, and are called *skew-bevel wheels*.

In skew-bevel wheels the properties of a line of connexion are not possessed by every line traversing the line of contact, but only by every line traversing the line of contact at right angles.

If the velocity ratio to be communicated were variable, the point D would alter its position, and the line DT its direction, at different periods of the motion, and the wheels would be hyperboloids of an eccentric or irregular cross-section; but forms of this kind are not used in practice.

53. *Sliding Contact (circular): Grooved Wheels.*—As the adhesion or friction between a pair of smooth wheels is seldom sufficient to prevent their slipping on each other, contrivances are used to increase their mutual hold. One of those consists in forming the rim of each wheel into a series of alternate ridges and grooves

parallel to the plane of rotation; it is applicable to cylindrical and bevel wheels, but not to skew-bevel wheels. The comparative motion of a pair of wheels so ridged and grooved is the same with that of a pair of smooth wheels in rolling contact, whose cylindrical or conical surfaces lie midway between the tops of the ridges and bottoms of the grooves, and those ideal smooth surfaces are called the *pitch surfaces* of the wheels.

The relative motion of the faces of contact of the ridges and grooves is a *rotatory sliding* or *grinding* motion, about the line of contact of the pitch-surfaces as an instantaneous axis.

Grooved wheels have hitherto been but little used.

54. *Sliding Contact (direct): Teeth of Wheels, their Number and Pitch.*—The ordinary method of connecting a pair of wheels, or a wheel and a rack, and the only method which insures the exact maintenance of a given numerical velocity ratio, is by means of a series of alternate ridges and hollows parallel or nearly parallel to the successive lines of contact of the ideal smooth wheels whose velocity ratio would be the same with that of the toothed wheels. The ridges are called *teeth*; the hollows, *spaces*. The teeth of the driver push those of the follower before them, and in so doing sliding takes place between them in a direction across their lines of contact.

The *pitch-surfaces* of a pair of toothed wheels are the ideal smooth surfaces which would have the same comparative motion by rolling contact that the actual wheels have by the sliding contact of their teeth. The *pitch-circles* of a pair of circular toothed wheels are sections of their pitch-surfaces, made for *spur-wheels* (that is, for wheels whose axes are parallel) by a plane at right angles to the axes, and for bevel wheels by a sphere described about the common apex. For a pair of skew-bevel wheels the pitch-circles are a pair of contiguous rectangular sections of the pitch-surfaces. The *pitch-point* is the point of contact of the pitch-circles.

The pitch-surface of a wheel lies intermediate between the points of the teeth and the bottoms of the hollows between them. That part of the acting surface of a tooth which projects beyond the pitch-surface is called the *face*; that part which lies within the pitch-surface, the *flank*.

Teeth, when not otherwise specified, are understood to be made in one piece with the wheel,—the material being generally cast-iron, brass, or bronze. Separate teeth, fixed into mortises in the rim of the wheel, are called *cogs*. A *pinion* is a small toothed wheel; a *trundle* is a pinion with cylindrical *staves* for teeth.

The radius of the pitch-circle of a wheel is called the *geometrical radius*; a circle touching the ends of the teeth is called the *addendum circle*, and its radius the *real radius*; the difference between these radii, being the projection of the teeth beyond the pitch-surface, is called the *addendum*.

The distance, measured along the pitch-circle, from the face of one tooth to the face of the next, is called the *pitch*. The pitch and the number of teeth in wheels are regulated by the following principles:—

I. In wheels which rotate continuously for one revolution or more, it is obviously necessary *that the pitch should be an aliquot part of the circumference.*

In wheels which reciprocate without performing a complete revolution this condition is not necessary. Such wheels are called *sectors*.

II. In order that a pair of wheels, or a wheel and a rack, may work correctly together, it is in all cases essential *that the pitch should be the same in each.*

III. Hence, in any pair of circular wheels which work together, the numbers of teeth in a complete circumference are directly as the radii and inversely as the angular velocities.

IV. Hence also, in any pair of circular wheels which rotate continuously for one revolution or more, the ratio of the numbers of teeth and its reciprocal the angular velocity ratio must be expressible in whole numbers.

From this principle arise problems of a kind which will be referred to in treating of *Trains of Mechanism*.

V. Let n, N be the respective numbers of teeth in a pair of wheels, N being the greater. Let t, T be a pair of teeth in the smaller and larger wheel respectively, which at a particular instant work together. It is required to find, first, how many pairs of teeth must pass the line of contact of the pitch-surfaces before t and T work together again (let this number be called a); and, secondly, with how many different teeth of the larger wheel the tooth t will work at different times (let this number be called b); thirdly, with how many different teeth of the smaller wheel the tooth T will work at different times (let this be called c).

CASE 1. If n is a divisor of N,

$$a = \mathrm{N}\,;\; b = \frac{\mathrm{N}}{n}\,;\; c = 1 \quad . \quad . \quad . \quad . \quad . \quad (20).$$

CASE 2. If the greatest common divisor of N and n be d, a number less than n, so that $n = md$, $\mathrm{N} = \mathrm{M}d$; then

$$a = m\mathrm{N} = \mathrm{M}n = \mathrm{M}md\,;\; b = \mathrm{M}\,;\; c = m \quad . \quad . \quad . \quad (21).$$

CASE 3 If N and n be prime to each other,

$$a = n\mathrm{N}\,;\; b = \mathrm{N}\,;\; c = n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22).$$

It is considered desirable by millwrights, with a view to the preservation of the uniformity of shape of the teeth of a pair of wheels, that each given tooth in one wheel should work with as many different teeth in the other wheel as possible. They therefore study that the numbers of teeth in each pair of wheels which work together shall either be prime to each other, or shall have their greatest common divisor as small as is consistent with a velocity ratio suited for the purposes of the machine.

55. *Sliding Contact—Forms of the Teeth of Spur-wheels and Racks.*—A line of connexion of two pieces in sliding contact is a line perpendicular to their surfaces at a point where they touch. Bearing this in mind, the principle of the comparative motion of a pair of teeth belonging to a pair of spur-wheels, or to a spur-wheel and a rack, is found by applying the principles stated generally in sects. 46 and 47 to the case of parallel axes for a pair of spur-wheels, and to the case of an axis perpendicular to the direction of shifting for a wheel and a rack.

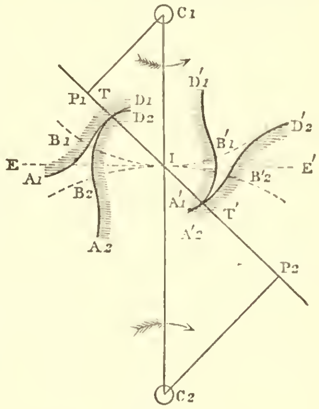


Fig. 15.

In fig. 15, let C_1, C_2 be the centres of a pair of spur-wheels; $B_1IB'_1$, $B_2IB'_2$ portions of their pitch-circles, touching at I, the pitch-point. Let the wheel 1 be the driver, and the wheel 2 the follower.

Let $D_1TB_1A_1$, $D_2TB_2A_2$ be the positions, at a given instant, of the acting surfaces of a pair of teeth in the driver and follower respectively, touching each other at T; the line of connexion of those teeth is P_1P_2, perpendicular to their surfaces at T. Let C_1P_1, C_2P_2 be perpendiculars let fall from the centres of the wheels on the line of contact. Then, by sect. 46, the angular velocity-ratio is

$$\frac{\alpha_2}{\alpha_1} = \frac{C_1P_1}{C_2P_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23).$$

The following principles regulate the forms of the teeth and their relative motions:—

I. The angular velocity ratio due to the sliding contact of the teeth will be the same with that due to the rolling contact of the pitch-circles, if the line of connexion of the teeth cuts the line of centres at the pitch-point.

For, let P_1P_2 cut the line of centres at I; then, by similar triangles,

$$\alpha_1 : \alpha_2 :: C_2P_2 : C_1P_1 :: IC_2 :: IC_1 \quad . \quad . \quad . \quad (24);$$

which is also the angular velocity ratio due to the rolling contact of the circles $B_1IB'_1$, $B_2IB'_2$.

This principle determines the *forms* of all teeth of spur-wheels. It also determines the forms of the teeth of straight racks, if one of the centres be removed, and a straight line EIE′, parallel to the direction of motion of the rack, and perpendicular to C_1IC_2, be substituted for a pitch-circle.

II. The component of the velocity of the point of contact of the teeth T along the line of connexion is

$$\alpha_1 \,.\, C_1P_1 = \alpha_2 \,.\, C_2P_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (25).$$

III. The relative velocity perpendicular to P_1P_2 of the teeth at their point of contact,—that is, their *velocity of sliding* on each other,—is found by supposing one of the wheels, such as 1, to be fixed, the line of centres C_1C_2 to rotate backwards round C_1 with the angular velocity α_1, and the wheel 2 to rotate round C_2 as before, with the angular velocity α_2 relatively to the line of centres C_1C_2, so as to have the same motion as if its pitch-circle *rolled* on the pitch-circle of the first wheel. Thus the *relative* motion of the wheels is unchanged; but 1 is considered as fixed, and 2 has the *total motion* given by the principles of sects. 37 and 38,—that is, a rotation about the instantaneous axis I, with the angular velocity $\alpha_1 + \alpha_2$. Hence the *velocity of sliding* is that due to this rotation about I, with the radius IT; that is to say, its value is

$$(\alpha_1 + \alpha_2) \,.\, \mathrm{IT} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26);$$

so that it is greater the farther the point of contact is from the line of centres; and at the instant when that point passes the line of centres, and coincides with the *pitch-point*, the velocity of sliding is null, and the action of the teeth is, for the instant, that of rolling contact.

IV. The *path of contact* is the line traversing the various positions of the point T. If the line of connexion preserves always the same position, the path of contact coincides with it, and is straight; in other cases the path of contact is curved.

It is divided by the pitch-point I into two parts,—the *arc* or *line of approach* described by T in approaching the line of centres, and the *arc* or *line of recess* described by T after having passed the line of centres.

During the *approach*, the *flank* D_1B_1 of the driving tooth drives the *face* D_2B_2 of the following tooth, and the teeth are sliding *towards* each other. During the *recess* (in which the position of the teeth is exemplified in the figure by curves marked with accented letters), the *face* $B'_1A'_1$ of the driving tooth drives the *flank* $B'_2A'_2$ of the following tooth, and the teeth are sliding *from* each other.

The path of contact is bounded where the approach commences by the addendum-circle of the follower, and where the recess terminates by the addendum-circle of the driver. The length of the path of contact should be such that there shall always be at least one pair of teeth in contact; and it is better still to make it so long that there shall always be at least two pairs of teeth in contact.

V. The *obliquity* of the action of the teeth is the angle $EIT = IC_1P_1 = IC_2P_2$.

In practice it is found desirable that the mean value of the obliquity of action during the contact of teeth should not exceed 15°, nor the maximum value 30°.

It is unnecessary to give separate figures and demonstrations for inside gearing. The only modification required in the formulæ is, that in equation 26 the *difference* of the angular velocities should be substituted for their sum.

56. *Involute Teeth.*—The simplest form of tooth which fulfils the conditions of sect. 55 is obtained in the following manner (see fig. 16). Let C_1, C_2 be the centres of two wheels, $B_1IB'_1$, $B_2IB'_2$ their pitch-circles, I the pitch-point; let the obliquity of action of the teeth be constant, so that the same straight line P_1IP_2 shall represent at once the constant line of connexion of teeth and the path of contact. Draw C_1P_1, C_2P_2 perpendicular to P_1IP_2, and with those lines as radii describe about the centres of the wheels the circles $D_1D'_1$, $D_2D'_2$, called *base-circles*. It is evident that the radii of the base-circles bear to each other the same proportions as the radii of the pitch-circles, and also that

$$\left.\begin{array}{l} C_1P_1 = IC_1 \,.\, \cos \text{obliquity} \\ C_2P_2 = IC_2 \,.\, \cos \text{obliquity} \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad (27).$$

(The obliquity which is found to answer best in practice is about $14\frac{1}{2}°$; its cosine is about $\frac{3\,1}{3\,2}$, and its sine about $\frac{1}{4}$. These values, though not absolutely exact, are near enough to the truth for practical purposes.)

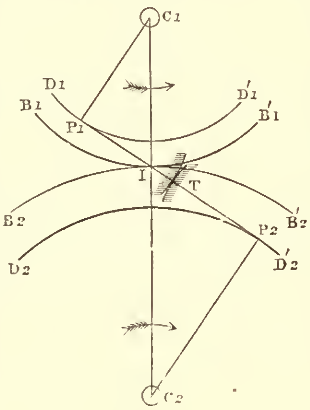


Fig. 16.

Suppose the base-circles to be a pair of circular pulleys connected by means of a cord whose course from pulley to pulley is P_1IP_2. As the line of connexion of those pulleys is the same with that of the proposed teeth, they will rotate with the required velocity ratio. Now, suppose a tracing point T to be fixed to the cord, so as to be carried along the path of contact P_1IP_2, that point will trace on a plane rotating along with the wheel 1 part of the involute of the base-circle $D_1D'_1$, and on a plane rotating along with the wheel 2 part of the involute of the base-circle $D_2D'_2$; and the two curves so traced will always touch each other in the required point of contact T, and will therefore fulfil the condition required by Principle I. of sect. 55.

Consequently, one of the forms suitable for the teeth of wheels is the involute of a circle; and the obliquity of the action of such teeth is the angle whose cosine is the ratio of the radius of their base-circle to that of the pitch-circle of the wheel.

All involute teeth of the same pitch work smoothly together.

To find the length of the path of contact on either side of the pitch-point I, it is to be observed that the distance between the fronts of two successive teeth, as measured along P_1IP_2, is less than the pitch in the ratio of cos obliquity : 1; and consequently that, if distances equal to the pitch be marked off either way from I towards P_1 and P_2 respectively, as the extremities of the path of contact, and if, according to Principle IV. of sect. 55, the addendum-circles be described through the points so found, there will always be at least two pairs of teeth in action at once. In practice it is usual to make the path of contact somewhat longer, viz., about $2\frac{1}{5}$th times the pitch; and with this length of path, and the obliquity already mentioned of $14\frac{1}{2}°$, the addendum is about $\frac{3}{10}$ths of the pitch.

The teeth of a *rack*, to work correctly with wheels having involute teeth, should have plane surfaces perpendicular to the line of connexion, and consequently making with the direction of motion of the rack angles equal to the complement of the obliquity of action.

57. *Teeth for a given Path of Contact—Mr Sang's Method.*—In the preceding section the form of the teeth is found by assuming a figure for the path of contact, viz., the straight line. Any other convenient figure may be assumed for the path of contact, and the corresponding forms of the teeth found by determining what curves a point T, moving along the assumed path of contact, will trace on two disks rotating round the centres of the wheels with angular velocities bearing that relation to the component velocity of T along TI, which is given by Principle II. of sect. 55, and by equation 25. This method of finding the forms of the teeth of wheels forms the subject of an elaborate and most interesting treatise by Mr Edward Sang.

All wheels having teeth of the same pitch, traced from the same path of contact, work correctly together, and are said to belong to the *same set*.

58. *Teeth traced by Rolling Curves.*—If any curve R (fig. 17) be rolled on the inside of the pitch-circle BB of a wheel, it appears, from sect. 37, that the instantaneous axis of the rolling curve at any instant will be at the point I, where it touches the pitch-circle for the moment, and that consequently the line AT, traced by a tracing-point T, fixed to the rolling curve upon the plane of the wheel, will be everywhere perpendicular to the straight line TI; so that the traced curve AT will be suitable for the flank of a tooth, in which T is the point of contact corresponding to the position I of the pitch-point. If the same rolling curve R, with the same tracing-point T, be rolled on the *outside* of any other pitch-circle, it will have the *face* of a tooth suitable to work with the *flank* AT.

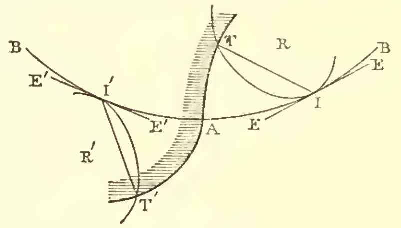


Fig. 17.

In like manner, if either the same or any other rolling curve R' be rolled the opposite way, on the *outside* of the pitch-circle BB, so that the tracing point T' shall start from A, it will trace the *face* AT' of a tooth suitable to work with a *flank* traced by rolling the same curve R' with the same tracing-point T' *inside* any other pitch-circle.

The figure of the *path of contact* is that traced on a fixed plane by the tracing-point, when the rolling curve is rotated in such a manner as always to touch a fixed straight line EIE (or E'I'E', as the case may be) at a fixed point I (or I').

If the same rolling curve and tracing point be used to trace both the faces and the flanks of the teeth of a number of wheels of different sizes but of the same pitch, all those wheels will work correctly together, and will form a *set*. The teeth of a *rack*, of the same set, are traced by rolling the rolling curve on both sides of a straight line.

The teeth of wheels of any figure, as well as of circular wheels, may be traced by rolling curves on their pitch-surfaces; and all teeth of the same pitch, traced by the same rolling curve with the same tracing-point, will work together correctly if their pitch-surfaces are in rolling contact.

59. *Epicycloidal Teeth.*—The most convenient rolling curve is the circle. The path of contact which it traces is identical with itself; and the flanks of the teeth are internal and their faces external epicycloids for wheels, and both flanks and faces are cycloids for a rack.

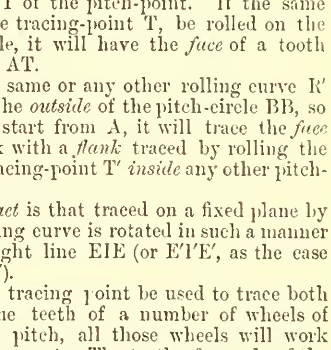


Fig. 18.

For a pitch-circle of twice the radius of the rolling or *describing* circle (as it is called) the internal epicycloid is a straight line, being, in fact, a diameter of the pitch circle, so that the flanks of the teeth for such a pitch-circle are planes radiating from the axis. For a smaller pitch-circle the flanks would be convex and *incurved* or *under-cut*, which would be inconvenient: therefore the smallest wheel of a set should have its pitch-circle of twice the radius of the describing circle, so that the flanks may be either straight or concave.

In fig. 18, let BB' be part of the pitch-circle of a wheel with epicycloidal teeth; CIC' the line of centres; I the pitch-point; EIE' a straight tangent to the pitch-circle at that point; R the internal and R′ the equal external describing circles, so placed as to touch the pitch-circle and each other at I. Let DID′ be the path of contact, consisting of the arc of approach DI and the arc of recess ID′. In order that there may always be at least two pairs of teeth in action, each of those arcs should be equal to the pitch.

The obliquity of the action in passing the line of centres is nothing; the maximum obliquity is the angle EID = E′ID; and the mean obliquity is one-half of that angle.

It appears from experience that the mean obliquity should not exceed 15°; therefore the maximum obliquity should be about 30°; therefore the equal arcs DI and ID′ should each be one-sixth of a circumference; therefore the circumference of the describing circle should be *six times the pitch.*

It follows that the smallest pinion of a set in which pinion the flanks are straight should have twelve teeth.

60. *Nearly Epicycloidal Teeth—Willis's Method.*—To facilitate the drawing of epicycloidal teeth in practice, Willis has shown how to approximate to their figure by means of two circular arcs,—one concave, for the flank, and the other convex, for the face,—and each having for its radius the *mean* radius of curvature of the epicycloidal arc. Willis's formulæ are founded on the following properties of epicycloids:—

Let R be the radius of the pitch-circle; r that of the describing circle; θ the angle made by the normal TI to the epicycloid at a given point T, with a tangent to the circle at I; that is, the obliquity of the action at T.

Then the radius of curvature of the epicycloid at T is—

$$\left.\begin{aligned}&\text{For an internal epicycloid, } \rho = 4r\sin\theta\,\frac{R-r}{R-2r}\\&\text{For an external epicycloid, } \rho' = 4r\sin\theta\,\frac{R+r}{R+2r}\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (28).$$

Also, to find the position of the centres of curvature relatively to the pitch-circle, we have, denoting the chord of the describing circle TI by c, $c = 2r\sin\theta$; and therefore

$$\left.\begin{aligned}&\text{For the flank, } \rho - c = 2r\sin\theta\,\frac{R}{R-2r}\\&\text{For the face, } \rho' - c = 2r\sin\theta\,\frac{R}{R+2r}\end{aligned}\right\} \quad . \quad . \quad (29).$$

For the proportions approved of by Willis, $\sin\theta = \frac{1}{4}$ nearly; $r = p$ (the pitch) nearly; $c = \frac{1}{2}p$ nearly; and, if N be the number of teeth in the wheel, $\frac{r}{R} = \frac{6}{N}$ nearly; therefore, approximately,

$$\left.\begin{aligned}\rho - c &= \frac{p}{2}\cdot\frac{N}{N-12}\\ \rho' - c &= \frac{p}{2}\cdot\frac{N}{N+12}\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (30).$$

Hence the following construction (fig. 19). Let BB be part of the pitch-circle, and a the point where a tooth is to cross it. Set off $ab = ac = \frac{1}{2}p$. Draw radii bd, ce; draw fb, cg, making angles of $75\frac{1}{2}$° with those radii. Make $bf = \rho' - c$, $cg = \rho - c$. From f, with the radius fa, draw the circular arc ah; from g, with the radius ga, draw the circular arc ak. Then ah is the face and ak the flank of the tooth required.

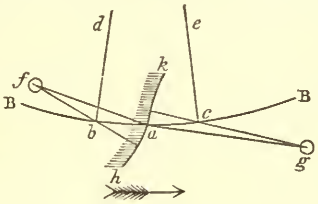


Fig. 19.

To facilitate the application of this rule, Willis published tables of $\rho - c$ and $\rho' - c$, and invented an instrument called the "odontograph."

61. *Trundles and Pin-Wheels.*—If a wheel or trundle have cylindrical pins or staves for teeth, the faces of the teeth of a wheel suitable for driving it are described by first tracing external epicycloids, by rolling the pitch-circle of the pin-wheel or trundle on the pitch-circle of the driving-wheel, with the centre of a stave for a tracing-point, and then drawing curves parallel to, and within the epicycloids, at a distance from them equal to the radius of a stave. Trundles having only six staves will work with large wheels.

62. *Backs of Teeth and Spaces.*—Toothed wheels being in general intended to rotate either way, the *backs* of the teeth are made similar to the fronts. The *space* between two teeth, measured on the pitch-circle, is made about $\frac{1}{11}$th part wider than the thickness of the tooth on the pitch-circle; that is to say,

Thickness of tooth = $\frac{5}{11}$ pitch;
Width of space = $\frac{6}{11}$ pitch.

The difference of $\frac{1}{11}$ of the pitch is called the *back-lash.* The clearance allowed between the points of teeth and the bottoms of the spaces between the teeth of the other wheel is about $\frac{1}{10}$th of the pitch.

63. *Stepped and Helical Teeth.*—Hooke invented the making of the fronts of teeth in a series of steps with a view to increase the smoothness of action. A wheel thus formed resembles in shape a series of equal and similar toothed disks placed side by side, with the teeth of each a little behind those of the preceding disk. He also invented, with the same object, teeth whose fronts, instead of being parallel to the line of contact of the pitch-circles, cross it obliquely, so as to be of a screw-like or helical form. In wheelwork of this kind the contact of each pair of teeth commences at the foremost end of the helical front, and terminates at the aftermost end; and the helix is of such a pitch that the contact of one pair of teeth shall not terminate until that of the next pair has commenced.

Stepped and helical teeth have the desired effect of increasing the smoothness of motion, but they require more difficult and expensive workmanship than common teeth; and helical teeth are, besides, open to the objection that they exert a laterally oblique pressure, which tends to increase resistance, and unduly strain the machinery.

64. *Teeth of Bevel-Wheels.*—The acting surfaces of the teeth of bevel-wheels are of the conical kind, generated by the motion of a line passing through the common apex of the pitch-cones, while its extremity is carried round the outlines of the cross section of the teeth made by a sphere described about that apex.

The operations of describing the exact figures of the teeth of bevel-wheels, whether by involutes or by rolling curves, are in every respect analogous to those for describing the figures of the teeth of spur-wheels, except that in the case of bevel-wheels all those operations are to be performed on the surface of a sphere described about the apex instead of on a plane, substituting *poles* for *centres*, and *great circles* for *straight lines.*

In consideration of the practical difficulty, especially in the case of large wheels, of obtaining an accurate spherical surface, and of drawing upon it when obtained, the following approximate method, proposed originally by Tredgold, is generally used:—

Let O (fig. 20) be the common apex of a pair of bevel-wheels; OB_1I, OB_2I their pitch cones; OC_1, OC_2 their axes; OI their line of contact. Perpendicular to OI draw A_1IA_2, cutting the axes in A_1, A_2; make the outer rims of the patterns and of the wheels portions of the cones A_1B_1I, A_2B_2I, of which the narrow zones occupied by the teeth will be sufficiently near to a spherical surface described about O for practical purposes. To find the figures of the teeth, draw on a flat surface circular arcs ID_1, ID_2, with the radii A_1I, A_2I; those arcs will be the *developments* of arcs of the pitch-circles B_1I, B_2I, when the conical surfaces A_1B_1I, A_2B_2I are spread out flat. Describe the figures of teeth for the developed arcs as for a pair of spur-wheels; then wrap the developed arcs on the cones, so as to make them coincide with the pitch-circles, and trace the teeth on the conical surfaces.

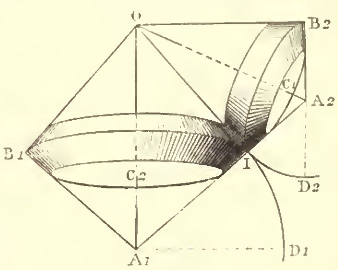


Fig. 20.

65. *Teeth of Skew-Bevel Wheels.*—The crests of the teeth of a skew-bevel wheel are parallel to the generating straight line of the hyperboloidal pitch-surface; and the transverse sections of the teeth at a given pitch-circle are similar to those of the teeth of a bevel-wheel whose pitch-surface is a cone touching the hyperboloidal surface at the given circle.

66. *Cams.*—A *cam* is a single tooth, either rotating continuously or oscillating, and driving a sliding or turning piece either constantly or at intervals. All the principles which have been stated in sect. 55 as being applicable to teeth are applicable to cams; but in designing cams it is not usual to determine or take into consideration the form of the ideal pitch-surface, which would give the same comparative motion by rolling contact that the cam gives by sliding contact.

67. *Screws.*—The figure of a screw is that of a convex or concave cylinder, with one or more helical projections, called *threads*, winding round it. Convex and concave screws are distinguished technically by the respective names of *male* and *female*; a short concave screw is called a *nut*; and when a *screw* is spoken of without qualification a *convex* screw is usually understood.

The relation between the *advance* and the *rotation*, which compose the motion of a screw working in contact with a fixed screw or helical guide, has already been demonstrated in sect. 41; and the same relation exists between the magnitudes of the rotation of a screw about a fixed axis and the advance of a shifting nut in which it rotates. The advance of the nut takes place in the opposite direction to that of the advance of the screw in the case in which the nut is fixed. The *pitch* or *axial pitch* of a screw has the meaning assigned to it in that section, viz., the distance, measured parallel to the axis, between the corresponding points in two successive turns of the *same thread*. If, therefore, the screw has several equidistant threads, the true pitch is equal to the *divided axial pitch*, as measured between two adjacent threads, multiplied by the number of threads.

If a helix be described round the screw, crossing each turn of the thread at right angles, the distance between two corresponding points on two successive turns of the same thread, measured along this *normal helix*, may be called the *normal pitch*; and when the screw has more than one thread the normal pitch from thread to thread may be called the *normal divided pitch*.

The distance from thread to thread, measured on a circle described about the axis of the screw, called the pitch-circle, may be called the *circumferential pitch*; for a screw of one thread it is one circumference; for a screw of n threads, $\frac{\text{one circumference}}{n}$.

Let r denote the radius of the pitch circle;
n the number of threads;
θ the obliquity of the threads to the pitch circle, and of the normal helix to the axis;

P_a, $\frac{P_a}{n}=p_a$ } the axial { pitch, divided pitch;

P_n, $\frac{P_n}{n}=p_n$ } the normal { pitch, divided pitch;

P_c the circumferential pitch;

then

$$\left.\begin{aligned} p_c &= p_a\ \cot\theta = p_n\ \cos\theta = \frac{2\pi r}{n} \\ p_a &= p_n\ \sec\theta = p_c\ \tan\theta = \frac{2\pi r\ \tan\theta}{n} \\ p_n &= p_c\ \sin\theta = p_a\ \cos\theta = \frac{2\pi r\ \sin\theta}{n} \end{aligned}\right\} \quad (31).$$

If a screw rotates, the number of threads which pass a fixed point in one revolution is the number of threads in the screw.

A pair of convex screws, each rotating about its axis, are used as an elementary combination to transmit motion by the sliding contact of their threads. Such screws are commonly called *endless screws*. At the point of contact of the screws their threads must be parallel; and their line of connexion is the common perpendicular to the acting surfaces of the threads at their point of contact. Hence the following principles:—

I. If the screws are both right-handed or both left-handed, the angle between the directions of their axes is the sum of their obliquities; if one is right-handed and the other left-handed, that angle is the difference of their obliquities.

II. The normal pitch for a screw of one thread, and the normal divided pitch for a screw of more than one thread, must be the same in each screw.

III. The angular velocities of the screws are inversely as their numbers of threads.

Hooke's wheels with oblique or helical teeth are in fact screws of many threads, and of large diameters as compared with their lengths.

The ordinary position of a pair of endless screws is with their axes at right angles to each other. When one is of considerably greater diameter than the other, the larger is commonly called in practice a *wheel*, the name *screw* being applied to the smaller only; but they are nevertheless both screws in fact.

To make the teeth of a pair of endless screws fit correctly and work smoothly, a hardened steel screw is made of the figure of the smaller screw, with its thread or threads notched so as to form a cutting tool; the larger screw, or "wheel," is cast approximately of the required figure; the larger screw and the steel screw are fitted up in their proper relative position, and made to rotate in contact with each other by turning the steel screw, which cuts the threads of the larger screw to their true figure.

68. *Coupling of Parallel Axes—Oldham's Coupling.*—A *coupling* is a mode of connecting a pair of shafts so that they shall rotate in the same direction with the same mean angular velocity. If the axes of the shafts are in the same straight line, the coupling consists in so connecting their contiguous ends that they shall rotate as one piece; but if the axes are not in the same straight line combinations of mechanism are required. A coupling for parallel shafts which acts by *sliding contact* was invented by Oldham, and is represented in fig. 21. C_1, C_2 are the axes of the two parallel shafts; D_1, D_2 two disks facing each other, fixed on the

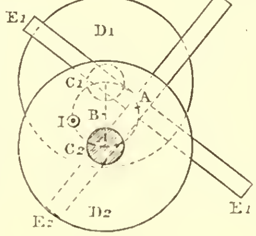


Fig. 21.

ends of the two shafts respectively; E_1E_1 a bar sliding in a diametral groove in the face of D_1; E_2E_2 a bar sliding in a diametral groove in the face of D_2: those bars are fixed together at A, so as to form a rigid cross. The angular velocities of the two disks and of the cross are all equal at every instant; the middle point of the cross, at A, revolves in the dotted circle described upon the line of centres C_1C_2 as a diameter twice for each turn of the disks and cross; the instantaneous axis of rotation of the cross at any instant is at I, the point in the circle C_1C_2 diametrically opposite to A.

Oldham's coupling may be used with advantage where the axes of the shafts are intended to be as nearly in the same straight line as is possible, but where there is some doubt as to the practicability or permanency of their exact continuity.

69. *Wrapping Connectors—Belts, Cords, and Chains.*—Flat belts of leather or of gutta percha, round cords of catgut, hemp, or other material, and metal chains are used as wrapping connectors to transmit rotatory motion between pairs of pulleys and drums.

Belts (the most frequently used of all wrapping connectors) require nearly cylindrical pulleys. A belt tends to move towards that part of a pulley whose radius is greatest; pulleys for belts, therefore, are slightly swelled in the middle, in order that the belt may remain on a pulley, unless forcibly shifted. A belt when in motion is shifted off a pulley, or from one pulley on to another of equal size alongside of it, by pressing against that part of the belt which is moving *towards* the pulley.

Cords require either cylindrical drums with ledges or grooved pulleys.

Chains require pulleys or drums, grooved, notched, and toothed, so as to fit the links of the chain.

Wrapping connectors for communicating continuous motion are endless.

Wrapping connectors for communicating reciprocating motion have usually their ends made fast to the pulleys or drums which they connect, and which in this case may be sectors.

The line of connexion of two pieces connected by a wrapping connector is the centre line of the belt, cord, or chain; and the comparative motions of the pieces are determined by the principles of sect. 46 if both pieces turn, and of sect. 47 if one turns and the other shifts, in which latter case the motion must be reciprocating.

The *pitch-line* of a pulley or drum is a curve to which the line of connexion is always a tangent; that is to say, it is a curve parallel to the acting surface of the pulley or drum, and distant from it by half the thickness of the wrapping connector.

Pulleys and drums for communicating a constant velocity ratio are circular. The *effective radius*, or radius of the pitch-circle of a circular pulley or drum, is equal to the real radius added to half the thickness of the connector. The angular velocities of a pair of connected circular pulleys or drums are inversely as the effective radii.

A *crossed* belt, as in fig. 22, A, reverses the direction of the rotation communicated; an *uncrossed* belt, as in fig. 22, B, preserves that direction.

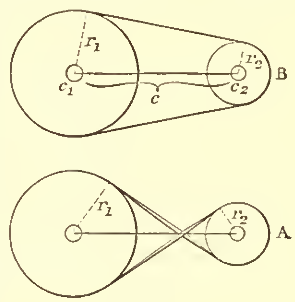


Fig. 22.

The *length* L of an endless belt connecting a pair of pulleys whose effective radii are r_1, r_2, with parallel axes whose distance apart is C, is given by the following formulæ, in each of which the first term, containing the radical, expresses the length of the straight parts of the belt, and the remainder of the formula the length of the curved parts.

For a crossed belt,—

$$L=2\sqrt{c^2-(r_1+r_2)^2}+(r_1+r_2)\left(\pi-2\sin^{-1}\frac{r_1+r_2}{c}\right) \quad (32,\ A);$$

and for an uncrossed belt,—

$$L=2\sqrt{\{c^2-(r_1-r_2)^2\}}+\pi(r_1+r_2)+2(r_1-r_2)\sin^{-1}\frac{r_1-r_2}{c} \quad (32,B);$$

in which r_1 is the greater radius, and r_2 the less.

When the axes of a pair of pulleys are not parallel, the pulleys should be so placed that the part of the belt which is *approaching* each pulley shall be in the plane of the pulley.

70. *Speed-Cones* (see fig. 23).—A pair of speed-cones is a contrivance for varying and adjusting the velocity ratio communicated between a pair of parallel shafts by means of a belt. The speed-cones are either continuous cones or conoids, as A, B, whose velocity ratio can be varied gradually while they are in motion by shifting the belt, or sets of pulleys whose radii vary by steps, as C, D, in which case the velocity ratio can be changed by shifting the belt from one pair of pulleys to another.

In order that the belt may fit accurately in every possible position on a pair of speed-cones, the quantity L must be constant, in equations 32, A, or 32, B, according as the belt is crossed or uncrossed.

For a *crossed* belt, as in A and C, fig. 23, L depends solely on c and on $r_1 + r_2$. Now c is constant because the axes are parallel; therefore the *sum of the radii* of the pitch-circles connected in every position of the belt is to be constant. That condition is fulfilled by a pair of continuous cones generated by the revolution of two straight lines inclined opposite ways to their respective axes at equal angles.

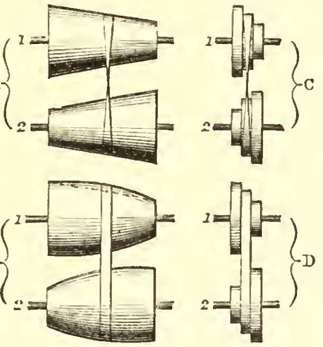


Fig. 23.

For an uncrossed belt, the quantity L in equation 32, B is to be made constant. The exact fulfilment of this condition requires the solution of a transcendental equation; but it may be fulfilled with accuracy sufficient for practical purposes by using, instead of 32, B, the following *approximate* equation:—

$$L \text{ nearly} = 2c + \pi(r_1 + r_2) + \frac{(r_1 - r_2)^2}{c} \quad . \quad . \quad . \quad (33).$$

The following is the most convenient practical rule for the application of this equation:—

Let the speed-cones be equal and similar conoids, as in B, fig. 23, but with their large and small ends turned opposite ways. Let r_1 be the radius of the large end of each, r_2 that of the small end, r_0 that of the middle; and let v be the *sagitta*, measured perpendicular to the axes, of the arc by whose revolution each of the conoids is generated, or, in other words, the *bulging* of the conoids in the middle of their length. Then

$$v = r_0 - \frac{r_1 + r_2}{2} = \frac{(r_1 - r_2)^2}{2\pi c} \quad . \quad . \quad . \quad . \quad . \quad (34).$$

$2\pi = 6{\cdot}2832$; but 6 may be used in most practical cases without sensible error.

The radii at the middle and end being thus determined, make the generating curve an arc either of a circle or of a parabola.

71. *Linkwork in General.*—The pieces which are connected by linkwork, if they rotate or oscillate, are usually called *cranks, beams,* and *levers.* The *link* by which they are connected is a rigid rod or bar, which may be straight or of any other figure; the straight figure, being the most favourable to strength, is always used when there is no special reason to the contrary. The link is known by various names under various circumstances, such as *coupling-rod, connecting-rod, crank-rod, eccentric-rod,* &c. It is attached to the pieces which it connects by two pins, about which it is free to turn. The effect of the link is to maintain the distance between the axes of those pins invariable; hence the common perpendicular of the axes of the pins is *the line of connexion,* and its extremities may be called the *connected points.* In a turning piece, the perpendicular let fall from its connected point upon its axis of rotation is the *arm* or *crank-arm.*

The axes of rotation of a pair of turning pieces connected by a link are almost always parallel, and perpendicular to the line of connexion; in which case the angular velocity ratio at any instant is the reciprocal of the ratio of the common perpendiculars let fall from the line of connexion upon the respective axes of rotation.

If at any instant the direction of one of the crank-arms coincides with the line of connexion, the common perpendicular of the line of connexion and the axis of that crank-arm vanishes, and the directional relation of the motions becomes indeterminate. The position of the connected point of the crank-arm in question at such an instant is called a *dead-point.* The velocity of the other connected point at such an instant is null, unless it also reaches a dead-point at the same instant, so that the line of connexion is in the plane of the two axes of rotation, in which case the velocity ratio is indeterminate. Examples of dead-points, and of the means of preventing the inconvenience which they tend to occasion, will appear in the sequel.

72. *Coupling of Parallel Axes.*—Two or more parallel shafts (such as those of a locomotive engine, with two or more pairs of driving wheels) are made to rotate with constantly equal angular velocities by having equal cranks, which are maintained parallel by a coupling-rod of such a length that the line of connexion is equal to the distance between the axes. The cranks pass their dead-points simultaneously. To obviate the unsteadiness of motion which this tends to cause, the shafts are provided with a second set of cranks at right angles to the first, connected by means of a similar coupling-rod, so that one set of cranks pass their dead points at the instant when the other set are farthest from theirs.

73. *Comparative Motion of Connected Points.*—As the link is a rigid body, it is obvious that its action in communicating motion may be determined by finding the comparative motion of the connected points, according to the principles laid down in §§ 71, 78, pp. 690, 692, and this is often the most convenient method of proceeding.

If a connected point belongs to a turning piece, the direction of its motion at a given instant is perpendicular to the plane containing the axis and crank-arm of the piece. If a connected point belongs to a shifting piece, the direction of its motion at any instant is given, and a plane can be drawn perpendicular to that direction.

The line of intersection of the planes perpendicular to the paths of the two connected points at a given instant is the *instantaneous axis of the link* at that instant; and the *velocities of the connected points are directly as their distances from that axis.*

In drawing on a plane surface, the two planes perpendicular to the paths of the connected points are represented by two lines (being their sections by a plane normal to them), and the instantaneous axis by a point (fig. 24); and, should the length of the two lines render it impracticable to produce them until they actually intersect, the velocity ratio of the connected points may be found by the principle that it is equal to the ratio of the segments which a line parallel to the line of connexion cuts off from any two lines drawn from a given point, perpendicular respectively to the paths of the connected points.

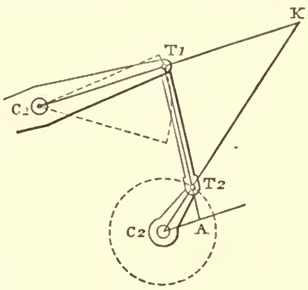


Fig. 24.

To illustrate this by one example. Let C_1 be the axis, and T_1 the connected point of the beam of a steam-engine; T_1T_2 the connecting or crank-rod; T_2 the other connected point, and the centre of the crank-pin; C_2 the axis of the crank and its shaft. Let v_1 denote the velocity of T_1 at any given instant; v_2 that of T_2. To find the ratio of these velocities, produce C_1T_1, C_2T_2, till they intersect in K; K is the instantaneous axis of the connecting rod, and the velocity ratio is

$$v_1 : v_2 :: KT_1 : KT_2 . \quad . \quad . \quad . \quad . \quad . \quad (35).$$

Should K be inconveniently far off, draw any triangle with its sides respectively parallel to C_1T_1, C_2T_2, and T_1T_2; the ratio of the two sides first mentioned will be the velocity ratio required. For example, draw C_2A parallel to C_1T_1, cutting T_1T_2 in A; then

$$v_1 : v_2 :: C_2A : C_2T_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (36).$$

74. *Eccentric.*—An eccentric circular disk fixed on a shaft, and used to give a reciprocating motion to a rod, is in effect a crank-pin of sufficiently large diameter to surround the shaft, and so to avoid the weakening of the shaft which would arise from bending it so as to form an ordinary crank. The centre of the eccentric is its connected point; and its eccentricity, or the distance from that centre to the axis of the shaft, is its crank-arm.

An eccentric may be made capable of having its eccentricity altered by means of an adjusting screw, so as to vary the extent of the reciprocating motion which it communicates.

75. *Reciprocating Pieces—Stroke—Dead-Points.*—The distance between the extremities of the path of the connected point in a reciprocating piece (such as the piston of a steam-engine) is called the *stroke* or *length of stroke* of that piece. When it is connected with a continuously turning piece (such as the crank of a steam-engine) the ends of the stroke of the reciprocating piece correspond to the *dead-points* of the path of the connected point of the turning piece, where the line of connexion is continuous with or coincides with the crank-arm.

Let S be the length of stroke of the reciprocating piece, L the length of the line of connexion, and R the crank-arm of the continuously turning piece. Then, if the two ends of the stroke be in one straight line with the axis of the crank,

$$S = 2R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (37);$$

and if these ends be not in one straight line with that axis, then S, L − R, and L + R, are the three sides of a triangle, having the angle opposite S at that axis; so that, if θ be the supplement of the arc between the dead-points,

$$\left.\begin{aligned} S^2 &= 2(L^2 + R^2) - 2(L^2 - R^2)\cos\theta \\ \cos\theta &= \frac{2L^2 + 2R^2 - S^2}{2(L^2 - R^2)} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (38).$$

76. *Coupling of Intersecting Axes—Hooke's Universal Joint.*—Intersecting axes are coupled by a contrivance of Hooke's, known as the "universal joint," which belongs to the class of linkwork (see fig. 25). Let O be the point of intersection of the axes OC_1, OC_2, and θ their angle of inclination to each other. The pair of shafts C_1, C_2 terminate in a pair of forks F_1, F_2, in bearings at the extremi-

ties of which turn the gudgeons at the ends of the arms of a rectangular cross, having its centre at O. This cross is the link; the connected points are the centres of the bearings F_1, F_2. At each instant each of those points moves at right angles to the central plane of its shaft and fork; therefore the line of intersection of the central planes of the two forks at any instant is the instantaneous axis of the cross, and the *velocity ratio* of the points F_1, F_2 (which, as the forks are equal, is also the *angular velocity ratio* of the shafts) is equal to the ratio of the distances of those points from that instantaneous axis. The *mean* value of that velocity ratio is that of equality, for each successive *quarter-turn* is made by both shafts in the same time; but its actual value fluctuates between the limits—

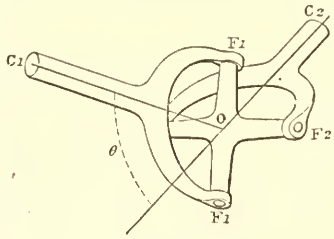


Fig. 25.

$$\left.\begin{array}{l}\dfrac{a_2}{a_1}=\dfrac{1}{\cos\theta}\text{ when }F_1\text{ is the plane }OC_1C_2\\ \text{and }\dfrac{a_2}{a_1}=\cos\theta\text{ when }F_2\text{ is in that plane}\end{array}\right\}\quad . \quad . \quad . \quad (39).$$

Its value at intermediate instants is given by the following equations:—let ϕ_1, ϕ_2 be the angles respectively made by the central planes of the forks and shafts with the plane OC_1C_2 at a given instant; then

$$\left.\begin{array}{l}\cos\theta=\tan\phi_1\tan\phi_2\\ \dfrac{a_2}{a_1}=-\dfrac{d\phi_2}{d\phi_1}=\dfrac{\tan\phi_1+\cot\phi_1}{\tan\phi_2+\cot\phi_2}\end{array}\right\}\quad . \quad . \quad . \quad . \quad (40).$$

77. *Intermittent Linkwork—Click and Ratchet.*—A *click* acting upon a ratchet-wheel or rack, which it pushes or pulls through a certain arc at each forward stroke and leaves at rest at each backward stroke, is an example of intermittent linkwork. During the forward stroke the action of the click is governed by the principles of linkwork; during the backward stroke that action ceases. A *catch* or *pall*, turning on a fixed axis, prevents the ratchet-wheel or rack from reversing its motion.

Division 5. Trains of Mechanism.

78. *General Principles.*—A *train of mechanism* consists of a series of pieces each of which is follower to that which drives it and driver to that which follows it.

The comparative motion of the first driver and last follower is obtained by combining the proportions expressing by their terms the velocity ratios and by their signs the directional relations of the several elementary combinations of which the train consists.

79. *Trains of Wheelwork.*—Let A_1, A_2, A_3, &c., A_{m-1}, A_m denote a series of axes, and a_1, a_2, a_3, &c., a_{m-1}, a_m their angular velocities. Let the axis A_1 carry a wheel of N_1 teeth, driving a wheel of n_2 teeth on the axis A_2, which carries also a wheel of N_2 teeth, driving a wheel of n_3 teeth on the axis A_3, and so on; the numbers of teeth in drivers being denoted by N's, and in followers by n's, and the axes to which the wheels are fixed being denoted by numbers. Then the resulting velocity ratio is denoted by

$$\frac{a_m}{a_1}=\frac{a_2}{a_1}\cdot\frac{a_3}{a_2}\cdot\ \&c.\ .\ .\ \frac{a_m}{a_{m-1}}=\frac{N_1\cdot N_2\ .\ .\ \&c.\ .\ .\ .\ N_{m-1}}{n_2\cdot n_3\ .\ .\ \&c.\ .\ .\ .\ n_m}\quad(41);$$

that is to say, the velocity ratio of the last and first axes is the ratio of the product of the numbers of teeth in the drivers to the product of the numbers of teeth in the followers.

Supposing all the wheels to be in outside gearing, then, as each elementary combination reverses the direction of rotation, and as the number of elementary combinations $m-1$ is one less than the number of axes m, it is evident that if m is odd the direction of rotation is preserved, and if even reversed.

It is often a question of importance to determine the number of teeth in a train of wheels best suited for giving a determinate velocity ratio to two axes. It was shown by Young that, to do this with the *least total number of teeth*, the velocity ratio of each elementary combination should approximate as nearly as possible to 3·59. This would in many cases give too many axes; and, as a useful practical rule, it may be laid down that from 3 to 6 ought to be the limit of the velocity ratio of an elementary combination in wheelwork. The smallest number of teeth in a pinion for epicycloidal teeth ought to be *twelve* (see sect. 59),—but it is better, for smoothness of motion, not to go below *fifteen*; and for involute teeth the smallest number is about *twenty-four*.

Let $\frac{B}{C}$ be the velocity ratio required, reduced to its least terms, and let B be greater than C. If $\frac{B}{C}$ is not greater than 6, and C lies between the prescribed minimum number of teeth (which may be called t) and its double $2t$, then one pair of wheels will answer the purpose, and B and C will themselves be the numbers required. Should B and C be inconveniently large, they are, if possible, to be resolved into factors, and those factors (or if they are too small, multiples of them) used for the number of teeth. Should B or C, or both, be at once inconveniently large and prime, then, instead of the exact ratio $\frac{B}{C}$, some ratio approximating to that ratio, and capable of resolution into convenient factors, is to be found by the method of continued fractions.

Should $\frac{B}{C}$ be greater than 6, the best number of elementary combinations $m-1$ will lie between

$$\frac{\log B-\log C}{\log 6}\text{ and }\frac{\log B-\log C}{\log 3}.$$

Then, if possible, B and C themselves are to be resolved each into $m-1$ factors (counting 1 as a factor), which factors, or multiples of them, shall be not less than t nor greater than $6t$; or if B and C contain inconveniently-large prime factors, an approximate velocity ratio, found by the method of continued fractions, is to be substituted for $\frac{B}{C}$ as before.

So far as the resultant velocity ratio is concerned, the *order* of the drivers N and of the followers n is immaterial; but to secure equable wear of the teeth, as explained in sect. 54, the wheels ought to be so arranged that, for each elementary combination, the greatest common divisor of N and n shall be either 1, or as small as possible.

80. *Double Hooke's Coupling.*—It has been shown in section 76 that the velocity ratio of a pair of shafts coupled by a universal joint fluctuates between the limits $\cos\theta$ and $\frac{1}{\cos\theta}$. Hence one or both of the shafts must have a vibratory and unsteady motion, injurious to the mechanism and framework. To obviate this evil a short intermediate shaft is introduced, making equal angles with the first and last shaft, coupled with each of them by a Hooke's joint, and having its own two forks in the same plane. Let a_1, a_2, a_3 be the angular velocities of the first, intermediate, and last shaft in this *train of two Hooke's couplings*. Then, from the principles of sect. 76 it is evident that at each instant $\frac{a_2}{a_1}=\frac{a_2}{a_3}$, and consequently that $a_3=a_1$; so that the fluctuations of angular velocity ratio caused by the first coupling are exactly neutralized by the second, and the first and last shafts have equal angular velocities at each instant.

81. *Converging and Diverging Trains of Mechanism.*—Two or more trains of mechanism may *converge* into one,—as when the two pistons of a pair of steam-engines, each through its own connecting-rod, act upon one crank-shaft. One train of mechanism may *diverge* into two or more,—as when a single shaft, driven by a prime mover, carries several pulleys, each of which drives a different machine. The principles of comparative motion in such converging and diverging trains are the same as in simple trains.

Division 6. Aggregate Combinations.

82. *General Principles.*—Willis has designated as "aggregate combinations" those assemblages of pieces of mechanism in which the motion of one follower is the *resultant* of component motions impressed on it by more than one driver. Two classes of aggregate combinations may be distinguished which, though not different in their actual nature, differ in the *data* which they present to the designer, and in the method of solution to be followed in questions respecting them.

Class I. comprises those cases in which a piece A is not carried directly by the frame C, but by another piece B, *relatively* to which the motion of A is given,—the motion of the piece B relatively to the frame C being also given. Then the motion of A relatively to the frame C is the *resultant* of the motion of A relatively to B and of B relatively to C; and that resultant is to be found by the principles already explained in division 3 of this chapter, sects. 34 to 41.

Class II. comprises those cases in which the motions of three points in one follower are determined by their connexions with two or with three different drivers, so that the motion of the follower, as a whole, is to be determined by the principles of §§ 71, 78, pp. 690, 692.

This classification is founded on the kinds of problems arising from the combinations. Willis adopts another classification, founded on the *objects* of the combinations, which objects he divides into two classes, viz., (1) to produce *aggregate velocity*, or a velocity which is the resultant of two or more components in the same path, and (2) to produce *an aggregate path*, that is, to make a given point in a rigid body move in an assigned path by communicating certain motions to other points in that body.

It is seldom that one of these effects is produced without at the same time producing the other; but the classification of Willis depends upon which of those two effects, even supposing them to occur together, is the practical object of the mechanism.

83. *Reduplication of Cords—Differential Windlass—Blocks, Sheaves, and Tackle.*—The axis C (fig. 26) carries a larger barrel AE and a smaller barrel DB, rotating as one piece with the angular velocity a_1 in the direction AE. The pulley or *sheave* FG has a weight W hung to its centre. A cord has one end made fast to and wrapped round the barrel AE; it passes from A under the sheave FG, and has the other end wrapped round and made fast to the barrel BD. Required the relation between the velocity of translation v_2 of W and the angular velocity a_1 of the *differential barrel.*

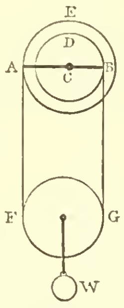


Fig. 26.

In this case v_2 is an *aggregate velocity,* produced by the joint action of the two drivers AE and BD, transmitted by wrapping connectors to FG, and combined by that sheave so as to act on the follower W, whose motion is the same with that of the centre of FG.

The velocity of the point F is $a_1 . AC$, *upward* motion being considered positive. The velocity of the point G is $-a_1 . CB$, *downward* motion being negative. Hence (p. 690, §§ 71, 72) the instantaneous axis of the sheave FG is in the diameter FG, at the distance

$$\frac{FG}{2} \cdot \frac{AC - BC}{AC + BC}$$

from the centre towards G; the angular velocity of the sheave is

$$a_2 = a_1 \cdot \frac{AC + BC}{FG} ;$$

and, consequently, the velocity of its centre is

$$v_2 = a_2 \cdot \frac{FG}{2} \cdot \frac{AC - BC}{AC + BC} = \frac{a_1(AC - BC)}{2} \quad . \quad . \quad (42),$$

or the *mean between the velocities of the two vertical parts of the cord.*

If the cord be fixed to the frame-work at the point B, instead of being wound on a barrel, the velocity of W is half that of AF.

A case containing several sheaves is called a *block.* A *fall-block* is attached to a fixed point; a *running-block* is movable to and from a fall-block, with which it is connected by two or more plies of a rope. The whole combination constitutes a *tackle* or *purchase.*

The two plies of a rope at opposite sides of a sheave in the fall-block have equal and opposite velocities. The two plies at opposite sides of a sheave in the running-block have velocities (as in the case of the sheave FG) differing equally in opposite directions from the velocity of the running-block.

One end of the rope is fastened either to the fall-block or the running-block The other, or free end, is called the *fall.* Let v_1 be the velocity of the fall, v_2 that of the running-block; and let it be required to find their ratio; and let velocities towards the fall-block be positive, and from it negative.

CASE 1. If the fastened end of the rope be attached to the fall-block its velocity is 0, and this also is the velocity of the first ply. The rope passes under a sheave in the running-block, so that the velocity of the second ply is $2v_2$. It then passes over a sheave in the fall-block; the velocity of the third ply is $-2v_2$; then under a sheave in the running-block; the velocity of the fourth ply is $4v_2$; and so on,—the general law being this:—let n be an *even* number, then

$$\left.\begin{array}{l} \text{the velocity of the } n^{\text{th}} \text{ ply} = nv_2 \\ \quad ,, \quad (n+1)^{\text{th}} \text{ ply} = -nv_2 \\ = v_1, \text{ if the fall be the } (n+1)^{\text{th}} \text{ ply} \end{array}\right\} \quad . \quad . \quad . \quad (43).$$

CASE 2. If the fastened end of the rope be attached to the running-block, the velocity of the first ply is v_2; of the second, $-v_2$; of the third, $3v_2$; of the fourth, $-3v_2$; and, generally, if n be an *odd* number,

$$\left.\begin{array}{l} \text{velocity of the } n^{\text{th}} \text{ ply} = nv_2 \\ \quad ,, \quad (n+1)^{\text{th}} \text{ ply} = -nv_2 \\ = v_1, \text{ if the fall be the } (n+1)^{\text{th}} \text{ ply} \end{array}\right\} \quad . \quad . \quad . \quad (44).$$

Generally,—

$$\frac{v_1}{v_2} = -n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (45),$$

where n is the *number of plies of rope by which the running-block hangs.*

The sheaves in a block are usually made all of the same diameter, and turn on a fixed pin, and they have, consequently, different angular velocities. But by making the diameter of each sheave proportional to the velocity, relatively to the block, of the ply of rope which it is to carry, the angular velocities of the sheaves in one block may be rendered equal, so that the sheaves may be made all in one piece, and may have journals turning in fixed bearings. This is called *White's tackle,* from the inventor.

For details and technical terms see SHIPBUILDING.

84. *Differential Screw.*—On the same axis let there be two screws of the respective pitches p_1 and p_2, made in one piece, and rotating with the angular velocity a. Let this piece be called B. Let the first screw turn in a fixed nut C, and the second in a sliding nut A. The velocity of advance of B relatively to C is (according to sect. 41) ap_1, and of A relatively to B (according to sect. 67) $-ap_2$; hence the velocity of A relatively to C is

$$a(p_1 - p_2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (46),$$

being the same with the velocity of advance of a screw of the pitch $p_1 - p_2$. This combination, called *Hunter's* or the *differential screw,* combines the strength of a large thread with the slowness of motion due to a small one.

85. *Epicyclic Trains.*—The term *epicyclic train* is used by Willis to denote a train of wheels carried by an arm, and having certain rotations relatively to that arm, which itself rotates. The arm may either be driven by the wheels or assist in driving them. The comparative motions of the wheels and of the arm, and the *aggregate paths* traced by points in the wheels, are determined by the principles of the composition of rotations, and of the description of rolling curves, explained in sects. 37 to 40.

86. *Link Motion.*—Let S (fig. 27) be the shaft of a steam-engine, O its axis, E_f the *forward eccentric,* suitably placed for moving the slide-valve when the shaft rotates forwards, F its centre, OF its crank-arm, C_f its rod, E_b the *backward eccentric,* suitably placed for moving the slide-valve when the shaft rotates backwards, B its centre, OB its crank-arm, C_b its rod. L is a long narrow box called the *link,* jointed at T_f and T_b to the eccentric rods; R is the valve-rod which works the slide-valve, jointed to P, a slider, which, by moving either L or R, or both, can be adjusted to any required position in the link.

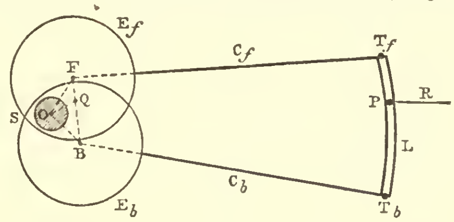


Fig. 27.

When P is at T_f the valve is said to be in *full forward gearing,* being acted upon by E_f alone. When P is at T_b the valve is said to be in *full backward gearing,* being acted upon by E_b alone. When P is placed in an intermediate position, the valve has an aggregate motion due to the joint action of E_f and E_b. The most exact mode of determining that motion is to make a skeleton drawing of the apparatus in various positions; but an *approximation* to the motion of the valve may be obtained by joining FB, and taking Q so that

$$T_fP : T_bP : : FQ : BQ ;$$

then the valve will move nearly as if it were worked by one eccentric, having its centre at Q.

87. *Parallel Motions (exact).*—A *parallel motion* is a combination of turning pieces in mechanism designed to guide the motion of a reciprocating piece either exactly or approximately in a straight line, so as to avoid the friction which arises from the use of straight guides for that purpose.

Fig. 28 represents an exact parallel motion, first proposed, it is believed, by Mr Scott Russell.

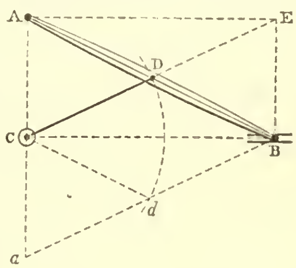


Fig. 28.

The arm CD turns on the axis C, and is jointed at D to the middle of the bar ADB, whose length is double of that of CD, and one of whose ends B is jointed to a slider, sliding in straight guides along the line CB. Draw BE perpendicular to CB, cutting CD produced in E, then E is the instantaneous axis of the bar ADB; and the direction of motion of A is at every instant perpendicular to EA, that is, along the straight line AC*a*. While the stroke of A is AC*a*, extending to equal distances on either side of C, and equal to twice the chord of the arc D*d*, the stroke of B is only equal to twice the sagitta; and thus A is guided through a comparatively long stroke by the sliding of B through a comparatively short stroke, and by rotatory motions at the joints C, D, B. (For details, see STEAM-ENGINE.)

88. *Parallel Motion—Watt's Approximate* (see fig. 29).—Let CT, *ct* be a pair of levers connected by a link T*t*, and oscillating about the axes C*c* between the positions marked 1 and 3. Let the middle positions of the levers CT_2, ct_2 be parallel to each other. It is required to find a point P in the link T*t* such that its middle

position P_2 and its extreme positions P_1, P_3 shall be in the same straight line SS, perpendicular to CT_2, ct_2, and so to place the axes C, c on the lines CT_2, ct_2 that the path of P between the positions P_1, P_2, P_3 shall be as near as possible to a straight line.

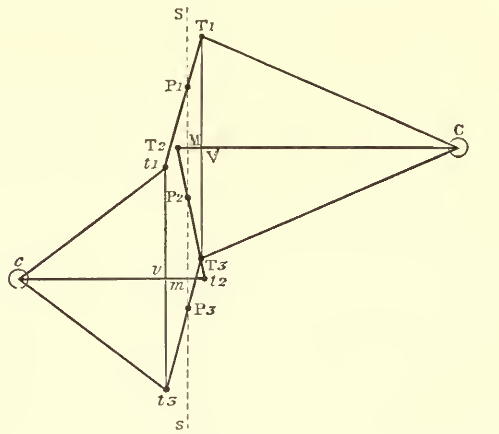


Fig. 29.

The axes C, c are to be so placed that the middle M of the versed sine VT_2, and the middle m of the versed sine vt_2, of the respective arcs whose equal chords T_1T_3, t_1t_3 represent the stroke, may each be in the line SS. Then T_1 and T_3 will be as far to one side of SS as T_2 is to the other, and t_1 and t_3 will be as far to the latter side of SS as t_2 is to the former; consequently, the two extreme positions of the links T_1t_1, T_3t_3 are parallel to each other, and inclined to SS at the same angle in one direction that the middle position of the link T_2t_2 is inclined to that line in the other direction, and the three intersections P_1, P_2, P_3 are at the same point on the link.

The position of the point P on the link is found by the following proportional equation:—

$$\left.\begin{aligned} Tt &: PT : Pt \\ :: TV + tv &: TV : tv \\ :: CM + cm &: cm \ : CM \end{aligned}\right\} \quad \ldots\ldots \quad (47).$$

Suppose the axes C, c to be given, the line of stroke SS, and the length of stroke $L = T_1T_3 = t_1t_3$, and that it is required to find the dimensions of the levers and link. Let fall CM and *cm* perpendicular to SS; then

$$\left.\begin{aligned} TV &= \frac{L^2}{8CM};\ tv = \frac{L^2}{8cm}; \\ CT &= CM + \tfrac{1}{2}TV;\ ct = cm + \tfrac{1}{2}tv; \\ Tt &= \sqrt{\{Mm^2 + \tfrac{1}{4}(TV + tv)^2\}} \end{aligned}\right\} \quad \ldots \quad (48).$$

If C and c are at the same side of SS, the smaller of the two perpendiculars is to be treated as negative in the formulæ, and the difference of the versed sines used instead of their sum; and the point P will lie in the *prolongation* of the link beyond Tt to the side of the longer lever. When the arcs of oscillation of the levers on either side of their middle positions do not exceed 20°, the intermediate portions of the path of P between P_1, P_2, and P_3 are near enough to a straight line for practical purposes; and that point may be used to guide a sliding piece, such as the piston-rod of a steam-engine, for which purpose this parallel motion was originally invented by Watt.

Chapter II. On Applied Dynamics.

89. *Laws of Motion.*—The action of a machine in transmitting *force* and *motion* simultaneously, or performing *work*, is governed, in common with the phenomena of moving bodies in general, by two "laws of motion," for which see pp. 676 *sq.*

90. *Comparison of Deviating Force with Gravity.*—See pp. 698, 699, §§ 104–106.

91. *Deviating Forces Classed—Deflecting Force—Accelerating and Retarding Forces.*—See p. 701, §§ 114–119.

92. *Division of the Subject.*—On this classification of the deviating forces in machines is founded the following division of the subject of dynamics as applied to machines:—

Division 1.—Balanced forces in machines of uniform velocity.
Division 2.—Deflecting forces in such machines.
Division 3.—Working of machines of varying velocity.

Division 1. *Balanced Forces in Machines of Uniform Velocity.*

93. *Application of Force to Mechanism.*—Forces are applied in units of weight; and the unit most commonly employed in Britain is the *pound avoirdupois.* The action of a force applied to a body is always in reality distributed over some definite space, either a volume of three dimensions or a surface of two. An example of a force distributed throughout a volume is the *weight* of the body itself, which acts on every particle, however small. The *pressure* exerted between two bodies at their surface of contact, or between the two parts of one body on either side of an ideal surface of separation, is an example of a force distributed over a surface. The mode of distribution of a force applied to a solid body requires to be considered when its stiffness and strength are treated of; but, in questions respecting the action of a force upon a rigid body considered as a whole, the *resultant* of the distributed force, determined according to the principles of statics, and considered as acting in a *single line* and applied at a *single point*, may, for the occasion, be substituted for the force as really distributed. Thus, the weight of each separate piece in a machine is treated as acting wholly at its *centre of gravity*, and each pressure applied to it as acting at a point called the *centre of pressure* of the surface to which the pressure is really applied.

94. *Forces applied to Mechanism Classed.*—If θ be the *obliquity* of a force F applied to a piece of a machine,—that is, the angle made by the direction of the force with the direction of motion of its point of application,—then by the principles of Statics, F may be resolved into two rectangular components, viz.:—

$$\left.\begin{aligned} &\text{Along the direction of motion, } P = F\cos\theta \\ &\text{Across the direction of motion, } Q = F\sin\theta \end{aligned}\right\} \quad \ldots \quad (49).$$

If the component along the direction of motion acts *with* the motion, it is called an *effort*; if *against* the motion, a *resistance.* The component *across* the direction of motion is a *lateral pressure*; the unbalanced lateral pressure on any piece, or part of a piece, is *deflecting force.* A lateral pressure may increase resistance by causing friction; the friction so caused acts against the motion, and is a resistance, but the lateral pressure causing it is not a resistance. Resistances are distinguished into *useful* and *prejudicial*, according as they arise from the useful effect produced by the machine or from other causes.

95. *Work.*—*Work* consists in moving against resistance. The work is said to be *performed*, and the resistance *overcome.* Work is measured by the product of the resistance into the distance through which its point of application is moved. The *unit of work* commonly used in Britain is a resistance of one pound overcome through a distance of one foot, and is called a *foot-pound.*

Work is distinguished into *useful work* and *prejudicial* or *lost work*, according as it is performed in producing the useful effect of the machine, or in overcoming prejudicial resistance.

96. *Energy—Potential Energy.*—*Energy* means *capacity for performing work.* The *energy of an effort*, or *potential energy*, is measured by the product of the effort into the distance through which its point of application is *capable* of being moved. The unit of energy is the same with the unit of work.

When the point of application of an effort *has been moved* through a given distance, energy is said to have been *exerted* to an amount expressed by the product of the effort into the distance through which its point of application has been moved.

97. *Variable Effort and Resistance.*—If an effort has different magnitudes during different portions of the motion of its point of application through a given distance, let each different magnitude of the effort P be multiplied by the length Δs of the corresponding portion of the path of the point of application; the sum

$$\Sigma . P\Delta s \quad \ldots\ldots\ldots \quad (50)$$

is the whole energy exerted. If the effort varies by insensible gradations, the energy exerted is the integral or limit towards which that sum approaches continually as the divisions of the path are made smaller and more numerous, and is expressed by

$$\int P ds \quad \ldots\ldots\ldots \quad (51).$$

Similar processes are applicable to the finding of the work performed in overcoming a varying resistance.

98. *Dynamometer or Indicator.*—A dynamometer or indicator is an instrument which measures and records the energy exerted by an effort. It usually consists essentially, first, of a piece of paper moving with a velocity proportional to that of the point of application of the effort, and having a straight line marked on it parallel to its direction of motion, called the zero line; and, secondly, of a spring acted upon and bent by the effort, and carrying a pencil whose perpendicular distance from the zero line, as regulated by the bending of the spring, is proportional to the effort. The pencil traces on the piece of paper a line such that its *ordinate* perpendicular to the zero line at a given point represents the effort P for the corresponding point in the path of the point of effort, and the *area between two ordinates* represents the energy exerted, $\int P ds$, for the corresponding portion of the path of the point of effort.

99. *Principle of the Equality of Energy and Work.*—From the first law of motion it follows that in a machine whose pieces move with uniform velocities the efforts and resistances must balance each

other. Now from the laws of statics (see above) it is known that, in order that a system of forces applied to a system of connected points may be in equilibrium, it is necessary that the sum formed by putting together the products of the forces by the respective distances through which their points of application are capable of moving simultaneously, each along the direction of the force applied to it, shall be zero,—products being considered positive or negative according as the direction of the forces and the possible motions of their points of application are the same or opposite.

In other words, the sum of the negative products is equal to the sum of the positive products. This principle, applied to a machine whose parts move with uniform velocities, is equivalent to saying that in any given interval of time *the energy exerted is equal to the work performed.*

The symbolical expression of this law is as follows:—let efforts be applied to one or any number of points of a machine; let any one of these efforts be represented by P, and the distance traversed by its point of application in a given interval of time by ds; let resistances be overcome at one or any number of points of the same machine; let any one of these resistances be denoted by R, and the distance traversed by its point of application in the given interval of time by ds'; then

$$\Sigma . \mathrm{P}ds = \Sigma . \mathrm{R}ds' \quad \ldots \ldots \quad (52).$$

The lengths ds, ds' are proportional to the velocities of the points to whose paths they belong, and the proportions of those velocities to each other are deducible from the construction of the machine by the principles of pure mechanism explained in Chapter I.

100. *Efficiency.*—The *efficiency* of a machine is the ratio of the *useful* work to the *total* work,—that is, to the energy exerted,—and is represented by

$$\frac{\Sigma . \mathrm{R}_u ds'}{\Sigma . \mathrm{R}ds'} = \frac{\Sigma . \mathrm{R}_u ds'}{\Sigma . \mathrm{R}_u ds' + \Sigma . \mathrm{R}_p ds'} = \frac{\Sigma . \mathrm{R}_u ds'}{\Sigma . \mathrm{P}ds} = \frac{\mathrm{U}}{\mathrm{E}} \quad . \quad . \quad (53),$$

R_u being taken to represent useful and R_p prejudicial resistances.

The more nearly the efficiency of a machine approaches to unity the better is the machine.

101. *Power and Effect.*—The *power* of a machine is the energy exerted, and the *effect* the useful work performed, in some interval of time of definite length, such as a second, an hour, or a day.

The unit of power, called conventionally a *horse-power*, is 550 foot-pounds per second, or 33,000 foot-pounds per minute, or 1,980,000 foot-pounds per hour.

102. *Modulus of a Machine.*—In the investigation of the properties of a machine, the useful resistances to be overcome and the useful work to be performed are usually given. The prejudicial resistances are generally functions of the useful resistances of the weights of the pieces of the mechanism, and of their form and arrangement; and, having been determined, they serve for the computation of the *lost* work, which, being added to the useful work, gives the expenditure of energy required. The result of this investigation, expressed in the form of an equation between this energy and the useful work, is called by Moseley the *modulus* of the machine. The general form of the modulus may be expressed thus—

$$\mathrm{E} = \mathrm{U} + \phi(\mathrm{U}, \mathrm{A}) + \psi(\mathrm{A}) \quad . \quad . \quad . \quad . \quad . \quad (54),$$

where A denotes some quantity or set of quantities depending on the form, arrangement, weight, and other properties of the mechanism. Moseley, however, has pointed out that in most cases this equation takes the much more simple form of

$$\mathrm{E} = (1 + \mathrm{A})\mathrm{U} + \mathrm{B}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (55),$$

where A and B are *constants*, depending on the form, arrangement, and weight of the mechanism. The efficiency corresponding to the last equation is

$$\frac{\mathrm{U}}{\mathrm{E}} = \frac{1}{1 + \mathrm{A} + \mathrm{B}/\mathrm{U}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (56).$$

103. *Trains of Mechanism.*—In applying the preceding principles to a train of mechanism, it may either be treated as a whole, or it may be considered in sections consisting of single pieces, or of any convenient portion of the train,—each section being treated as a machine driven by the effort applied to it and energy exerted upon it through its line of connexion with the preceding section, performing useful work by driving the following section, and losing work by overcoming its own prejudicial resistances.

It is evident that *the efficiency of the whole train is the product of the efficiencies of its sections.*

104. *Rotating Pieces—Couples of Forces.*—It is often convenient to express the energy exerted upon and the work performed by a turning piece in a machine in terms of the *moment* of the *couples of forces* acting on it, and of the angular velocity. See p. 728, § 219.

The ordinary British unit of moment is a *foot-pound*; but it is to be remembered that this is a foot-pound of a different sort from the unit of energy and work.

If a force be applied to a turning piece in a line not passing through its axis, the axis will press against its bearings with an equal and parallel force, and the equal and opposite reaction of the bearings will constitute, together with the first-mentioned force, a couple whose arm is the perpendicular distance from the axis to the line of action of the first force.

A couple is said to be *right* or *left handed* with reference to the observer, according to the direction in which it tends to turn the body, and is a *driving* couple or a *resisting* couple according as its tendency is with or against that of the actual rotation.

Let dt be an interval of time, α the angular velocity of the piece; then αdt is the angle through which it turns in the interval dt, and $ds = vdt = r\alpha dt$ is the distance through which the point of application of the force moves. Let P represent an effort, so that $\mathrm{P}r$ is a driving couple, then

$$\mathrm{P}ds = \mathrm{P}vdt = \mathrm{P}r\alpha dt = \mathrm{M}\alpha dt \quad . \quad . \quad . \quad . \quad . \quad (57)$$

is the energy exerted by the couple M in the interval dt; and a similar equation gives the work performed in overcoming a resisting couple. When several couples act on one piece, the resultant of their moments is to be multiplied by the common angular velocity of the whole piece.

105. *Reduction of Forces to a given Point, and of Couples to the Axis of a given Piece.*—In computations respecting machines it is often convenient to substitute for a force applied to a given point, or a couple applied to a given piece, the *equivalent* force or couple applied to some other point or piece; that is to say, the force or couple, which, if applied to the other point or piece, would exert equal energy or employ equal work. The principles of this reduction are that the ratio of the given to the equivalent force is the reciprocal of the ratio of the velocities of their points of application, and the ratio of the given to the equivalent couple is the reciprocal of the ratio of the angular velocities of the pieces to which they are applied.

These velocity ratios are known by the construction of the mechanism, and are independent of the absolute speed.

106. *Balanced Lateral Pressure of Guides and Bearings.*—The most important part of the lateral pressure on a piece of mechanism is the reaction of its guides, if it is a sliding piece, or of the bearings of its axis, if it is a turning piece; and the balanced portion of this reaction is equal and opposite to the resultant of all the other forces applied to the piece, its own weight included. There may be or may not be an unbalanced component in this pressure, due to the deviated motion. Its laws will be considered in the sequel.

107. *Friction—Unguents.*—The most important kind of resistance in machines is the *friction* or *rubbing resistance* of surfaces which slide over each other. The *direction* of the resistance of friction is opposite to that in which the sliding takes place. Its *magnitude* is the product of the *normal pressure* or force which presses the rubbing surfaces together in a direction perpendicular to themselves into a specific constant already mentioned in Part I., sect. 13, as the *coefficient of friction*, which depends on the nature and condition of the surfaces of the unguent, if any, with which they are covered. The *total pressure* exerted between the rubbing surfaces is the resultant of the normal pressure and of the friction, and its *obliquity*, or inclination to the common perpendicular of the surfaces, is the *angle of repose* formerly mentioned in sect. 13, whose tangent is the coefficient of friction. Thus, let N be the normal pressure, R the friction, T the total pressure, f the coefficient of friction, and ϕ the angle of repose; then

$$\left.\begin{aligned} f &= \tan\phi \quad . \quad . \quad . \\ \mathrm{R} = f\mathrm{N} &= \mathrm{N}\tan\phi = \mathrm{T}\sin\phi \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (58).$$

Experiments on friction have been made by Coulomb, Vince, Rennie, Wood, D. Rankine, and others. The most complete and elaborate experiments are those of Morin, published in his *Notions Fondamentales de Mécanique*, and republished in Britain in the works of Moseley and Gordon. The following is an exceedingly condensed abstract of the most important results, as regards machines, of these experiments:—

Surfaces.	f.
Wood on wood, dry	0·25 to 0·5
Do., soaped	0·2
Metals on oak, dry	0·5 to 0·6
Do., wet	0·24 to 0·26
Do., soaped	0·2
Do., elm, dry	0·2 to 0·25
Hemp on oak, dry	0·53
Do., wet	0·33
Leather on oak, wet or dry	0·27 to 0·35
Leather on metals, dry	0·56
Do., wet	0·36
Do., greasy	0·23
Do., oiled	0·15
Metals on metals, dry	0·15 to 0·2
Do., wet	0·30
Smooth surfaces with ungents, occasionally greased	0·07 to 0·08
Do. do., well greased	0·05
Do. do., do., best results	0·03 to 0·036

It is to be understood that the above-stated law of friction is only true for dry surfaces when the pressure is not sufficient to indent or abrade the surfaces, and for greased surfaces when the pressure is not sufficient to force out the unguent from between the surfaces. If the proper limit be exceeded, the friction increases more rapidly than in the simple ratio of the normal pressure.

The limit of pressure for unguents diminishes as the speed increases. The following are some of its approximate values as inferred from experience in railway locomotive and carriage axles :—

Velocity of rubbing in feet per second	1	$2\frac{1}{3}$	5
Intensity of normal pressure per lb per square inch of surface	392	224	140

In pivots, the intensity of the pressure is usually fixed at about one ton per square inch.

Unguents should be comparatively thick for heavy pressures, that they may resist being forced out, and comparatively thin for light pressures, that their viscidity may not add to the resistance.

Unguents are of three classes, viz. :—

1. *Fatty*: consisting of animal or vegetable fixed oils, such as tallow, lard, lard-oil, seal-oil, whale-oil, olive-oil. *Drying* oils, which absorb oxygen and harden, are obviously unfit for unguents.

2. *Soapy*: composed of fatty oil, alkali, and water. The best grease of this class should not contain more than about 25 or 30 per cent. of water ; bad kinds contain 40 or 50 per cent. The additional water diminishes the cost, but spoils the unguent.

3. *Bituminous*: composed of solid and liquid mineral compounds of hydrogen and carbon.

108. *Work of Friction—Moment of Friction.*—The work performed in a unit of time in overcoming the friction of a pair of surfaces is the product of the friction by the velocity of sliding of the surfaces over each other, if that is the same throughout the whole extent of the rubbing surfaces. If that velocity is different for different portions of the rubbing surfaces, the velocity of each portion is to be multiplied by the friction of that portion, and the results summed or integrated.

When the relative motion of the rubbing surfaces is one of rotation, the work of friction in a unit of time, for a portion of the rubbing surfaces at a given distance from the axis of rotation, may be found by multiplying together the friction of that portion, its distance from the axis, and the angular velocity. The product of the force of friction by the distance at which it acts from the axis of rotation is called the *moment of friction*. The total moment of friction of a pair of rotating rubbing surfaces is the sum or integral of the moments of friction of their several portions.

To express this symbolically, let du represent the area of a portion of a pair of rubbing surfaces at a distance r from the axis of their relative rotation ; p the intensity of the normal pressure at du per unit of area ; and f the coefficient of friction. Then the moment of friction of du is

$$fprdu\,;$$

the total moment of friction is

$$f\!\int pr.du\,;$$

and the work performed in a unit of time in overcoming friction, when the angular velocity is a, is

$$af\!\int pr.du. \qquad \cdots\cdots\cdots (59).$$

It is evident that the moment of friction, and the work lost by being performed in overcoming friction, are less in a rotating piece as the bearings are of smaller radius. But a limit is put to the diminution of the radii of journals and pivots by the conditions of durability and of proper lubrication stated in sect. 107, and also by conditions of strength and stiffness.

109. *Total Pressure between Journal and Bearing.*—A single piece rotating with an uniform velocity has four mutually balanced forces applied to it :—(1) the effort exerted on it by the piece which drives it ; (2) the resistance of the piece which follows it,—which may be considered for the purposes of the present question as useful resistance ; (3) its weight ; and (4) the reaction of its own cylindrical bearings. There are given the following data :—

The direction of the effort.
The direction of the useful resistance.
The weight of the piece and the direction in which it acts.
The magnitude of the useful resistance.
The radius of the bearing r.
The angle of repose ϕ, corresponding to the friction of the journal on the bearing.

And there are required the following:—

The direction of the reaction of the bearing.
The magnitude of that reaction.
The magnitude of the effort.

Let the useful resistance and the weight of the piece be compounded by the principles of statics into one force, and let this be called *the given force*.

The directions of the effort and of the given force are either parallel or meet in a point. If they are parallel, the direction of the reaction of the bearing is also parallel to them ; if they meet in a point, the direction of the reaction traverses the same point.

Also, let AAA, fig. 30, be a section of the bearing, and C its axis ; then the direction of the reaction, at the point where it intersects the circle AAA, must make the angle ϕ with the radius of that circle ; that is to say, it must be a line such as PT touching the smaller circle BB, whose radius is $r . \sin \phi$. The side on which it touches that circle is determined by the fact that the obliquity of the reaction is such as to oppose the rotation.

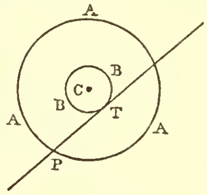


Fig. 30.

Thus is determined the direction of the reaction of the bearing ; and the magnitude of that reaction and of the effort are then found by the principles of the equilibrium of three forces already stated in Part I., sect. 7 (see also p. 702, § 124).

The work lost in overcoming the friction of the bearing is the same with that which would be performed in overcoming at the circumference of the small circle BB a resistance equal to the whole pressure between the journal and bearing.

In order to diminish that pressure to the smallest possible amount, the effort, and the resultant of the useful resistance, and the weight of the piece (called above the "given force") ought to be opposed to each other as directly as is practicable consistently with the purposes of the machine.

110. *Friction of Pivots and Collars.*—When a shaft is acted upon by a force tending to shift it lengthways, that force must be balanced by the reaction of a bearing against a *pivot* at the end of the shaft ; or, if that be impossible, against one or more *collars*, or rings *projecting* from the body of the shaft. The bearing of the pivot is called a *step* or *footstep*. Pivots require great hardness, and are usually made of steel. The *flat* pivot is a cylinder of steel having a plane circular end as a rubbing surface. Let N be the total pressure sustained by a flat pivot of the radius r ; if that pressure be uniformly distributed, which is the case when the rubbing surfaces of the pivot and its step are both true planes, the *intensity* of the pressure is

$$p = \frac{N}{\pi r^2} \quad \cdots\cdots\cdots \quad (60);$$

and, introducing this value into equation 59, the *moment of friction of the flat pivot* is found to be

$$\tfrac{2}{3} f N r \quad \cdots\cdots\cdots \quad (61),$$

or two-thirds of that of a cylindrical journal of the same radius under the same normal pressure.

The friction of a *conical* pivot exceeds that of a flat pivot of the same radius, and under the same pressure, in the proportion of the side of the cone to the radius of its base.

The moment of friction of a *collar* is given by the formula—

$$\tfrac{2}{3} f N \frac{r^3 - r'^3}{r^2 - r'^2} \quad \cdots\cdots\cdots \quad (62),$$

where r is the external and r' the internal radius.

In the *cup and ball* pivot the end of the shaft and the step present two recesses facing each other, into which are fitted two shallow cups of steel or hard bronze. Between the concave spherical surfaces of those cups is placed a steel ball, being either a complete sphere or a lens having convex surfaces of a somewhat less radius than the concave surfaces of the cups. The moment of friction of this pivot is at first almost inappreciable from the extreme smallness of the radius of the circles of contact of the ball and cups, but, as they wear, that radius and the moment of friction increase.

It appears that the rapidity with which a rubbing surface wears away is proportional to the friction and to the velocity jointly, or nearly so. Hence the pivots already mentioned wear unequally at different points, and tend to alter their figures. Schiele has invented a pivot which preserves its original figure by wearing equally at all points in a direction parallel to its axis. The following are the principles on which this equality of wear depends :—

The rapidity of wear of a surface measured in an *oblique* direction is to the rapidity of wear measured normally as the secant of the obliquity is to unity. Let OX (fig. 31) be the axis of a pivot, and let RPC be a portion of a curve such that at any point P the secant of the obliquity to the normal of the curve of a line parallel to the axis is inversely proportional to the ordinate PY, to which the velocity of P is proportional. The rotation of that curve round OX will generate the form of pivot required. Now let PT be a tangent to the

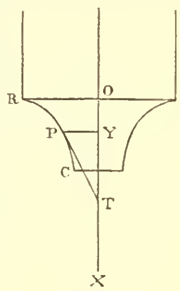


Fig 31.

curve at P, cutting OX in T; PT = PY × *secant obliquity*, and this is to be a constant quantity; hence the curve is that known as the *tractory* of the straight line OX, in which PT = OR = constant. This curve is described by having a fixed straight edge parallel to OX, along which slides a slider carrying a pin whose centre is T. On that pin turns an arm, carrying at a point P a tracing-point, pencil, or pen. Should the pen have a nib of two jaws, like those of an ordinary drawing-pen, the plane of the jaws must pass through PT. Then, while T is slid along the axis from O towards X, P will be drawn after it from R towards C along the tractory. This curve, being an asymptote to its axis, is capable of being indefinitely prolonged towards X; but in designing pivots it should stop before the angle PTY becomes less than the angle of repose of the rubbing surfaces, otherwise the pivot will be liable to stick in its bearing.

The moment of friction of "Schiele's anti-friction pivot," as it is called, is equal to that of a cylindrical journal of the radius OR = PT the constant tangent, under the same pressure.

111. *Friction of Teeth.*—Let N be the normal pressure exerted between a pair of teeth of a pair of wheels; s the total distance through which they slide upon each other; n the number of pairs of teeth which pass the plane of axis in a unit of time; then

$$nfNs \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (63)$$

is the work lost in unity of time by the friction of the teeth. The sliding s is composed of two parts, which take place during the approach and recess respectively. Let those be denoted by s_1 and s_2, so that $s = s_1 + s_2$. In sect. 55 the *velocity* of sliding at any instant has been given, viz., $u = c(\alpha_1 + \alpha_2)$, where u is that velocity, c the distance TI at any instant from the point of contact of the teeth to the pitch-point, and α_1, α_2 the respective angular velocities of the wheels.

Let v be the common velocity of the two pitch-circles, r_1, r_2 their radii; then the above equation becomes

$$u = cv\left(\frac{1}{r_1} + \frac{1}{r_2}\right).$$

To apply this to involute teeth, let c_1 be the length of the approach, c_2 that of the recess, u_1 the *mean* velocity of sliding during the approach, u_2 that during the recess; then

$$u_1 = \frac{c_1 v}{2}\left(\frac{1}{r_1} + \frac{1}{r_2}\right); \quad u_2 = \frac{c_2 v}{2}\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

also, let θ be the obliquity of the action; then the times occupied by the approach and recess are respectively

$$\frac{c_1}{v\cos\theta}, \qquad \frac{c_2}{v\cos\theta};$$

giving, finally, for the length of sliding between each pair of teeth,

$$s = s_1 + s_2 = \frac{c_1^2 + c_2^2}{2\cos\theta}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \quad . \quad . \quad . \quad . \quad (64),$$

which, substituted in equation 63, gives the work lost in a unit of time by the friction of involute teeth. This result, which is exact for involute teeth, is approximately true for teeth of any figure.

For inside gearing, if r_1 be the less radius and r_2 the greater, $\frac{1}{r_1} - \frac{1}{r_2}$ is to be substituted for $\frac{1}{r_1} + \frac{1}{r_2}$.

112. *Friction of Cords and Belts.*—A flexible band, such as a cord, rope, belt, or strap, may be used either to exert an effort or a resistance upon a pulley round which it wraps. In either case the tangential force, whether effort or resistance, exerted between the band and the pulley is their mutual friction, caused by and proportional to the normal pressure between them.

Let T_1 be the tension of the free part of the band at that side *towards* which it tends to draw the pulley, or *from* which the pulley tends to draw it; T_2 the tension of the free part at the other side; T the tension of the band at any intermediate point of its arc of contact with the pulley; θ the ratio of the length of that arc to the radius of the pulley; $d\theta$ the ratio of an indefinitely small element of that arc to the radius; $F = T_1 - T_2$ the total friction between the band and the pulley; dF the elementary portion of that friction due to the elementary arc $d\theta$; f the coefficient of friction between the materials of the band and pulley.

Then, according to a well-known principle in statics, the normal pressure at the elementary arc $d\theta$ is $Td\theta$, T being the mean tension of the band at that elementary arc; consequently the friction on that arc is $dF = fTd\theta$. Now that friction is also the difference between the tensions of the band at the two ends of the elementary arc, or $dT = dF = fTd\theta$; which equation, being integrated throughout the entire arc of contact, gives the following formulæ:—

$$\left.\begin{aligned} &\text{hyp. log}\frac{T_1}{T_2} = f\theta \\ &\frac{T_1}{T_2} = e^{f\theta} \\ &F = T_1 - T_2 = T_1(1 - e^{-f\theta}) = T_2(e^{f\theta} - 1) \end{aligned}\right\} \quad . \quad . \quad (65).$$

When a belt connecting a pair of pulleys has the tensions of its two sides originally equal, the pulleys being at rest, and when the pulleys are next set in motion, so that one of them drives the other by means of the belt, it is found that the advancing side of the belt is exactly as much tightened as the returning side is slackened, so that the *mean* tension remains unchanged. Its value is given by this formula—

$$\frac{T_1 + T_2}{2} = \frac{e^{f\theta} + 1}{2(e^{f\theta} - 1)} \quad . \quad . \quad . \quad . \quad . \quad (66),$$

which is useful in determining the original tension required to enable a belt to transmit a given force between two pulleys.

The equations 65 and 66 are applicable to a kind of *brake* called a *friction-strap*, used to stop or moderate the velocity of machines by being tightened round a pulley. The strap is usually of iron, and the pulley of hard wood.

Let a denote the arc of contact expressed in *turns and fractions of a turn*; then

$$\left.\begin{aligned} &\theta = 6\cdot2832a \\ &e^{f\theta} = \text{number whose common logarithm is } 2\cdot7288fa \end{aligned}\right\} \quad (67).$$

113. *Stiffness of Ropes.*—Ropes offer a resistance to being bent, and, when bent, to being straightened again, which arises from the mutual friction of their fibres. It increases with the sectional area of the rope, and is inversely proportional to the radius of the curve into which it is bent.

The *work lost* in pulling a given length of rope over a pulley is found by multiplying the length of the rope in feet by its stiffness in pounds, that stiffness being the excess of the tension at the leading side of the rope above that at the following side, which is necessary to bend it into a curve fitting the pulley, and then to straighten it again.

The following empirical formulæ for the stiffness of hempen ropes have been deduced by Morin from the experiments of Coulomb:—

Let F be the stiffness in pounds avoirdupois; d the diameter of the rope in inches, $n = 48d^2$ for white ropes and $35d^2$ for tarred ropes; r the *effective* radius of the pulley in inches; T the tension in pounds. Then

$$\left.\begin{aligned} &\text{For white ropes, } F = \frac{n}{r}(0\cdot0012 + 0\cdot001026n + 0\cdot0012T) \\ &\text{For tarred ropes, } F = \frac{n}{r}(0\cdot006 + 0\cdot001392n + 0\cdot00168T) \end{aligned}\right\} (68).$$

114. *Friction-Couplings.*—Friction is useful as a means of communicating motion where sudden changes either of force or velocity take place, because, being limited in amount, it may be so adjusted as to limit the forces which strain the pieces of the mechanism within the bounds of safety. Amongst contrivances for effecting this object are *friction-cones*. A rotating shaft carries upon a cylindrical portion of its figure a wheel or pulley turning loosely on it, and consequently capable of remaining at rest when the shaft is in motion. This pulley has fixed to one side, and concentric with it, a short frustum of a hollow cone. At a small distance from the pulley the shaft carries a short frustum of a solid cone accurately turned to fit the hollow cone. This frustum is made always to turn along with the shaft by being fitted on a square portion of it, or by means of a rib and groove, or otherwise, but is capable of a slight longitudinal motion, so as to be pressed into, or withdrawn from, the hollow cone by means of a lever. When the cones are pressed together or engaged, their friction causes the pulley to rotate along with the shaft; when they are disengaged, the pulley is free to stand still. The angle made by the sides of the cones with the axis should not be less than the angle of repose. In the *friction-clutch*, a pulley loose on a shaft has a hoop or gland made to embrace it more or less tightly by means of a screw; this hoop has short projecting arms or ears. A fork or *clutch* rotates along with the shaft, and is capable of being moved longitudinally by a handle. When the clutch is moved towards the hoop, its arms catch those of the hoop, and cause the hoop to rotate and to communicate its rotation to the pulley by friction. There are many other contrivances of the same class, but the two just mentioned may serve for examples.

115. *Heat of Friction—Unguents.*—The work lost in friction is employed in producing heat. This fact is very obvious, and has been known from a remote period; but the *exact* determination of the proportion of the work lost to the heat produced, and the experimental proof that that proportion is the same under all circumstances, and with all materials, solid, liquid, and gaseous, are comparatively recent achievements of Joule. The quantity of work which produces a British unit of heat (or so much heat as elevates the temperature of one pound of pure water, at or near ordinary atmospheric temperatures, by one degree of Fahrenheit) is 772 foot-pounds. This constant, now designated as "Joule's equivalent," is the principal experimental datum of the science of thermodynamics.

The heat produced by friction, when moderate in amount, is useful in softening and liquefying thick unguents; but when excessive it is prejudicial, by decomposing the unguents, and sometimes even by softening the metal of the bearings, and raising their temperature so high as to set fire to neighbouring combustible matters.

Excessive heating is prevented by a constant and copious supply of a good unguent. The elevation of temperature produced by the friction of a journal is sometimes used as an experimental test of the quality of unguents. When the velocity of rubbing is about 4 or 5 feet per second, the elevation of temperature has been found by some recent experiments to be, with good fatty and soapy unguents, 40° to 50° Fahr.; with good mineral unguents, about 30°.

116. *Rolling Resistance.*—By the rolling of two surfaces over each other without sliding a resistance is caused which is called sometimes "rolling friction," but more correctly *rolling resistance.* It is of the nature of a *couple*, resisting rotation. Its *moment* is found by multiplying the normal pressure between the rolling surfaces by an *arm*, whose length depends on the nature of the rolling surfaces, and the work lost in a unit of time in overcoming it is the product of its moment by the *angular velocity* of the rolling surfaces relatively to each other. The following are approximate values of the arm in decimals of a foot:—

Oak upon oak	0·006	(Coulomb).
Lignum vitæ on oak	0·004	,,
Cast iron on cast iron	0·002	(Tredgold).

117. *Reciprocating Forces—Stored and Restored Energy.*—When a force acts on a machine alternately as an effort and as a resistance, it may be called a *reciprocating force.* Of this kind is the weight of any piece in the mechanism whose centre of gravity alternately rises and falls; for during the rise of the centre of gravity that weight acts as a resistance, and energy is employed in lifting it to an amount expressed by the product of the weight into the vertical height of its rise; and during the fall of the centre of gravity the weight acts as an effort, and exerts in assisting to perform the work of the machine an amount of energy exactly equal to that which had previously been employed in lifting it. Thus that amount of energy is not lost, but has its operation deferred; and it is said to be *stored* when the weight is lifted, and *restored* when it falls.

In a machine of which each piece is to move with a uniform velocity, if the effort and the resistance be constant, the weight of each piece must be balanced on its axis, so that it may produce lateral pressure only, and not act as a reciprocating force. But if the effort and the resistance be alternately in excess, the uniformity of speed may still be preserved by so adjusting some moving weight in the mechanism that when the effort is in excess it may be lifted, and so balance and employ the excess of effort, and that when the resistance is in excess it may fall, and so balance and overcome the excess of resistance,—thus *storing* the periodical excess of energy, and *restoring* that energy to perform the periodical excess of work.

Other forces besides gravity may be used as reciprocating forces for storing and restoring energy,—for example, the elasticity of a spring or of a mass of air.

In most of the delusive machines commonly called "perpetual motions," of which so many are patented in each year, and which are expected by their inventors to perform work without receiving energy, the fundamental fallacy consists in an expectation that some reciprocating force shall restore more energy than it has been the means of storing.

Division 2. *Deflecting Forces.*

118. *Deflecting Force for Translation in a Curved Path.*—In machinery, deflecting force is supplied by the tenacity of some piece, such as a crank, which guides the deflected body in its curved path, and is *unbalanced*, being employed in producing deflexion, and not in balancing another force.

119. *Centrifugal Force.*—See p. 682, § 35, and p. 701, § 119.

120. *Rectangular Resolution of Centrifugal Force.*—See p. 701, §§ 117 and 119.

121. *Centrifugal Force of a Rotating Body.* — *The centrifugal force exerted by a rotating body on its axis of rotation is the same in magnitude as if the mass of the body were concentrated at its centre of gravity, and acts in a plane passing through the axis of rotation and the centre of gravity of the body.*

The particles of a rotating body exert centrifugal forces on each other, which strain the body, and tend to tear it asunder; but these forces balance each other, and do not affect the resultant centrifugal force exerted on the axis of rotation.[1]

If the axis of rotation traverses the centre of gravity of the body, the centrifugal force exerted on that axis is nothing.

Hence, unless there be some reason to the contrary, each piece of a machine should be balanced on its axis of rotation; otherwise the centrifugal force will cause strains, vibration, and increased friction, and a tendency of the shafts to jump out of their bearings.

122. *Centrifugal Couples of a Rotating Body.*—Besides the tendency (if any) of the combined centrifugal forces of the particles of a rotating body to *shift* the axis of rotation, they may also tend to *turn* it out of its original direction. The latter tendency is called a *centrifugal couple*, and vanishes for rotation about a principal axis (see p. 732, § 237).

It is essential to the steady motion of every rapidly rotating piece in a machine that its axis of rotation should not merely traverse its centre of gravity, but should be a permanent axis; for otherwise the centrifugal couples will increase friction, produce oscillation of the shaft, and tend to make it leave its bearings.

The principles of this and the preceding section are those which regulate the adjustment of the weight and position of the *counterpoises* which are placed between the spokes of the driving-wheels of locomotive engines.

123. *Revolving Pendulum—Governors.*—In fig. 32 AO represents an upright axis or spindle; B a weight called a *bob*, suspended by rod OB from a horizontal axis at O, carried by the vertical axis. When the spindle is at rest the bob hangs close to it; when the spindle rotates, the bob, being made to revolve round it, diverges until the resultant of the centrifugal force and the weight of the bob is a force acting at O in the direction OB, and then it revolves steadily in a circle. This combination is called a *revolving, centrifugal*, or *conical pendulum.* Revolving pendulums are usually constructed with *pairs* of rods and bobs, as OB, O*b*, hung at opposite sides of the spindle, that the centrifugal forces exerted at the point O may balance each other.

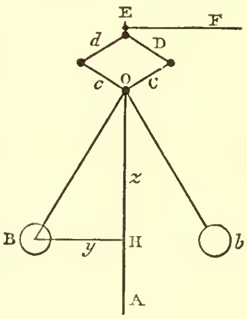


Fig. 32.

In finding the position in which the bob will revolve with a given angular velocity α, for most practical cases connected with machinery the mass of the rod may be considered as insensible compared with that of the bob. Let the bob be a sphere, and from the centre of that sphere draw $BH = y$ perpendicular to OA. Let $OH = z$; let W be the weight of the bob, F its centrifugal force. Then the condition of its steady revolution is $W : F :: z : y$; that is to say, $\frac{y}{z} = \frac{F}{W} = \frac{y\alpha^2}{g}$; consequently

$$z = \frac{g}{\alpha^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (69).$$

Or, if $n = \frac{\alpha}{2\pi} = \frac{\alpha}{6 \cdot 2832}$ be the number of turns or fractions of a turn in a second,

$$z = \frac{g}{4\pi^2 n^2} = \frac{0 \cdot 8165 \text{ foot}}{n^2} = \frac{9 \cdot 79771 \text{ inches}}{n^2} \Bigg\} \quad . \quad . \quad (70);$$

z is called the *altitude of the pendulum.*

If the rod of a revolving pendulum be jointed, as in fig. 33, not to a point in the vertical axis, but to the end of a projecting arm C, the position in which the bob will revolve will be the same as if the rod were jointed to the point O, where its prolongation cuts the vertical axis.

A revolving pendulum is an essential part of most of the contrivances called *governors*, for regulating the speed of prime movers.

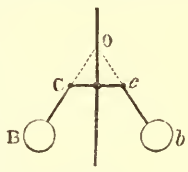


Fig. 33.

The earlier kinds of governors act on the prime mover by the variations of their altitude. Thus in Watt's steam-engine governor the rods, through a combination of levers and linkwork C, *c*, D, *d* (fig. 32), act on a lever EF, which acts upon the throttle-valve for the admission of steam so as to enlarge or contract its opening when the speed becomes too small or too great.

In a more recent kind of governors invented by the Messrs Siemens, which may be called *differential governors*, the regulation of the prime mover is effected by means of the difference between the velocity of a wheel driven by it and that of a wheel regulated by a revolving pendulum. Fig. 34 illustrates this class of governors. A is a vertical dead-centre or fixed shaft, about which the after-mentioned pieces turn; C is a pulley driven by the prime mover, and fixed to a bevel-wheel, which is seen below it; E is a bevel-wheel similar to the first, and having the same apex. To this wheel are hung the bobs B, of which there are

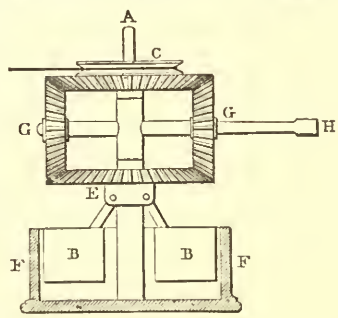


Fig. 34.

[1] This is a particular case of a more general principle, that *the motion of the centre of gravity of a body is not affected by the mutual actions of its parts*, for the proof of which see p. 718, § 179.

usually four, although two only are shown. Those bobs form sectors of a ring, and are surrounded by a cylindrical casing F. When the bobs revolve with their proper velocity, they are adjusted so as nearly to touch this casing; should they exceed that velocity, they fly outwards and touch the casing, and are retarded by the friction. For practical purposes their velocity of rotation about the vertical axis may be considered constant. G, G are horizontal arms projecting from a socket which is capable of rotation about A, and carrying vertical bevel wheels which rest on E and support C, and transmit motion from C to E. There are usually four of the arms G, G with their wheels, though two only are shown. H is one of those arms which projects, and has a rod attached to its extremity to act on the throttle-valve of a steam-engine, the sluice of a water-wheel, or the regulator of the prime mover, of whatever sort it may be.

When C rotates with an angular velocity equal and contrary to that of E with its revolving pendulums, the arms G, G remain at rest; but should C deviate from that velocity, those arms rotate in one direction or the other, as the case may be, with an angular velocity equal to one half of the difference between the angular velocity of C and that of E, and continue in motion until the regulator is adjusted so that the prime mover shall impart to C an angular velocity exactly equal to that of the revolving pendulums.

There are various modifications of the differential governor, but they all act on the same principle.

Division 3. Working of Machines of Varying Velocity.

124. *General Principles.*—In order that the velocity of every piece of a machine may be uniform, it is necessary that the forces acting on each piece should be always exactly balanced. Also, in order that the forces acting on each piece of a machine may be always exactly balanced, it is necessary that the velocity of that piece should be uniform.

An excess of the effort exerted on any piece, above that which is necessary to balance the resistance, is accompanied with acceleration; a deficiency of the effort, with retardation.

When a machine is being started from a state of rest, and brought by degrees up to its proper speed, the effort must be in excess; when it is being retarded for the purpose of stopping it, the resistance must be in excess.

An excess of effort above resistance involves an excess of energy exerted above work performed; that excess of energy is employed in producing acceleration.

An excess of resistance above effort involves an excess of work performed above energy expended; that excess of work is performed by means of the retardation of the machinery.

When a machine undergoes alternate acceleration and retardation, so that at certain instants of time, occurring at the end of intervals called *periods* or *cycles*, it returns to its original speed, then in each of those periods or cycles the alternate excesses of energy and of work neutralize each other; and at the end of each cycle the principle of the equality of energy and work stated in sect. 96, with all its consequences, is verified exactly as in the case of machines of uniform speed.

At intermediate instants, however, other principles have also to be taken into account, which are deduced from the second law of motion, sect. 89, as applied by the aid of the principles of sect. 90, to *direct deviation*, or acceleration and retardation.

125. *Energy of Acceleration and Work of Retardation for a Shifting Body.*—Let w be the weight of a body which has a motion of translation in any path, and in the course of the interval of time Δt let its velocity be increased at a uniform rate of acceleration from v_1 to v_2. The rate of acceleration will be

$$\frac{dv}{dt} = \text{constant} = \frac{v_2 - v_1}{\Delta t};$$

and (p. 698, § 104) to produce this acceleration a uniform effort will be required, expressed by

$$P = \frac{w \cdot (v_2 - v_1)}{g \Delta t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (71).$$

(The product $\frac{wv}{g}$ of the mass of a body by its velocity is called its *momentum*; so that the effort required is found by dividing the increase of momentum by the time in which it is produced.)

To find the *energy* which has to be exerted to produce the acceleration from v_1 to v_2, it is to be observed that the *distance* through which the effort P acts during the acceleration is

$$\Delta s = \frac{v_2 + v_1}{2} \Delta t;$$

consequently, the *energy of acceleration* is

$$P \Delta s = \frac{w(v_2 - v_1)(v_2 + v_1)}{2g} = \frac{w(v_2^2 - v_1^2)}{2g} \quad . \quad . \quad . \quad (72),$$

being proportional to the increase in the square of the velocity, and *independent of the time*.

In order to produce a *retardation* from the greater velocity v_2 to the less velocity v_1, it is necessary to apply to the body a *resistance*, connected with the retardation and the time by an equation identical in every respect with equation 71, except by the substitution of a resistance for an effort; and in overcoming that resistance the body *performs work* to an amount determined by equation 72, putting Rds for Pds.

126. *Energy Stored and Restored by Deviations of Velocity.*—Thus a body alternately accelerated and retarded, so as to be brought back to its original speed, performs work during its retardation exactly equal in amount to the energy exerted upon it during its acceleration; so that that energy may be considered as *stored* during the acceleration, and *restored* during the retardation, in a manner analogous to the operation of a reciprocating force (sect. 117).

Let there be given the mean velocity $V = \frac{1}{2}(v_2 + v_1)$ of a body whose weight is w, and let it be required to determine the fluctuation of velocity $v_2 - v_1$, and the extreme velocities v_1, v_2, which that body must have, in order alternately to store and restore an amount of energy E. By equation 72 we have

$$E = \frac{w(v_2^2 - v_1^2)}{2g}$$

which, being divided by $V = \frac{1}{2}(v_2 + v_1)$, gives

$$\frac{E}{V} = \frac{w(v_2 - v_1)}{g};$$

and consequently

$$v_2 - v_1 = \frac{gE}{Vw} \quad . \quad . \quad . \quad . \quad . \quad . \quad (73).$$

The ratio of this fluctuation to the mean velocity, sometimes called the *unsteadiness* of the motion of the body, is

$$\frac{v_2 - v_1}{V} = \frac{gE}{V^2 w} \quad . \quad . \quad . \quad . \quad . \quad . \quad (74).$$

127. *Actual Energy of a Shifting Body.*—The energy which must be exerted on a body of the weight w, to accelerate it from a state of rest up to a given velocity of translation v, and the equal amount of work which that body is capable of performing by overcoming resistance while being retarded from the same velocity of translation v to a state of rest, is

$$\frac{wv^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (75).$$

This is called the *actual energy* of the motion of the body, and is half the quantity which in some treatises is called *vis viva*.

The energy stored or restored, as the case may be, by the deviations of velocity of a body or a system of bodies, is the amount by which the actual energy is increased or diminished.

128. *Principle of the Conservation of Energy in Machines.*—The following principle, expressing the general law of the action of machines with a velocity uniform or varying, includes the law of the equality of energy and work stated in sect. 99 for machines of uniform speed.

In any given interval during the working of a machine, the energy exerted added to the energy restored is equal to the energy stored added to the work performed.

129. *Actual Energy of Circular Translation—Moment of Inertia.*—Let a body of the weight w undergo translation in a circular path of the radius ρ, with the angular velocity of deflexion α, so that the common linear velocity of all its particles is $v = \alpha\rho$. Then the actual energy of that body is

$$\frac{wv^2}{2g} = \frac{w\alpha^2\rho^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad (76).$$

By comparing this with the expression for the centrifugal force $(w\alpha^2/\rho g)$, it appears that the actual energy of a revolving body is equal to the potential energy $F\rho/2$ due to the action of the deflecting force along one-half of the radius of curvature of the path of the body.

The product $w\rho^2/g$, by which the half-square of the angular velocity is multiplied, is called the *moment of inertia* of the revolving body.

130. *Actual Energy and Moment of Inertia of Rotation—Radius of Gyration.*—See p. 732, §§ 234–237.

131. *Examples of Radii of Gyration.*—See p. 733, § 238.

132. *Fly-wheels.*—A fly-wheel is a rotating piece in a machine, generally shaped like a wheel (that is to say, consisting of a rim with spokes), and suited to store and restore energy by the periodical variations in its angular velocity.

The principles according to which variations of angular velocity store and restore energy are the same with those of sect. 126, only substituting *moment of inertia* for *mass*, and *angular* for *linear* velocity.

Let W be the weight of a fly-wheel, R its radius of gyration, α_2 its maximum, α_1 its minimum, and $A = \frac{1}{2}(\alpha_2 + \alpha_1)$ its mean angular velocity. Let

$$\frac{1}{S} = \frac{\alpha_2 - \alpha_1}{A}$$

denote the *unsteadiness* of the motion of the fly-wheel; the denominator S of this fraction is called the *steadiness*. Let e denote the quantity by which the energy exerted in each cycle of the working of the machine alternately exceeds and falls short of the work performed, and which has consequently to be alternately stored by acceleration and restored by retardation of the fly-wheel. The value of this *periodical excess* is—

$$e = \frac{R^2 W(a_2^2 - a_1^2)}{2g} \quad \ldots \ldots \quad (77),$$

from which, dividing both sides by A^2, we obtain the following equations:—

$$\left.\begin{aligned} \frac{e}{A^2} &= \frac{R^2 W}{gS} \\ \frac{R^2 W A^2}{2g} &= \frac{Se}{2} \end{aligned}\right\} \quad \ldots \ldots \quad (78).$$

The latter of these equations may be thus expressed in words:—*The actual energy due to the rotation of the fly, with its mean angular velocity, is equal to one-half of the periodical excess of energy multiplied by the steadiness.*

In ordinary machinery S = about 32; in machinery for fine purposes S = from 50 to 60.

The periodical excess e may arise either from variations in the effort exerted by the prime mover, or from variations in the resistance of the work, or from both these causes combined. When but one fly-wheel is used, it should be placed in as direct connexion as possible with that part of the mechanism where the greatest amount of the periodical excess originates; but when it originates at two or more points, it is best to have a fly-wheel in connexion with each of those points. For example, in a machine-work, the steam-engine, which is the prime mover of the various tools, has a fly-wheel on the crank-shaft to store and restore the periodical excess of energy arising from the variations in the effort exerted by the connecting-rod upon the crank; and each of the slotting machines, punching machines, rivetting machines, and other tools has a fly-wheel of its own to store and restore energy, so as to enable the very different resistances opposed to those tools at different times to be overcome without too great unsteadiness of motion.

According to the computation of General Morin, the periodical excess e in steam-engines with single cranks is from $\frac{1}{10}$th to nearly $\frac{1}{4}$th of the energy exerted during one revolution of the crank. For a pair of steam-engines driving one shaft, with a pair of cranks at right angles to each other, the value of e is one-fourth of its value for a single cranked engine of the same kind, and of the same power with the two combined.

The ordinary radius of gyration of a steam-engine fly-wheel is from three to five times the length of the crank-arm. (For further particulars on this subject, see STEAM-ENGINE.)

For tools performing useful work at intervals, and having only their own friction to overcome during the intermediate intervals, e should be assumed equal to the whole work performed at each separate operation.

133. *Brakes.*—A brake is an apparatus for stopping and diminishing the velocity of a machine by friction, such as the friction-strap already referred to in sect. 112. To find the distance s through which a brake, exerting the friction F, must rub in order to stop a machine having the total actual energy E at the moment when the brake begins to act, reduce, by the principles of sect. 105, the various efforts and other resistances of the machine which act at the same time with the friction of the brake to the rubbing surface of the brake, and let R be their resultant,—*positive* if resistance, *negative* if effort preponderates. Then

$$s = \frac{E}{F + R} \quad \ldots \ldots \quad (79).$$

134. *Energy distributed between two Bodies—Projection and Propulsion.*—Hitherto the effort by which a machine is moved has been treated as a force exerted between a movable body and a fixed body, so that the whole energy exerted by it is employed upon the movable body, and none upon the fixed body. This conception is sensibly realized in practice when one of the two bodies between which the effort acts is either so heavy as compared with the other, or has so great a resistance opposed to its motion, that it may, without sensible error, be treated as fixed. But there are cases in which the motions of both bodies are appreciable, and must be taken into account,—such as the projection of projectiles, where the velocity of the *recoil* or backward motion of the gun bears an appreciable proportion to the forward motion of the projectile; and such as the propulsion of vessels, where the velocity of the water thrown backward by the paddle, screw, or other propeller bears a very considerable proportion to the velocity of the water moved forwards and sideways by the ship. In cases of this kind the energy exerted by the effort is *distributed* between the two bodies between which the effort is exerted in shares proportional to the velocities of the two bodies during the action of the effort; and those velocities are to each other directly as the portions of the effort unbalanced by resistance on the respective bodies, and inversely as the weights of the bodies.

To express this symbolically, let W_1, W_2 be the weights of the bodies; P the effort exerted between them; S the distance through which it acts; R_1, R_2 the resistances opposed to the effort overcome by W_1, W_2 respectively; E_1, E_2 the shares of the whole energy E exerted upon W_1, W_2 respectively. Then

$$\left.\begin{aligned} &E : E_1 : E_2 \\ :: &\frac{W_2(P - R_1) + W_1(P - R_2)}{W_1 W_2} : \frac{P - R_1}{W_1} : \frac{P - R_2}{W_2} \end{aligned}\right\} \quad \ldots \quad (80).$$

If $R_1 = R_2$, which is the case when the resistance, as well as the effort, arises from the mutual actions of the two bodies, the above becomes,

$$\left.\begin{aligned} &E : E_1 : E_2 \\ :: &W_1 + W_2 : W_2 : W_1 \end{aligned}\right\} \quad \ldots \ldots \quad (81);$$

that is to say, the energy is exerted on the bodies in shares inversely proportional to their weights; and they receive accelerations inversely proportional to their weights, according to the principle of dynamics, already quoted in a note to sect. 121, that the mutual actions of a system of bodies do not affect the motion of their common centre of gravity.

For example, if the weight of a gun be 160 times that of its ball, $\frac{160}{161}$ of the energy exerted by the powder in exploding will be employed in propelling the ball, and $\frac{1}{161}$ in producing the recoil of the gun, provided the gun up to the instant of the ball's quitting the muzzle meets with no resistance to its recoil except the friction of the ball.

135. *Centre of Percussion.*—It is obviously desirable that the deviations or changes of motion of oscillating pieces in machinery should, as far as possible, be effected by forces applied at their centres of percussion.

If the deviation be a *translation*,—that is, an equal change of motion of all the particles of the body,—the centre of percussion is obviously the centre of gravity itself; and, according to the second law of motion, if dv be the deviation of velocity to be produced in the interval dt, and W the weight of the body, then

$$P = \frac{W}{g} \cdot \frac{dv}{dt} \quad \ldots \ldots \quad (82)$$

is the unbalanced effort required.

If the deviation be a rotation about an axis traversing the centre of gravity, there is no centre of percussion; for such a deviation can only be produced by a *couple* of forces, and not by any single force. Let da be the deviation of angular velocity to be produced in the interval dt, and I the moment of the inertia of the body; then $\frac{1}{2}Id(a^2) = Iada$ is the variation of the body's actual energy. Let M be the moment of the unbalanced couple required to produce the deviation; then, by equation 57, sect. 104, the energy exerted by this couple in the interval dt is $Madt$, which, being equated to the variation of energy, gives

$$M = I\frac{da}{dt} = \frac{R^2 W}{g} \cdot \frac{da}{dt} \quad \ldots \ldots \quad (83).$$

Now (fig. 35), let the required deviation be a rotation of the body BB about an axis O, not traversing the centre of gravity G, da being, as before, the deviation of angular velocity to be produced in the interval dt. A rotation with the angular velocity a about an axis O may be considered as compounded of a rotation with the same angular velocity about an axis drawn through G parallel to O and a translation with the velocity a. OG, OG being the perpendicular distance between the two axes. Hence the required deviation may be regarded as compounded of a deviation of translation $dv = OG \cdot da$, to produce which there would be required, according to equation 82, a force applied at G perpendicular to the plane OG—

$$P = \frac{W}{g} \cdot OG \cdot \frac{da}{dt} \quad \ldots \ldots \quad (84),$$

and a deviation da of rotation about an axis drawn through G parallel to O, to produce which there would be required a couple of the moment M given by equation 83. According to the principles of statics, the resultant of the force P, applied at G perpendicular to the plane OG, and the couple M is a force equal and parallel to P, but applied at a distance GC from G, in the prolongation of the perpendicular OG, whose value is

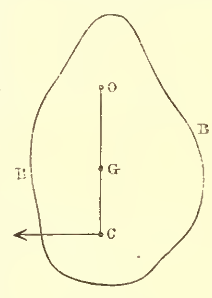


Fig. 35.

$$GC = \frac{M}{P} = \frac{R^2}{OG} \quad \ldots \ldots \quad (85).$$

Thus is determined the position of the centre of percussion C, corresponding to the axis of rotation O. It is obvious from this equation that, for an axis of rotation parallel to O traversing C, the centre of percussion is at the point where the perpendicular OG meets O.

136. *Impact.*—Impact or collision is a pressure of short duration exerted between two bodies. For the detailed investigation of its laws the reader is referred to MECHANICS, p. 719, § 180 *sq.*

The effects of impact are sometimes an alteration of the distribution of actual energy between the two bodies, and always a loss of a portion of that energy, depending on the imperfection of the elasticity of the bodies, in permanently altering their figures, and producing heat. The determination of the distribution of the actual energy after collision and of the loss of energy is effected by means of the following principles:—

I. The motion of the common centre of gravity of the two bodies is unchanged by the collision.

II. The loss of energy consists of a certain proportion of that part of the actual energy of the bodies which is due to their motion relatively to their common centre of gravity.

Unless there is some special reason for using impact in machines, it ought to be avoided, on account not only of the waste of energy which it causes, but from the damage which it occasions to the frame and mechanism.

CHAPTER III. PURPOSES AND EFFECTS OF MACHINES.

137. *Observing Machines and Working Machines.*—The present chapter must necessarily be limited to some very general observations on the principal classes into which machines may be divided, with reference to their purposes and effects, leaving details of particular examples for treatment under the respective special headings.

Machines may be divided, in the first instance, into two great divisions, viz.:—

I. *Observing Machines*, in which either the modification of motion alone, or the balancing of forces alone, is the object in view,—the performance of work being either null or incidental, and being limited to that which arises from the resistance of the machine.

II. *Working machines*, in which the performance of work is the main object.

138. *Classification of Observing Machines.*—Observing machines might very properly have been classed as *instruments*, being designed to aid the human senses and memory in obtaining and recording information. They may be divided, in the first instance, into four classes, according as the subject of observation by their aid is number, measure, or weight, into—

A. Counting machines.
B. Measuring machines.
C. Copying and drawing machines.
D. Weighing machines.

And to these may be added a fifth class, in which the functions of the first four are more or less combined, viz.:—

E. Recording machines.

139. (A.) *Counting Machines.*—The most important as well as the most common of counting machines are *time-keepers*, which count and indicate the numbers of oscillations of bodies which oscillate isochronously (viz., pendulums for clocks, balance-wheels for watches and marine chronometers) so as to measure time. In constructing such machines, the objects to be aimed at are the exact isochronism of the pendulum or balance, and the equable action of the motive power, so that it shall overcome the friction of the mechanism without affecting the rate.

Other counting machines count the oscillations of the beam of a steam-engine, or the revolutions of the cylinder of a gas-meter or of the wheel of a water-meter.

Others perform additions, subtractions, and multiplications, and of these the most elaborate kind (as, *e.g.*, that of Babbage) compute tables of functions by the addition of differences.

140. (B.) *Measuring Machines.*—Measuring machines are pieces of mechanism, by means of which the motion of some body of the nature of an index through some geometrical magnitude, such as a distance or an angle, is connected with some other motion, either equal or greater or smaller in some given ratio, and capable of being more readily compared with some standard of measure.

To this class belong all those astronomical and surveying instruments in which the motion of a line of sight (generally the line of collimation of a telescope) through a given angle is connected with the motion of an index or vernier round a corresponding arc of a graduated circle; also those micrometers in which the advance of the end of a screw of fine pitch is measured by observing the simultaneous arc of rotation of a graduated circle attached to it.

Such micrometers have attained increased importance by the discovery of Whitworth,—that the mechanical magnifying of small distances by a train of screws affords a more accurate means of measurement than optical magnifying by the microscope,—and by the perfection to which that engineer has brought that art of accurate workmanship which is necessary in order to render mechanical magnifying possible.

Amongst measuring machines are included the *platometers* or *planimeters* of Sang, Morin, and Clerk Maxwell, which measure areas by means of mechanism. The amount of resistance in a measuring machine should be perfectly uniform, and sufficiently great to prevent accidental forces from disturbing the machine, without being so great as to render it inconveniently stiff. To combine these objects requires great accuracy of workmanship, together with strength and rigidity in the structure of the frame and mechanism.

141. (C.) *Copying and Drawing Machines.*—In copying machines for enlarging or reducing drawings there is usually a combination of levers and linkwork connecting a tracing-point, which is moved over the lines of the original figure, with a drawing-point, which draws the copy in such a manner that the velocity ratio of their motions is a given constant quantity, and that the directions of their motions make a constant angle.

Mechanism depending for its principle on the theory of the composition of rotations is used to draw ellipses, epicycloids, epitrochoids, and other curves.

142. (D.) *Weighing Machines.*—In weighing machines the motion of the mechanism is used only for the purpose that its cessation, or its becoming an oscillation about a certain position, may indicate the equilibrium of the forces applied to the machine. Those forces may either be weights, which are to be compared with each other, or forces of other kinds, to be compared directly or indirectly with weights.

The machine for comparing weights which is capable of the most minute accuracy is also the simplest, being the *balance*, in which the equality of two weights is ascertained by their balancing each other at the ends of a lever of equal arms. In the *steelyard*, consisting either of one lever or of a train of levers, the unknown weight has an unchangeable point of application, and is compared with a known weight by shifting the latter along the lever to which it is applied until the machine is balanced; the ratio of the weights is then the reciprocal of the velocity ratio of their points of application. The steelyard is more convenient for weighing very heavy loads than the balance, but is not capable of such minute accuracy.

It is essential to accuracy in balances and steelyards that the friction should be less than the smallest admissible amount of error. To diminish the friction as much as possible, the axes of motion are all *knife-edges*, as they are termed, of steel or hardened iron, resting on hard surfaces of hardened iron or steel for ordinary purposes, and of some hard mineral, such as agate, for scientific purposes.

The weight of a column of fluid is determined by balancing it against a column of fluid whose weight is known, as in the barometer, where the weight of a column of the atmosphere is balanced against that of a column of mercury.

Weights are compared with each other indirectly, and other forces compared with weights, by means of their effects in bending a spring,—a convenient method, but not susceptible of minute accuracy.

The elastic pressure exerted by a fluid may be compared with weight, either by balancing the pressure against the weight of a column of a liquid, or by maintaining a piston in equilibrium against that pressure, by means of a weight pressing it directly, or of a weight acting through a steelyard, or of the elasticity of a spring which has been compared with weights.

143. (E.) *Recording Machines.*—Recording machines may be divided into two classes:—*self-registering instruments*, which, by the aid of clockwork, record measurements either of space or of force, together with the instants of time at which these measurements were made; and *dynamometers*, already mentioned in Chap. II. of this article, which register measurements of force, together with the space through which it has acted, thus recording energy or work.

144. *Working Machines Classed.*—The object or purpose of working machines is to perform useful work; and their classification relatively to their objects and purposes is founded on the kind of useful work which they perform. In this point of view they may be classed as follows:—

A. Machines for lifting or lowering solid weights.
B. Machines for the horizontal transport of weights, either combined or not with lifting or lowering.
C. Machines for projecting solids.
D. Machines for lifting fluids.
E. Machines for propelling or projecting fluids.
F. Machines for dividing bodies.
G. Machines for shaping bodies by removing portions of them.
H. Machines for shaping bodies by pressure.
I. Machines for uniting bodies into fabrics.
J. Machines for printing.
K. Machines for producing sound.
L. Miscellaneous machines.

It is not pretended that the above classification (taken to a considerable extent from the writings of Young and of Babbage) exhausts all kinds of machines; it is brought forward merely as an attempt to introduce method to a certain extent into a subject which would otherwise be exceedingly confused.

145. (A.) *Machines for Lifting and Lowering Solids.*—The most common machines of this class are *capstans*, *cranes*, and *windlasses*.

They are usually worked by manual labour, but sometimes by hydraulic engines, or by steam-engines. The useful resistance, when a load is lifted, being the weight of that load, is in general greater than the effort exerted by the prime mover, so that the mechanism has to be adapted to giving the working-piece a less velocity than the piece to which the effort is applied. In lowering solid loads the weight of the load acts as the effort, and the energy exerted by it is expended in overcoming the friction of a brake in order that the speed of descent may not be excessive.

146. (B.) *Transporting Machines.*—The mechanism of transporting machines consists of two parts:—that by which the resistance is diminished, as the wheels and axles of vehicles; and that by which the resistance is overcome and the load propelled, comprising all kinds of locomotive and propelling machinery. In the present work transporting machines are treated of in the articles relating specially to the lines of conveyance to which they are applied.

147. (C.) *Machines for Projecting Solids.*—This class comprehends all kinds of artillery.

148. (D.) *Machines for Lifting Fluids.*—See HYDROMECHANICS.

149. (E.) *Machines for Propelling or Projecting Fluids.*—See the same article.

150. (F.) *Machines for Dividing Bodies.*—This class comprehends all machines for separating solid masses into parts, whether by digging, cutting, sawing, grinding, tearing, crushing, pounding, pressing out fluids, or otherwise; and whether applied to earth, stones, metals, timber, fruit, grain, fibres, or other materials.

151. (G.) *Machines for Shaping Bodies by Removing Portions of them.*—This class of machines to a certain extent resembles the preceding. It includes machines for cutting, grinding, and polishing blocks of stone into required figures, and for shaping pieces of wood, metal, or other material, whether by *turning*, to produce spherical, cylindrical, and other curved surfaces,—by *boring, punching, slotting*, or *gouging*, to produce cylindrical, rectangular, or other orifices and grooves,—by *screw-cutting*, by *planing*, by *grinding* and *polishing*, to produce curved or plane surfaces. The most difficult and important of all these operations is to produce a surface truly plane; and the perfecting of this operation by Whitworth is the most important step recently made in *Constructive Mechanics*, or the art of making machines and instruments. Next in point of difficulty may be placed the art of forming the concave reflecting surfaces of great specula for telescopes, such as those of the Herschels, of Lassell, and of Lord Rosse.

152. (H.) *Machines for Shaping Bodies by Pressure* comprehend, amongst others, *rolling-mills* for iron, *steam-hammers*, *wire-drawing* machines, *pinmaking* and *nailmaking* machines, *coining* and other *stamping* machinery, *brickmaking* machines, *presses* for packing and compressing, &c.

153. (I.) *Machines for Uniting Bodies into Fabrics* comprise *spinning* machinery, whether applied to ropes, yarn, or thread, *weaving* machinery of all kinds, *papermaking* machinery, *felting* machinery, and *sewing* machinery.

154. (J.) *Machines for Printing* are used to apply either colouring matters or matters for discharging colour to paper, cloth, and other materials.

155. (K.) *Machines for producing Sound.*—See ACOUSTICS and MUSIC.

156. (L.) *Miscellaneous Machines.*—There are numerous machines which perform processes, especially in the preparation of textile fabrics for the market, which it would be almost impossible to class. Examples of such machines will be found by referring to the articles relating to the various branches of manufacture.

CHAPTER IV. APPLIED ENERGETICS, OR THEORY OF PRIME MOVERS.

157. *Prime Movers in general—Their Efficiency.*—Prime movers, or receivers of power, are those pieces or combinations of pieces of mechanism which receive motion and force directly from some natural source of energy. The point where the mechanism belonging to the prime mover ends and that belonging to the train for modifying the force and motion begins is somewhat arbitrary; in general, however, the mechanism belonging to the prime mover may be held to include all pieces which regulate or assist in regulating the transmission of energy from the source of energy. Thus, in the ordinary rotative steam-engine, the crank-shaft belongs to the prime mover, because it carries the eccentric which moves the valves and the fly-wheel which stores and restores the periodical excess of energy of the engine, and drives the governor (when there is one) which regulates the admission of steam.

The *useful work* of the prime mover is the energy exerted by it upon that piece which it directly drives; and the ratio which this bears to the energy exerted by the source of energy is the *efficiency* of the prime mover.

It is often convenient to divide the prime mover into sections, and resolve its efficiency into factors, each factor being the efficiency of one of those sections. Thus the efficiency of a steam-engine may be resolved into the following factors:—

Efficiency of the furnace and boiler,—being the proportion of the total heat of combustion of the fuel which takes effect in heating and evaporating the water.

Efficiency of the steam in driving the piston,—being the proportion of the energy exerted by the steam on the piston (called the *indicated* energy or power, as being measured by an indicator) to the mechanical equivalent of the heat received by the water.

Efficiency of the mechanism from the piston to the crank-shaft inclusive,—being the proportion of the effective energy transmitted by the crank-shaft to the indicated energy.

The product of those three factors is the efficiency of the engine as a whole.

In all prime movers the loss of energy may be distinguished into two parts,—one being the unavoidable effect of the circumstances under which the machine necessarily works in the case under consideration; the other the effect of causes which are, or may be, capable of indefinite diminution by practical improvements. Those two parts may be distinguished as *necessary loss* and *waste*.

The efficiency which a prime mover would have under given circumstances if the *waste* of energy were altogether prevented, and the loss reduced to necessary loss alone, is called the *maximum* or the *theoretical* efficiency under the given circumstances.

For some prime movers there is a combination of circumstances which makes the theoretical efficiency greater than any other combination does. The theoretical efficiency under those circumstances is the *absolute maximum efficiency*.

The *duty* of a prime mover is its useful work in some given unit of time, as a second, a minute, an hour, a day. In some cases, such as that of the work of animals, the duty can be ascertained, while the efficiency can only be inferred indirectly or conjecturally from the want of precise data as to the whole energy expended.

158. *Sources of Energy Classed.*—The sources of energy used in practice may be classed as follows:—

A. Strength of men and animals.
B. Weight of liquids.
C. Motion of fluids.
D. Heat.
E. Electricity and magnetism.

159. (A.) *Strength of Men and Animals.*—The *mechanical daily duty* of a man or of a beast is the product of three quantities—the effort, the velocity, and the number of units of time per day during which work is continued. It is well known that for each individual man or animal there is a certain set of values of those three quantities which make their product, the daily duty, a maximum, and that any departure from those values diminishes the daily duty. Attempts have been made to represent by a formula the law of this diminution; but they have met with imperfect success. That which agrees on the whole best with the facts is the formula of Maschek, which is as follows:—let P_1 be the effort, V_1 the velocity, and T_1 the time of working per day, which give the maximum daily duty, and let P, V, T, be any other set of values of those quantities; then

$$\frac{P}{P_1} + \frac{V}{V_1} + \frac{T}{T_1} = 3 \quad \ldots \ldots \quad (86).$$

One consequence of this formula is, that the best time of working per day for men, and for all animals, is *one-third part of a day*, or eight hours,—a conclusion in accordance with experience.

The best effort P_1, and the best velocity V_1, are much less certain,—the difficulty of determining their true mean values for particular species being rendered very great by the differences, not only between individuals, but between races or varieties of the same species. The following table of values is proposed by Maschek as approximately true:—

Animals.	Weighing	P_1.	V_1.	$\frac{T_1}{3600}$.	P_1V_1.	$P_1V_1T_1$.
		lb.	Feet per second.	Hours per day.	Foot-lb per sec.	Foot-lb.
Man	150 lb	30	2·5	8	75	2,160,000
Horse (draught)	600 lb	120	4·0	8	480	13,824,000
Ox	600 lb	120	2·5	8	300	8,640,000
Ass	360 lb	72?	2·5	8	180	5,184,000?
Mule	500 lb	100?	3·5	8	350	10,080,000?

Of the numbers in this table those for the draught horse are probably the most accurate. For the thoroughbred horse it is certain that the value of V_1 is much greater, and that of P_1 much less, than for the draught horse,—the effect being probably that the *maximum* daily duty $P_1V_1T_1$ is nearly the same; but experimental data are wanting to determine these quantities with precision.

The following table, chiefly extracted from the works of Poncelet and Morin, with the addition of some results of experiments by Lieutenant David Rankine and by the author of this article, shows the daily duty of men and horses under certain specified circumstances:—

	P.	V.	$\frac{T}{3600}$.	PV.	PVT.
	lb.	Feet p. sec.	Hours p. day.	Foot-lb per sec.	Foot-lb per day.
MAN—					
1. Raising his own weight up stair or ladder	143	0·5	8	72·5	2,088,000
2. Do. do. do.	...	...	10	...	2,616,000
3. (Tread-wheel—see 1)					
4. Hauling up weight with rope	40	0·75	6	30	648,000
5. Lifting weights by hand	44	0·55	6	24·2	522,720
6. Carrying weights up stairs	143	0·13	6	18·5	399,600
7. Shovelling up earth to a height of 5 ft. 3 in.	6	1·3	10	7·8	280,800
8. Wheeling earth in barrow up slope of 1 in 12; ½ horiz. veloc. 0·9 ft. per sec. (returning empty)	132	0·075	10	9·9	356,400
9. Pushing or pulling horizontally (capstan or oar)	26·5	2·0	8	53	1,526,400
10. Turning a crank or winch	12·5 18·0 20·0	5·0 2·5 14·4	? 8 2 min.	62·5 45 288	1,296,000
11. Working pump	13·2	2·5	10	33	1,188,000
12. Hammering	15	?	8?	?	480,000
HORSE—					
13. (Thoroughbred) cantering and trotting, drawing a light railway carriage	min. 22·5 mean 30·5 max. 50	14·6	4	417·5	6,444,000
14. Horse (draught) drawing cart or boat, walking	120	3·6	8	432	12,441,600

160. *Horizontal Transport.*—When men and animals carry burdens, or draw or propel loads in certain vehicles, it is difficult, and sometimes impossible, to determine the duty performed in foot-pounds of work, because of the uncertainty of the amount in pounds of the resistance overcome. In this case, for the purpose of comparing performances of the same kind with each other, a unit is employed called a *foot-pound of horizontal transport*, meaning the conveying of a load of 1 pound 1 foot horizontally. The following table, compiled from the sources referred to in sect. 159, gives some examples of the daily duty of men and horses in units of horizontal transport, L denoting the load in lb, V the velocity in feet per second, and T the number of seconds per day of working:—

	L.	V.	$\frac{T}{3600}$.	LV.	LVT.
	lb.	Feet per second.	Hours per day.	lb conveyed 1 foot.	lb conveyed 1 foot.
MAN—					
15. Walking unloaded, transport of own weight	140	5	10	700	25,200,000
Do. do.	140	6	10	840	30,240,000
16. Wheeling load L in two-wheeled barrow, returning empty; V = ½ velocity	224	1·6	10	373	13,428,000
17. Do. one-wheeled barrow, do.	135	1·6	10	225	8,100,000
18. Travelling with burden	90	2.5	7	225	5,670,000
19. Conveying burden, returning unloaded	140	1·6	6	233	5,032,800
20. Carrying burden for 30 seconds only	252 126 0	... 11·7 23·1	... ...	... 1474·2 0	... ...
HORSE—					
21. Walking with cart always loaded	1500	3·6	10	5400	194,400,000
22. Trotting do. do.	750	7·2	4½	5400	87,480,000
23. Walking with cart, going loaded, returning empty; V = ½ mean velocity	1500	2·0	10	3000	108,000,000
24. Carrying burden, walking	270	3·6	10	972	34,992,000
25. Do. trotting	180	7·2	7	1296	32,659,200

161. (B.) *Weight of Liquids.*—(C.) *Motion of Fluids.*—In water-wheels and other hydraulic engines the weight and motion of a liquid usually act together as sources of energy.

To determine the necessary loss of energy and the theoretical efficiency, we have the following formulæ:—

The *power* or *energy* exerted per second is

$$Q\left(H + \frac{V_1^2}{2g}\right);$$

the *necessary loss* —

$$Q \cdot \frac{V_2^2}{2g};$$

the *theoretical effect* or *useful work* per second—

$$Q\left(H + \frac{V_1^2 - V_2^2}{2g}\right);$$

the *theoretical efficiency*—

$$\left(H + \frac{V_1^2 - V_2^2}{2g}\right) \div \left(H + \frac{V_1^2}{2g}\right) \qquad (87);$$

where Q denotes the weight of liquid which acts on the wheel or other engine per second; H the vertical fall from the point where the liquid first begins to act directly or indirectly on the wheel or other engine to the point where it ceases to act; V_1 the velocity of the liquid when it begins to act; and V_2 the least velocity, when it ceases to act, which will properly discharge the liquid, and prevent its accumulating so as to impede the wheel or engine.

(For details as to the actual efficiency and duty and the construction of hydraulic engines, see HYDROMECHANICS.)

In *windmills*, the air, being in motion, presses against and moves four or five radiating vanes or *sails*, whose surfaces are approximately helical, their axis of rotation being parallel, or slightly inclined in a vertical plane, to the direction of the wind. The best form and proportions for windmill sails, as determined experimentally by Smeaton, are as follows (see fig. 36):—

Angle of each sail with the plane of rotation—at DE = 18°;
Do. do. do. at BC = 7°;
OD = ⅙ of *whip* OA; bar DE = ⅕OA; bar BC = ⅓OA; AC = DE.

162. (D.) *Heat.*—In sect. 157 the three factors into which the efficiency of an engine moved by heat can be resolved have already been stated. The efficiency of the furnace and boiler in steam-engines varies from 0·4 to 0·85. It may be considered that the loss of heat to the extent of 0·15 by the chimney is necessary in order to produce a sufficient draught; any loss beyond this is *waste.* The theoretical efficiency of the *steam,* or *other elastic fluid,* which serves as the mechanism for converting heat into mechanical energy, is regulated by a law which will now be explained.

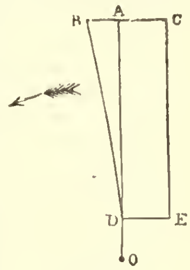


Fig. 36.

Heat acts on bodies in two ways—to elevate temperature and make the bodies hotter, and to produce mechanical changes. Heat employed in producing mechanical changes disappears or becomes *latent,* as it is termed, and can be reproduced by reversing those mechanical changes. When a cycle of mechanical changes, ending by the restoration of the body to its original condition, produces mechanical energy, heat disappears to an amount equal to that which would be generated by employing the mechanical energy in overcoming friction,—that is to say, a British unit of heat (or one degree Fahr. in one lb of liquid water) for every 772 foot-pounds of energy (being the constant already mentioned in sect. 115 as *Joule's equivalent*). This is called the *conversion of heat into mechanical energy.*

The *efficiency of the fluid* in a heat-engine is the proportion which the heat converted into mechanical energy bears to the whole heat received by the water or other fluid; and the *theoretical* or *maximum* value of that efficiency depends solely upon the respective temperatures at which the fluid receives heat and rejects the unconverted heat, according to the following law:—let t_1 represent the temperature at which the fluid receives heat, and t_2 the temperature at which it rejects the unconverted heat, as measured from the *absolute zero,*—that is, from a point 493°·2 Fahr. or 274° C. below the temperature of melting ice (temperatures so measured are called *absolute temperatures*); then the *maximum theoretical efficiency of the water or other fluid in a steam-engine or other heat-engine is*

$$\frac{t_1 - t_2}{t_1} \qquad (88).$$

The necessary loss of heat by the fluid is t_2/t_1 of the whole heat received by it; and any loss beyond this is *waste.*

The theoretical efficiency of the steam in ordinary steam-engines seldom exceeds ⅕th; the greatest actual efficiency is about ⅛th; the efficiency in good ordinary engines is about 0·1 or 0·08, and in bad and wasteful engines 0·04, or even less. (For details see STEAM-ENGINE.)

163. (E.) *Electricity and Magnetism.*—Electricity developed by chemical action in a galvanic battery has been to a small extent used to produce mechanical energy by alternately magnetizing and unmagnetizing soft-iron bars.

The data for determining the actual efficiency of such engines are deficient. Their theoretical efficiency depends on the following law demonstrated by Joule:—

Let γ_1 denote the strength of the electric current which would be developed in the conducting wire of the battery if there were no iron bar to be magnetized; γ_2 the strength to which the current is reduced by the reaction of the iron bar, tending to induce a contrary current. Then the theoretical efficiency of the engine is

$$\frac{\gamma_1 - \gamma_2}{\gamma_1} \qquad (89).$$

The proportion of the energy expended which is *necessarily lost* is γ_2/γ_1, and is employed in producing heat in the conducting circuit.

This law is exactly analogous to that of the theoretical efficiency of heat-engines given in equation 88.

There is reason to believe that electromagnetic engines are capable of a higher efficiency than heat-engines; but the greater cost of the materials consumed renders them much less economical commercially.

(W. J. M. R.)

MECHITHARISTS, a congregation of Armenian monks, in communion with the church of Rome, which has enjoyed papal recognition since 1712. Its founder Mechithar, or Mechitar da Pietro, a native of Sebaste (Sivas) in Armenia, was born on February 7, 1676; his original name was Manuk, which he exchanged for that by which he was subsequently known ("Comforter") when he entered the cloister of the Holy Cross in his native town. In the pursuit of knowledge he visited various seats of learning in Armenia, and in the years 1691, 1696, and 1699 respectively he attained the office of deacon, priest, and vartabed or doctor in theology. Having removed to Constantinople, he founded there in 1701 a religious institute for the intellectual, moral, and spiritual elevation of his countrymen, and for the cultivation of their language and literature. In 1703 sectarian jealousy obliged him to retire to the Morea, where he ultimately found a settlement at Modon, and built a cloister and church (1706-8). The outbreak of hostilities between the Turks and Venetians in 1715 compelled him to take refuge in Venice, where in 1717 he received from the senate the island of San Lazzaro, which ever since has been the home of his order. Mechithar, who died on April 27, 1749, was the author of a *Grammatica Armena*, printed in 1770, of an Armenian *Lexicon*, printed in 1744, of an Armenian translation of the Bible, printed in 1734, and of several commentaries on Biblical books. The order of Mechitharists, which, as already mentioned, received formal recognition (from Clement XI.) in 1712, uses the Armenian language and the Syrian rite; its rule resembles the Benedictine, prominent among the duties of its members being the proclamation of the gospel and the diffusion of good literature. They have accumulated at San Lazzaro a large library, specially rich in Armenian MSS.; and their linguistic attainments are considerable. Among their services to the cause of learning may be mentioned, in addition to the preparation of critical texts of the Armenian classics and of the Armenian version of the Bible, the publication in old translations of various works of Ephraem Syrus, Philo, and Eusebius, of which the originals have been lost. There are establishments belonging to the order elsewhere in Italy (Padua), as well as in Russia and Turkey, in Paris, in Austria-Hungary, and in Germany. Of these the most important is that of Vienna, which has existed since 1810, and has become a sort of learned "academy," receiving honorary members even from beyond the pale of the Roman Catholic Church.

MECHLIN, or MALINES, a city of Belgium, in the province of Antwerp, on the river Dyle, about 14 miles north of Brussels. The general aspect of the town, belted by a fine avenue of trees, with well-built houses, extensive gardens, and broad airy streets and squares of proverbial cleanliness, is pleasing to the eye; there is, however, a lack of life and motion, a repose bordering on stagnation; and the area occupied by the town is much too extensive for the population. Mechlin was for many centuries, and is to this day, the religious metropolis of Flanders, and its monuments and curiosities are in general of a sacred description. Among the most remarkable is the cathedral church of St Rombold or Rombaut, mainly built in the latter half of the 14th century; the square massive tower, rising 300 feet high and bearing four dials, each 48 feet in diameter, is visible from all the country round. The interior proportions of the edifice are grand, and it contains some fine works of art—statues of the apostles, standing against the pillars of the nave, Vandyck's picture of the Crucifixion, the Adoration of the Shepherds, by Erasmus Quellin, and others. The church of St John possesses a celebrated triptych of Rubens, and another by the same master is to be seen at Notre Dame. The "Halle" or market still retains some vestiges of the splendid palace raised on the site by Charles V. in 1530, and on the chief market-place is a monument erected to Margaret of Austria, daughter of the emperor Maximilian. Mechlin is an archiepiscopal see, occupied by a cardinal, primate of Belgium, deriving his spiritual power from Rome, and quite independent of (at times even openly opposed to) the civil Government. His palace is the headquarters of the Catholic party, and the seat of considerable moral and political influence extending over every parish in the land; the university of Louvain, the Catholic schools, more than four thousand in number, and the great seminary of Mechlin, the nursery of the Belgian priesthood, are entirely under the direction of the archbishop. The industrial activity of the town, formerly very great, has constantly decreased in the present century, and is now almost extinct. The important corporation of weavers was scattered by the political troubles of the 15th and 16th centuries; and the lace trade has gradually been transferred to Brussels and other towns. There still exist a few special manufactures, those of carved oak furniture, straw chairs, and wool and linen tissues being among the foremost; some tanyards and breweries are also to be found, and the means of communication furnished by the Dyle supply a tolerably brisk market in corn, oils, flax, hemp, and hops. As a railway station Mechlin possesses peculiar importance, being a junction of the chief Belgian Government lines and the great central workshop for constructing and repairing the rolling-stock. The population of Mechlin in 1880 was 42,381.

Mechlin appears to have been about the 8th century a mere group of cabins surrounding a noted monastery where St Rombaut, now the patron saint of the town, suffered martyrdom on the 24th of June 775. After having belonged to the first Frankish monarchs, it was given by Pippin the Little to his relative Adon, and passed, at the commencement of the 10th century, under the dominion of the bishops of Liége, in whose name it was governed by the powerful house of Berthold until the year 1333. When this family became extinct, Mechlin and the surrounding district were divided in two portions and sold by the bishops to the duke of Brabant and the count of Flanders, the former of whom, ten years later, once more united the whole territory under his own sway. By the marriage of Margaret of Brabant with Philip the Bold, Mechlin was brought under the sceptre of the house of Burgundy, whose fate it shared from that time. Stormed by the French in 1572, by the prince of Orange in 1578, by the English in 1580, the town suffered much during the wars of the 17th and 18th centuries. Napoleon I. had its fortifications razed in 1804, and made it the capital of the French "Département des deux Nèthes" until 1814, when it was comprised in the kingdom of the Netherlands, and it finally became part of Belgium in 1830.

MECKLENBURG, a territory in North Germany, on the Baltic Sea, extending from 53° 4′ to 54° 24′ N. lat., and from 10° 35′ to 13° 57′ E. long., corresponds with tolerable closeness to the old lower Saxon province of the same name, and is now unequally divided into the two grand-duchies of Mecklenburg-Schwerin and Mecklenburg-Strelitz. These are so closely related in history, political organization, natural features, and general development that it is convenient to treat them in a single article.

MECKLENBURG-SCHWERIN, the seventh state of the German empire in size and the eighth in population, is bounded on the N. by the Baltic Sea, on the W. by the principality of Ratzeburg and Lauenburg, on the S. by Brandenburg and Hanover, and on the E. by Pomerania and Mecklenburg-Strelitz. It embraces the duchies of Schwerin and Güstrow, the district of Rostock, the principality of Schwerin, and the barony of Wismar, besides several small "enclaves" in the adjacent territories. Its total area is about 5117 square miles.

MECKLENBURG-STRELITZ, the eleventh state of the German empire in area and the nineteenth in population, consists of two detached parts, the duchy of Strelitz on the east of Mecklenburg-Schwerin and the principality of

Ratzeburg on the west. The first of these is bounded by Mecklenburg-Schwerin, Pomerania, and Brandenburg, the second by Mecklenburg-Schwerin, Lauenburg, and the territory of the free town of Lübeck. Their joint area is 1126 square miles.

Mecklenburg lies wholly within the great North-European plain, and its flat surface is interrupted only by one range of low hills, intersecting the country from south-east to north-west, and forming the watershed between the Baltic Sea and the Elbe. Its highest point, the Helpter Berg, is 580 feet above the sea-level. The coast-line runs for 65 miles along the Baltic (without including indentations), for the most part in flat sandy stretches covered with dunes. The chief inlets are the bays of Wismar, Grosse Wiek, Salzhaff, and Kroy, and the roads of Warnemünde. The rivers are numerous though small; most of them are affluents of the Elbe, which itself traverses a small portion of Mecklenburg. Several of the streams are navigable, and the facilities for inland water traffic are increased by a tolerably extensive system of canals. Lakes are very numerous; about four hundred of fair size, covering an area of 500 square miles, are reckoned in the two duchies. The largest is Lake Müritz, 52 square miles in extent. The climate on the whole resembles that of Great Britain, but the winters are generally more severe; the mean annual temperature is 48° F., and the annual rainfall is about 28 inches. Although there are long stretches of marshy moorland along the coast, the soil is on the whole productive. According to the official returns of 1878, about 57 per cent. of the total area of Mecklenburg-Schwerin consisted of cultivated land, 17 per cent. of forest, and 13 per cent. of heath and pasture. In Mecklenburg-Strelitz the corresponding figures were 48, 20, and 9 per cent. Agriculture is by far the most important industry in both duchies. The following table shows the areas and products of the chief crops in 1880:—

Crops.	Mecklenburg-Schwerin.		Mecklenburg-Strelitz.	
	Acres.	Tons.	Acres.	Tons.
Rye	411,627	243,818	68,530	29,619
Oats	285,257	188,166	49,422	26,743
Wheat	108,550	43,420	26,240	93,378
Barley	44,687	33,487	10,722	7,244
Potatoes	92,942	345,233	16,440	70,537
Hay	259,497	333,737	46,805	93,464
Totals	1,202,560	1,187,861	218,159	320,985

Besides these, smaller areas are devoted to maize, buckwheat, pease, rape, hemp, flax, hops, and tobacco. The extensive pastures support large herds of sheep and cattle, including a noteworthy breed of merino sheep. The horses of Mecklenburg are of a fine sturdy quality, and are highly esteemed in Germany. In 1878 the two duchies contained 100,651 horses, 315,712 cattle, and 1,321,916 sheep. Red deer, wild swine, and various other kinds of game are found in the forests. The manufactures of Mecklenburg are of little importance. Its industrial establishments include a few iron foundries, wool-spinning mills, carriage and machine factories, dye-works, tanneries, brick-fields, soap-works, breweries, distilleries, numerous limekilns and tar-boiling works, tobacco and cigar factories, and about eight hundred mills of various kinds. Mining is also insignificant, though a fair variety of minerals is represented in the district. Amber is found on and near the Baltic coast. Trade, mainly confined to the larger duchy, is tolerably active. Rostock, Warnemünde, and Wismar are the principal commercial centres. The chief exports are grain and other agricultural produce, live stock, spirits, wood, and wool; the chief imports are colonial produce, iron, coal, salt, wine, beer, and tobacco. The horse and wool markets of Mecklenburg are largely attended by buyers from various parts of Germany. Fishing is carried on extensively in the numerous inland lakes. Within the last decade the mercantile fleet of Mecklenburg-Schwerin has doubled the number and quadrupled the tonnage of its ships, these consisting in 1881 of 370 sailing vessels and 11 steamers, with an aggregate burden of 112,388 tons. Mecklenburg-Strelitz has no seaboard.

Mecklenburg-Schwerin and Mecklenburg-Strelitz are both limited monarchies under grand-dukes, who are hereditary in the male line. The reigning families are closely related, and possess mutual rights of succession; should both families become extinct, their possessions pass to Prussia. The constitution, which is common to both the duchies, exhibits few traces of the liberal tendency of modern politics. The temporary modifications brought about by the agitation of 1848 were quickly rescinded, and matters returned to the old semi-feudal arrangements, which deprive the bulk of the people of all share in the government. The constitution as it now exists is based upon an agreement made between the duke of Mecklenburg-Schwerin and his estates in 1755, and adopted in the same year by Mecklenburg-Strelitz. The Landes-Union, or common assembly of the two duchies, consists of representatives of the Ritterschaft, or landed proprietors, and of the Landschaft, which embraces forty-seven towns. The peasantry is unrepresented, and the principality of Ratzeburg, in Mecklenburg-Strelitz, is governed directly by the grand-duke. The Landes-Union meets once annually, alternating between Sternberg and Malchin. When not sitting it is represented by a committee of nine members. Distinct from the Landes-Union are the convocation diet and the deputation diet, which are assemblies of the estates of one or other duchy for special business. In Mecklenburg-Schwerin the executive is placed in the hands of four ministers, holding the portfolios of foreign affairs, domestic affairs, finance, and justice (including education and religion). In Mecklenburg-Strelitz there is one minister, who is aided by a small council. In both duchies the military administration is in the hands of the crown. Mecklenburg-Schwerin has two votes in the federal council of the German empire, and sends six members to the imperial diet, while the smaller duchy has one representative in each assembly. As no official budget is published in either duchy, it is impossible to give accurate details of their financial position. In Mecklenburg-Schwerin it is usual to distinguish three branches of revenue, one under the control of the sovereign, one under the joint control of the sovereign and estates, and the third (of small amount) under the sole management of the estates. The income under the first heading is derived from the royal domains, the ordinary taxes, and special votes for special purposes, and amounts to about £600,000. With this sum are defrayed the ordinary expenses of government, including the annual contribution to the imperial treasury. The revenue under the second head is about £100,000. The public debt in 1880 amounted to £1,100,000. The revenues of Mecklenburg-Strelitz are unknown; its debt is estimated at about £300,000. The private income of the duke, derived from the royal domains, makes him one of the richest princes in Germany. The duchies of Mecklenburg contribute three regiments of infantry, a battalion of rifles, two regiments of dragoons, and four batteries of field artillery to the imperial army.

The educational institutions partake of the high character common to those of the German empire. The two duchies contain nine gymnasia, seven "Realschulen," three normal schools, and an adequate number of schools of a lower grade. There is a university at Rostock, which in 1882 had a teaching staff of 36 professors and an attendance of about 250 students. In 1880–81 only 0·56 per cent. of the recruits in Mecklenburg-Schwerin were unable to read and write their names, while all the recruits in Mecklenburg-Strelitz were able to do both. The predominant confession in Mecklenburg is the Lutheran, which is professed by both the grand-dukes. The proportion of Roman Catholics, Jews, and members of the Reformed Church is insignificant. The ultimate spiritual authority is exercised by consistories at Schwerin and Strelitz. Mecklenburg also contains a fair share of learned societies and benevolent institutions. The supreme court of appeal for both duchies, in all criminal and civil cases, is at Rostock.

The population of Mecklenburg-Schwerin in 1861 was 548,449; in 1871, 557,707; in 1875, 553,785; and in 1880, 577,055. The capital is Schwerin (30,146 inhabitants), but the most important town is Rostock (36,967 inhabitants). The population of Mecklenburg-Strelitz in 1861 was 99,060; in 1871, 96,982; in 1875, 95,673; in 1880, 100,269. The chief town is Neu-Strelitz. About 71 per cent. of the inhabitants are engaged in agricultural pursuits. The proportion of the rural to the urban population is as 3 to 1, or exactly the reverse ratio to that in the neighbouring Prussia. The peasantry of Mecklenburg still retain numerous traces of their Slavonic origin, especially in their speech, but their peculiarities have been much modified by amalgamation with the German colonists who settled within this district at various times. The townspeople and nobility are almost wholly of Saxon strain. The slow rate of increase in the population of Mecklenburg is chiefly accounted for by the constant stream of emigration. Between 1870 and 1880 the two duchies contributed in the highest proportion to the emigration from Germany. Out of 595,151 German emigrants who sailed from Bremen, Hamburg, Stettin, and Antwerp within that period, 24,870 came from Mecklenburg-Schwerin and 2481 from Mecklenburg-Strelitz, representing respectively 4·38 and 2·52 per 1000 inhabitants as the yearly average. Probably another cause of the slow growth of population is to be sought for in the difficulties thrown in the way of the marriage of the peasants by the semi-feudal character of their tenure. It is a significant fact that in 1880 the proportion of illegitimate births in the two duchies amounted to 14 per cent. as compared with 9 per cent. in the entire German empire.

History.—The Vandals, who in the time of Tacitus occupied the region now known as Mecklenburg, were succeeded in the 6th century by a Slavonic race. Though partly conquered by Charlemagne in 789, this people soon regained their independence, and long offered a successful resistance to all attempts on the part of the German emperors to overcome and Christianize them. At last, in 1160, Duke Henry of Saxony made himself master of the country. The native prince was, however, permitted to retain his sovereignty, and has transmitted to his descendants and successors of the present day the distinction of being the only ruling princes of Slavonic origin in Germany. In 1160 he was raised by the emperor Frederick I. to the dignity of a prince of the empire. From 1202 till 1227 Mecklenburg was under Danish supremacy; and in 1229, two years after its restoration to Germany, there occurred the first of a long series of divisions of the territory, which, with subsequent reunions, constitute so much of its complicated history. In 1348 Charles IV. made Mecklenburg a duchy. In 1523 the trials and commotions springing from the rivalry and jealousy of two joint rulers incited the prelates, nobility, and burghers to form a union among themselves, the effects of which are visible to the present day,—most prominently in the existence of the common Landes-Union. The Reformation was welcomed by the inhabitants of Mecklenburg in 1524; and about 1555 nearly all the monasteries were suppressed. In 1621, when a new partition took place, the town of Rostock "with its university and high court" was declared to be held in common. The diet also retained its joint character, and henceforth alternated between Sternberg and Malchin.

In the Thirty Years' War both Mecklenburg-Schwerin and Mecklenburg-Güstrow—as the parts were then called—incurred the suspicion of the emperor, who secretly sold them to Wallenstein, and expelled the dukes in his behalf. They were reinstated, however, by Gustavus Adolphus, and at the peace of Prague in 1635 they both made their peace with the emperor. At the peace of Westphalia Rostock and some other parts of Mecklenburg territory were given in pledge to Sweden, and they were not redeemed till 1803. The sufferings of the Mecklenburg peasantry during the Thirty Years' War were exceeded in no other part of sorely-tried Germany. Most were reduced to serfdom through poverty; in some cases whole villages utterly vanished. In 1695 the Mecklenburg-Güstrow line became extinct; and, after some contention between the brother and the nephew of the last duke of Mecklenburg-Schwerin for the vacant succession, the "Hamburg Division" (March 8, 1701) apportioned to each shares that are represented by the present duchies. The affixes Schwerin and Strelitz are derived from the capital towns of the two dukes.

Mecklenburg-Schwerin began its new independent existence by a series of constitutional struggles between its nobility and its rulers. The heavy debt incurred by Charles Leopold, who had joined Russia in a war against Sweden, brought matters to such a pitch that in 1728 the emperor Charles VI. deposed the duke in favour of his brother Christian Louis. Under this prince, the "Rostock Contract," which is still the basis of the constitution, was framed in 1755. During the Seven Years' War Mecklenburg-Schwerin assumed a hostile attitude towards Frederick the Great, and was in consequence occupied by Prussian troops. In 1806 it was overrun by the French, and in 1808 it joined the confederation of the Rhine. The duke, however, though he assisted Napoleon in 1812, was the first member of the confederation to renounce it, and in the following year his troops fought against France and Denmark. On joining the Germanic confederation he assumed the title of grand-duke, with the style of royal highness. In and after 1818 the duchy witnessed a considerable agitation in favour of a new and more liberal constitution, but the subsequent reaction rescinded all the concessions that had been made, and reduced matters to their former feudal condition. In 1819 and 1820 serfdom and personal bondage were abolished, and various slight ameliorations of the state of the peasantry have since been introduced.

Mecklenburg-Strelitz adopted the constitution of the sister duchy by an "Agnitions-Act" in 1755. In 1806 it was spared the infliction of a French occupation through the interest of the king of Bavaria; but in 1813 it was mulcted in the sum of two million thalers for the French army. In 1808 it entered the Rhenish confederation, but repudiated it in 1813 and joined the alliance against Napoleon. In 1815 the duke assumed the title of grand-duke.

Authorities.—Boll, *Geschichte Mecklenburgs*, 1855; Nizze, *Volkswirthschaftliche Zustände in Mecklenburg*, 1861; Boll, *Abriss der Mecklenburger Landeskunde*; Böger, *Topographisches Handbuch f.d. Grossherzogthümer Mecklenburg-Schwerin und Mecklenburg-Strelitz*, Kiel, 1881; the official *Staatskalender*, published annually; the *Beiträge zur Statistik Mecklenburgs*, published by the Statistical Office at Schwerin; *Jahrbücher des Vereins für Mecklenbürgische Geschichte*, 1836-1882. For the recent constitutional struggles see the various works of M. Wiggers, the most prominent leader of the democratic party. (J. F. M.)

MEDALS. See NUMISMATICS.

MEDEA, the daughter of Æetes, king of the Colchians, who were believed to be of Egyptian descent (Herod., ii. 104), and are said to have found a settlement on the east of the Euxine and to the south of the Caucasus. Medea was one of the "wise women" (witches or sorceresses) of antiquity, and perhaps, like Helen, was a human embodiment of some goddess connected with Eastern element-worship, possibly with Hera. For the story of her love for Jason the Argonaut, and of the revenge she took for his desertion of her for another bride, a Corinthian princess, Glauce, daughter of Creon, see ARGONAUTS and JASON. A more interesting inquiry is the origin of the tale, and its connexion with solar myths.

The legend of the Argonautic expedition is a very ancient one. It is alluded to in the *Odyssey* (xii. 70), in more than one passage of Æschylus,[1] and is given at some length in the fourth Pythian ode of Pindar, the close agreement of which with the Alexandrine compilation by Apollonius Rhodius, entitled *Argonautica*, in four books, shows that, according to the general law of mythology, the main features of the legend differed but little. The original story, it is probable, was contained in a still older epic poem called ἡ Ναυπακτία ποίησις...

The "Golden Fleece," in quest of which the adventurers

[1] He alludes to Phineus and the *Lemnia facinora* (*Eum.* 50; *Cho.* 620), and there were plays composed by him on both these subjects.

[2] Pausan., iv. 33, 7. He quotes from it two hexameter verses in x. 28, 2.

made a voyage from the home of Jason, Iolchus in the Thessalian Magnesia, is virtually identical with the fiery robe which Medea prepared for her rival Glauce, the new bride, with the Homeric "ægis," and with the garment smeared with phosphorus which was sent by Deianira to Hercules, and burst into a flame when brought near to a sacrificial fire.[1] Jason, as the story went, was not allowed by the guardian of the fleece, King Æetes, to approach it till he had performed a certain task in putting to the yoke fire-breathing bulls, which he effected by the aid of Medea. The bull is a well-known symbol of the sun, and it occurs in the bull-slaying group representing the Persian sun-god Mithras. Again, the slaying of a father by a son (the old sun killed by the new one) is seen alike in Œdipus having caused the death of his father Laius, in Æson, the father of Jason, having been restored to life by the magic arts of Medea, and in Pelias having been killed and boiled in a caldron by his own daughters at the instigation of the sorceress. Lastly, the legend that Medea was herself the granddaughter of the Sun, and that she escaped in a car drawn by flying dragons, given to her for safety by her grandsire,[2] equally tends to prove that the whole story is of solar origin, and can be explained on that theory alone.

This, indeed, has been well stated by Sir G. W. Cox.[3] The "dragon chariot is simply the chariot of Indra, Helios, and Achilles; and it is drawn by dragons because the word denoted simply beings of keen sight, and was naturally applied to the creatures which may be supposed to bear the sun across the heaven."

In all these legends about the sun the performance of certain imposed "toils" or labours is included, the idea expressed being the hard necessity of the sun going his daily course in the appointed time in spite of thickening storm-clouds and opposing powers of darkness, through which he has to fight his way, both visibly above and invisibly underneath the earth. Thus Hercules has his twelve labours (the number corresponding to the lunar months), while Jason is not only required by his uncle King Pelias to bring the golden fleece, but is commanded by Æetes to tame the bulls as a condition of obtaining it. The name Μήδεια may possibly be referred to *μήδεσθαι*, "to care for," as Jason may contain the root *ἰᾶσθαι*, "to heal," which is the meaning that Pindar attaches to it,[4] or to *ἴον*, the violet-coloured dawn, as in Iocaste, Iamos, and Iolaus.[5] In his relation to the snake, which guarded the fleece, and to the dragons' teeth which he sowed on the ground ploughed by the fiery bulls, compared with the serpent entwining the staff of the healing god Asclepius, we see that almost invariable connexion that subsists between solar and phallic worship.[6] This view is confirmed by the "ship Argo," one of the many sexual symbols of cup-shaped and boat-like form.[7] It is the "ship" which was the Teutonic symbol of the goddess Isis.[8]

The existing literature on the love of Medea for Jason shows how popular was the story in antiquity for its pathos and its sentimentality. Thus the *Medea* of Euripides was rendered by Ennius; Neophron of Sicyon and Melanthius[9] wrote plays of the same name; we have the long and fine Pythian ode of Pindar, already referred to, the touching epistle "Medea Jasoni" in the *Heroides* of Ovid, and the interesting, beautiful, and too little read *Argonautica* of Apollonius.

Of course, the similarity of the names Μῆδοι and Μήδεια led to etymological speculations on the identity of the nomenclature, and one Medus, a son of Medea, was believed to have been an eponym hero.[10] The author of the compilation known as Hesiod's *Theogony* says that Medeus was a son of Medea by Jason,[11] and was brought up, as Jason himself had been, by Chiron in the mountains. Euripides assigns but two children to Medea and Jason,[12] and Apollodorus[13] gives their names as Mermerus and Pheres.

[1] Soph., *Trach.*, 765.
[2] Eur., *Med.*, 1321; Hesiod, *Theog.*, 958.
[3] *Mythology and Folklore*, p. 264; see also *Mythology of the Aryan Nations*, pp. 240, 384, 388.
[4] *Pyth.*, iv. 119.
[5] Cox, *Aryan Mythology*, pp. 244, 385.
[6] Cox, *ibid.*, p. 363.
[7] *Aryan Mythology*, p. 104 and 354.
[8] Tac., *Germ.*, 9.
[9] Ar., *Pac.*, 1012.

MEDELLIN, a town of Colombia, South America, capital of the state of Antioquia, is situated at a height of 4845 feet above the sea, in the valley of the Rio Porce, a right-hand tributary of the Rio Cauca, and, though 100 miles from the confluence, not more than 16 miles east from the valley of the larger stream. It is a clean and well-built place, but has no public buildings of note. Though the population is estimated at 14,000, there is no great activity except on the market days, twice a week, when the buyers and sellers flock in from the country. See Fr. von Schenck in *Petermann's Mittheil.*, 1880.

MEDFORD, a town of the United States, in Middlesex county, Massachusetts, at the head of navigation on Mystic river, and 5 miles north-west of Boston by a branch of the Boston and Maine Railroad. It is a busy place, with a considerable variety of manufactures—woollens, carpets, buttons, bricks, leather, &c. Tufts College, situated near the town on Walnut Hill, was founded by the Universalists in 1853, and named in honour of Charles Tufts, the donor of the 70 acres occupied by the building and its grounds. The endowment amounts to more than $1,000,000. The population of Medford was 5717 in 1870 and 7537 in 1880.

MEDHURST, WALTER HENRY (1796–1857), one of the most distinguished Protestant missionaries to the Chinese, was born in London in 1796. His education began at St Paul's Cathedral school. As he grew up, he learned the business of a printer; and, having become interested in missions to the heathen, he sailed in 1816 for the London Missionary Society's station at Malacca, which was likely to be a great printing-centre. His linguistic powers soon showed themselves. He became proficient in Malay, in a knowledge of the written characters of Chinese, and in the colloquial use of more than one of its dialects. He was ordained at Malacca in 1819, and was in all missionary labours "more abundant,"—first at Penang, then at Batavia, and finally at Shanghai. To give only the names of his various works, some in English, some in Chinese, would take a considerable space. A dictionary of one of the Fuh-Kien dialects is still valuable; and his Chinese-English and English-Chinese dictionaries (Batavia, 1842) are more complete and reliable than any earlier or later works of the same kind. After the conclusion of the first English war with China he removed to Shanghai in 1843, and there he continued till 1856, laying the foundations, broad and deep, of a successful mission. His principal labour for several years, as one of a committee of delegates of whom he was *facile princeps*, was in the revision of existing Chinese versions of the Sacred Scriptures. The result was what should be called a new version of the Bible, marvellously correct in idiom, and faithful to the meaning of the original. The university of New York conferred upon him in 1843 the degree of D.D. Medhurst left Shanghai in 1856, with several members of his family, to try the effect of a visit to England for his failing health. He died, however, two days after reaching London, on the 24th January next year. Strong, sprightly, versatile, and genial, he was a man of extraordinary gifts and generous soul. No efforts (and many were made) could draw him from his devotion to the work of missions.

MEDIA. See PERSIA.

[10] Pausan., ii. 3, 8.
[11] *Theog.*, 1001.
[12] *Δίπτυχος γονή*, v. 1136. Hence in 969 the dual is used, *εἰσελθόντε*.
[13] *Bibl.*, i. 9, 28.

MEDICAL JURISPRUDENCE, or, as it is now more usually termed, Forensic Medicine, is that branch of state medicine which treats of the application of medical knowledge to the purposes of the law. The term medical jurisprudence, though sanctioned by long usage, is not an appropriate one; since the subject is, strictly speaking, a branch of medicine rather than of jurisprudence; it does not properly include sanitation or Hygiene (*q.v.*), both this and medical jurisprudence proper being distinct branches of state medicine. The connexion between medicine and the law was perceived long before medical jurisprudence was recognized, or had obtained a distinct appellation. It first took its rise in Germany, and subsequently, but more tardily, received recognition in Great Britain.

Forensic medicine, or medical jurisprudence proper as distinguished from hygiene, embraces all those questions which bring the medical man into contact with the law, and embraces (1) questions affecting the civil rights of individuals, and (2) injuries to the person.

I. Questions Affecting the Civil or Social Rights of Individuals.

1. *Development of the Human Frame.*—The development of the physical and mental powers of the human being is a matter of the highest importance, and is a factor of great consequence in determining criminal responsibility, civil responsibility, or the power of giving validity to civil contracts, and in determining the personal identity of a living person or of a corpse. Human life is usually divided into the five periods of *infancy*, *childhood*, *youth*, *manhood*, and *old age*. Some writers increase the number of these, unnecessarily, to seven periods, without any practical advantage.

Infancy is the period from birth till the first or milk set of teeth begin to be shed—usually about the seventh year. During this period the body increases in size and stature more, relatively, than at any other period of existence; and the mental faculties undergo great development. The milk teeth, twenty in number, are evolved in a definite order, beginning with the central incisors at about six months, and ending with the second molars about the termination of the second year. From the size and stature of the body, the development of the teeth, and the more or less advanced state of ossification or solidification of the bony skeleton, conclusions may be drawn as to the probable age of the infant.

Childhood extends from the commencement of the shedding of the milk teeth to the age of puberty—usually from the seventh to the fourteenth or fifteenth year. During this period the body expands, as well as the bony structures, without any clearly marked difference in structure being observable between the sexes except as regards the genitals, so that it is impossible to distinguish absolutely between the male and the female skeleton during this period. The milk-teeth are shed, and are replaced by the second or permanent set, thirty-two in number, though these do not usually all make their appearance during childhood. Marked differences between the proclivities of the sexes are noticeable even at an early period of childhood, and long before the characteristic functions begin to be developed.

Youth is marked at its commencement by the changes which occur at puberty—the development of the genitals in both sexes, the appearance of hair on the genitals, the appearance of a beard in the male, the development of the breasts in the female, the appearance of the monthly flow in the female, and the ability to secrete semen in the male. Marked mental changes now occur, and the generative functions are perfected. Youth terminates at the age of legal majority, twenty-one years; or perhaps the period ought to be extended to twenty-five years of age, as it is with some nations.

Manhood (or *Womanhood*) is the period of perfection of all the bodily and mental powers. It ceases in woman with the cessation of the monthly flow at about forty-five years of age; but in man it often extends to a much later period of life.

Old Age begins with the decay of the bodily and mental faculties, and is characterized by wrinkling of the skin, loss of the teeth, whitening of the hair, and feebleness of the limbs. In its later stages decay of the mental faculties, deafness, obscurity or loss of vision, and bowing of the spine are added.

2. *Duration of Human Life.*—The chances of human life form an important subject of inquiry, which has been elucidated by the labours of Price, Milne, Farr, and others; and on deductions from comparisons of birth and death rates is founded the system of annuities, insurance against loss in sickness, and the insurance of lives. Since the establishment of compulsory registration of deaths, our knowledge of the ordinary and extraordinary chances of human life has been much extended, and surer data are now available for calculations of probabilities of life, of survivorships, and of the payments which ought to be made in benefit clubs. See Insurance and Longevity.

3. *Personal Identity.*—It might be imagined that there is little danger, with the exercise of ordinary care, of mistaking one person for another; but the remarkable case of the Tichborne claimant, and some other less-known but perhaps equally singular instances, have demonstrated that mistakes as to the identity of individuals are easily made, and are more frequent than is commonly supposed. Where the identity has to be established or disproved after long absence, exposure to foreign climates and great hardships, wounds, &c., the problem is often one of extreme difficulty. The data for identifying a person are individual and family likeness, stature, the colour of the eyes, peculiarities of garb and manner, recollection of antecedent events, but more especially marks on the person either congenital or acquired. Such are *nævi* or mother's marks, scars, and disunited or badly united fractures, known to have existed upon the missing person. An accurate solution of the question is, nevertheless, often a matter of the greatest difficulty.

4. *Marriage.*—Under this head the medical jurist has to deal principally with the nubile age, viewed in the light of nature and according to legislative enactments, and with such physical circumstances as affect the legality of marriages, or justify divorce.

In Great Britain the age at which the sexes are first capable of propagating the species is later than in more southern climes. Ordinarily it does not occur before fifteen years of age for the male and fourteen for the female; exceptionally, however, it occurs at the ages of thirteen and of twelve (or even less) respectively in the male and female. By legislative enactment, nevertheless, parents and guardians may, in England at all events, forbid the marriage of young people till the age of legal majority. The only physical circumstances which in Great Britain form a bar to marriage are physical inability to consummate, and the insanity of one of the parties at the time of marriage. Both those circumstances have been pleaded and sustained in the law courts. In other countries minor physical circumstances, as disease, are held to invalidate marriage.

5. *Impotence and Sterility.*—These may arise from organic or from functional causes,—the former being alone irremediable, and as such taken cognizance of by the law courts. On this subject it is unnecessary to enlarge here.

6. *Pregnancy.*—This subject presents one of the widest fields for medico-legal evidence. The limits of age between which it is possible, the limits of utero-gestation, and the signs of pregnancy may all in turn be the subjects of investigation.

The limits of age between which pregnancy is possible are usually fixed by the appearance and cessation of the monthly flow; and these ordinarily begin about fourteen and cease at forty-five years of age. Exceptionally they appear as early as the tenth year, and may not cease till the end of the fifth decade of life. Cases, however, have occurred where a woman has conceived before menstruating; and a few doubtful cases of conception are recorded in women upwards of fifty, or even sixty, years of age. The general fact of pregnancy being limited by the age of puberty on the one hand and the cessation of the monthly flow—or fifty years as the extreme limit of age—must be accepted as the safest guide in practice.

The limits of utero-gestation are not in England fixed by legislation. The French code fixes the extreme limit of three hundred days. The ordinary period is forty weeks and a half, or two hundred and eighty-three days from the cessation of the last monthly flux. The limit of three hundred days, as fixed by the French code, is perhaps never exceeded, if ever reached. The uncertainty of females in fixing the exact date of conception has given rise to the discrepant opinions of physiologists on the subject. It is well known, however, that among the higher animals the period is not a precise one; and impregnation and conception are doubtless not necessarily coincident.

The signs of pregnancy are of the utmost importance to the medical jurist. He may be called upon to pronounce upon the virtue of a female, to sustain or rebut a plea for divorce, to determine whether a capital sentence shall be carried out, or to determine whether it is probable that an heir will be born to an estate. Should he err in his judgment—and mistakes are very possible in the earlier months of utero-gestation—he may commit a grievous wrong. Medical jurists are in the habit of classifying the signs of pregnancy as uncertain or certain; it is the former which are most regarded by the public, but the latter are alone of probative value to the jurist. The usual and uncertain signs are the cessation of the monthly flow, nausea, sickness, a darkening of the areola and the formation of a secondary areola around the nipple, enlargement of the breasts, increased size of the abdomen, the formation of a tumour in the womb, quickening, and the motions of the fœtus. There are also other minor signs of less importance. The certain signs are the uterine souffle, which is a peculiar soft sound heard over the abdomen, and synchronous with the maternal pulse; ballottement, or the examination for a floating tumour in the abdomen between the fifth and eighth months of pregnancy; and the pulsations of the fœtal heart, heard by means of the stethoscope. These pulsations are much quicker than, and not synchronous with, the maternal pulse. This is the only indubitable sign of pregnancy. It is inapplicable before the fourth month of gestation.

7. *Parturition.*—The *imminence* of the process of parturition is of comparatively little interest to the medical jurist; but the *signs of recent delivery* are all-important. These signs are the bruised, swollen, and lacerated state of the external genitals, relaxation and dilatation of the vagina and womb, the existence of a peculiar vaginal discharge known as the lochia, a relaxed and fissured condition of the abdominal walls, a peculiar aspect of the countenance, and the distended state of the breasts due to the secretion of milk. The lochial discharge is the most characteristic sign. All the signs may disappear within ten days of delivery, though this is not usual.

Connected with parturition, the question of *viability* of the child is not unimportant. After the intra-uterine age of seven months is reached a child is certainly viable. The period at which the fœtus becomes viable cannot be stated with certainty; but five calendar months, or one hundred and fifty days, is perhaps the nearest approximation which can be made. The viability of a child is judged by its size and weight, its general state of development, the state of the skin, hair, and nails, its strength or feebleness, the ability to cry, and its power of taking maternal nourishment. The question of viability has important bearings upon the crime of infanticide, and the succession to property.

The subject of *superfœtation*, or the possibility of two conceptions having occurred resulting in the birth of twins with a considerable intervening interval, is a very obscure one, and has given rise to much controversy,—its existence being affirmed by some medical jurists, and denied by others. There is much, however (*e.g.*, the existence of a double or bifid womb), to countenance the view that a double conception is possible.

In the curious case of a man marrying a woman having possession of an estate of inheritance, and by her having issue born alive and capable of inheriting her estate, the man on the death of his wife holds her lands for life as a tenant by the "curtesy" of England. Here the meaning of "born alive" is different from the meaning of the same expression as used respecting infanticide. In questions of tenancy by the curtesy it has been decided that any kind of motion of the child, as a twitching and tremulous motion of the lips, is sufficient evidence of live-birth. As regards infanticide, proof of a conclusive separate existence of the child is demanded before live-birth is admitted.

8. *Monsters and Hermaphrodites.*—To destroy any living human birth, however unlike a human creature it may be, is to commit a crime. Blackstone states that a monster which hath not the shape of mankind hath no inheritable blood; but the law has not defined a monster, nor what constitutes a human form. The same author states that if, in spite of deformity, the product of birth has human shape, it may be an heir. Hermaphrodites are beings with malformations of the sexual organs, simulating a double sex. Physiologists do not admit, however, the existence of true hermaphrodites with double perfect organs, capable of performing the functions of both sexes.

9. *Paternity and Affiliation.*—These are often matters of great doubt. A considerable time may elapse between the absence or death of a father and the birth of his reputed child. As has already been said, three hundred days is the utmost limit to which physiologists would extend the period of utero-gestation. This subject involves questions respecting children born during a second marriage of the mother, posthumous children, bastardy, and alleged cases of posthumous children.

10. *Presumption of Survivorship.*—When two or more persons perish by a common accident, when a mother and her new-born child are found dead, and in a few analogous cases, important civil rights may depend upon the question which lived the longest; and great ingenuity has been displayed in elucidating the disputes which have arisen in the law courts in such cases.

11. *Maladies Exempting from Discharge of Public Duties* frequently demand the attention of the medical man. He may be called upon to decide whether a man is able to undertake military or naval service, to act as a juryman without serious risk to life or health, or to attend as a witness at a trial. An endeavour to give a fearless and honest certificate should animate the medical man in the discharge of this delicate duty.

12. *Feigned and Simulated Diseases* often require much

skill and acuteness in order to detect the imposture. Where there is reason to suppose that a disease is simulated, much caution as to procedure is also required.

13. *Insanity or Mental Alienation.*—This subject presents an enormous field to the medical jurist. A medical man may be required to give evidence in any of the law courts, civil, criminal, or ecclesiastical, before commissions *de lunatico inquirendo*, or before a magistrate, as to the sanity or insanity of an individual; and he may have to sign certificates of unsoundness of mind with the view of providing for the safe custody and proper treatment of a lunatic. Hence he must be familiar with the chief forms of insanity (see INSANITY), and be able to distinguish and treat each of these. He will also be required to detect feigned insanity, and to examine persons charged with crime with the view of preventing real lunatics from being treated as criminals.

The terms "unsoundness of mind," applied to the condition of the mind itself, and "*non compos mentis*" to the person whose mind is affected, are legal terms applied to insanity. Lawyers have disputed as to whether imbecility should or should not be included under the head of insanity; but medical men include under this category all disorders or defects of the mind which disqualify a person for managing his affairs, and entering into a binding contract, or which render the individual morally irresponsible for his or her otherwise criminal actions. There is good legal authority for recognizing four forms of unsoundness of mind—*idiocy*, *dementia*, *mania*, and *monomania*.

The chief questions respecting unsoundness of mind which present themselves to the medical jurist are—is the person of sound or unsound mind; if unsound, are there real lucid intervals; is he fit to manage his affairs, to contract a marriage, or to execute a will; is he dangerous to others?

As grounds for restraint, the law recognizes only these conditions—danger to himself, inability to manage his own affairs and property, and danger to the person of others. Before an individual can be placed under restraint in an asylum the certificates of two medical men must be obtained, and the formal order of a relation or friend. The certificates to be valid must be signed by legally qualified medical practitioners having no interest, direct or indirect, in the patient, or in the asylum to which he is to be sent. The medical examiners must pay separate visits, each medical man examining the patient separately. The certificates, which remain valid for seven days only, must bear the exact address of the lunatic, his occupation, and the date of the examination; they must also set forth distinctly the grounds of the opinion they express, under the separate heads of facts observed by the examiner, and facts (to be specified) communicated by others. In the case of pauper lunatics one medical certificate only is required, which is supplemented by an order from a justice of the peace. In urgent cases also one medical certificate suffices for incarceration in an asylum, provided that within three days of the patient's reception two other such certificates are signed by two other medical practitioners, not being connected with the asylum, upon a like examination. The superintendent or proprietor of the asylum must in all cases forward to the commissioners of lunacy a notice of admission within one clear day from the patient's admission. Any infringement of the statutory regulations subjects the person who commits it to a heavy penalty.

II. INJURIES TO THE PERSON.

1. *Defloration.*—The signs of defloration are obscure and uncertain; and it is rather by the coexistence of several of the usual marks than the existence of any one sign, that any just conclusion can be arrived at.

2. *Rape.*—This crime consists in the carnal knowledge of a woman forcibly and against her will. The resistance must be to the utmost, else the crime of rape has not been committed in the legal sense of the word. The proofs of rape, accordingly, apart from the consistency of the woman's story, mainly depend on the presence of the signs of defloration, and on marks of injury on the man.

3. *Mutilation.*—This may consist in the cutting or maiming of any member; castration is the most important, and perhaps but rarely effected as a crime. Self-mutilation, giving rise to false accusations, is occasionally resorted to.

4. *Criminal Abortion.*—The crime of abortion consists in unlawfully administering to a woman, or causing to be taken by her (whether she be with child or not), with intent to procure her miscarriage, any poison or noxious thing, or using for the same purpose any instrument or other means whatsoever; also in the use of the same means, with the same intent, by any woman being with child.

5. *Homicide.*—The legal sense of the term homicide excludes such injuries as are the result of either accident or of suicide. It embraces murder or wilful homicide, manslaughter or culpable homicide, casual homicide, and justifiable homicide.

As a preliminary in all cases of homicide, it is the duty of the medical jurist in the first place to ascertain the fact of death, and to distinguish between real and apparent death; and then to determine, if possible, the period at which death took place.

Infanticide or child murder is by the British law treated with the same severity as the murder of an adult. Indeed infanticide as a crime distinct from murder has no legal recognition. Practically this severity defeats itself, and offences which are really cases of child murder are often treated simply as cases of concealment of birth. The iniquity of the old law which threw the onus of proof of still-birth on the mother now no longer exists, and the law demands strict proof of live-birth at the hands of the prosecution. Hence the subject involves very nice points of forensic medicine. The child must be proved to have arrived at the period when there was a probability of its living (proof of viability); and as the establishment of respiration is necessary to prove live-birth the evidences of this act must be carefully investigated. The size and position of the lungs, and the state of the vessels concerned in fœtal circulation, must be carefully noted. The fœtal lungs are dark, dense, and liver-like in appearance and consistence, and sink when immersed in water; whilst the fully respired lungs are rosy, marbled, and soft and crepitant when handled. Minor degrees of respiration are recognized by the appearance of little groups of dilated air-vesicles, and by the fact that, although the lungs as a whole may sink in water, certain portions of them, into which respired air has penetrated, float in water even after subjection to firm pressure in the hand. Care must be taken, nevertheless, to exclude buoyancy of the lung due to putrefaction; in this case the air may be expelled by gentle pressure, and the previously buoyant portion of lung now sinks in water. It is impossible, however, to distinguish certainly between a lung naturally inflated and one artificially insufflated.

It must be borne in mind that, although live-birth cannot be affirmed in the absence of signs of respiration, the presence of these signs is not proof of live-birth in the legal sense of the term. The law demands for live-birth a separate existence of the child after delivery; and breathing may take place whilst the child is still either wholly or partially within the maternal passages, and in some special cases whilst still within the womb itself.

When proofs of respiration—it may be to such an extent as to leave no doubt as to live-birth—have been found, the cause of death is then to be investigated. Wounds, and other forms of injury, must be sought for. There may be signs of strangulation, suffocation, puncture of the fontanelles, and consequent injury to the brain, the administration of a poison, or other means of procuring death. It must be borne in mind that some of these causes may be brought about by omission, or even by accident. Thus strangulation may arise from natural and unrelieved pressure of the navel string on the neck of the child; suffocation from immersion of the face of the child in the maternal discharges, or by pressure of clothes on the mouth. Death may result from hæmorrhage through neglect to tie the navel string, or the infant may perish from exposure to cold.

In the case of exposed infants it is very important to ascertain the real mother. As such exposure usually takes place soon after birth, comparison of the age of the infant with the signs of recent delivery in the suspected mother is the best method of proving the relation.

Ordinary *homicide* may be accomplished by several modes that may sometimes be ascertained by examination of the body. Of one of the most important of these consideration is deferred to the article POISONS.

Death by *asphyxia* is a common mode of accomplishing homicide, as by suffocation, drowning, hanging, strangulation, or by exposure to mephitic air. Suicide and accidental death from these causes are still more common. (1) *Drowning* is thought to produce death occasionally by the suddenness of the shock causing suspension of the functions of circulation and respiration—by shock without a struggle. The usual mode of death appears, however, to be by the circulation of unoxygenated blood through the brain acting as a poison upon that organ; and this is attended with all the phenomena of asphyxia, as in suffocation. The phenomena attending asphyxia are as follows. As soon as the oxygen in the arterial blood, through exclusion of air, sinks below the normal, the respiratory movements grow deeper and at the same time more frequent; both the inspiratory and expiratory phases are exaggerated, the supplementary respiratory muscles are brought into play, and the breathing becomes hurried. As the blood becomes more and more venous, the respiratory movements continue to increase both in force and frequency. Very soon the expiratory movements become more marked than the inspiratory, and every muscle which can in any way assist in expiration is brought into play. The orderly expiratory movements culminate in expiratory convulsions; these violent efforts speedily exhaust the nervous system, and the convulsions suddenly cease and are followed by a period of calm. The calm is one of exhaustion; all expiratory active movements have ceased, and all the muscles of the body are flaccid and quiet. But at long intervals lengthened deep inspiratory movements take place; then these movements become less frequent; the rhythm becomes irregular, so that each breath becomes a more and more prolonged gasp, which becomes at last a convulsive stretching of the whole body; and with extended limbs and a straightened trunk, with the head thrown back, the mouth widely open, the face drawn, and the nostrils dilated, the last breath is taken. The above phenomena are not all observed except in cases of sudden and entire exclusion of air from the lungs. In slow asphyxia, where the supply of air is gradually diminished (*e.g.*, in drowning), the phenomena are fundamentally the same, but with minor differences. The appearances of the body after death from drowning are various. There may be pallor of the countenance, or this may be livid and swollen. The air passages are filled with frothy mucus, and there may be water in the stomach. The ends of the fingers are often excoriated from grasping at objects; and weeds, &c., are sometimes found grasped in the hands. The distinction between murder and suicide by drowning can rarely be made out by examination of the body alone, and is usually decided from collateral circumstances or marks of a struggle. Attention must also be paid to the existence of wounds on the body, marks of strangulation on the neck, and the like. (2) *Hanging* may result in death from asphyxia, or, as is more particularly the case in judicial hanging, some injury is inflicted on the upper portion of the spinal cord, resulting in instant death. The ordinary appearances of death from asphyxia may be found: dark fluid blood, congestion of the brain, intensely congested lungs, the right cavities of the heart full, and the left comparatively empty of blood, and general engorgement of the viscera. Ecchymosis may be found beneath the site of the cord, or a mere parchmenty appearance. There may even be no mark of the cord visible. The mark, when present, usually follows an oblique course, and is high up the neck. The fact that a body may be suspended after death, and that if this be done speedily whilst the body is still warm there may be a *post-mortem* mark undistinguishable from the mark observed in death from hanging, must not be forgotten. (3) *Suffocation* may occur from the impaction of any substance in the glottis, or by covering up the mouth and nose. It is frequently of accidental origin, as when substances become accidentally impacted in the throat, and when infants are overlaid. The phenomena are those of pure asphyxia, which have already been detailed. On *post-mortem* examination the surface of the lungs is found covered with minute extravasations of blood, known as punctated ecchymosis. (4) *Strangulation* may be accomplished by drawing a cord tightly round the neck, or by forcibly compressing the windpipe (throttling). Hence there may be either a circular mark round the neck, not so oblique as after hanging, or the marks of the fingers may be found about the region of the larynx. The cartilaginous structures of the larynx and windpipe may be broken. The mark of the ligature is often low down in the neck. The signs of asphyxia are present in a marked degree. (5) *Mephitism.*—Death from the inhalation of irrespirable gases is a mode of assassination seldom employed, but is frequently resorted to on the Continent by suicides, charcoal fumes being commonly used for the purpose (see POISONS).

6. *Death from Starvation.*—Cases occur in which it is important to distinguish this from other modes of death. In such cases the skin becomes harsh and dry, and may acquire a peculiar odour; the subcutaneous fat disappears; the gums shrink away from the teeth; the tongue and mouth become dark-coloured and dry; the eyes are bloodshot; the intestines become thin and their coats translucent; the gall-bladder is distended. The period of total abstinence from food required to kill an adult is unknown, and greatly depends upon whether there be access to liquid. In some cases persons have been able to subsist on little or no nourishment for long periods, the body being in a state of quasi-hibernation.

7. *Death from Extremes of Temperature.*—(1) Death from cold is not often observed in the British Isles. A portion only of the body, as the extremity of a limb, may perish from extreme cold. After the first sensation of tingling experienced on exposure to severe cold, loss of sensation supervenes, with languor and an irresistible propensity to sleep. The tendency to this forms an extreme danger in such cases. (2) Death from extreme heat usually occurs in the form of burning and scalding, attended with destruction of a large portion of the cutaneous structures. Here the cause of death is obvious. The human body is capable of exposure to very hot air—as is seen in Turkish baths—for a considerable period with impunity. Sun-stroke is a cerebral affection brought on by too great exposure to a hot atmosphere, especially whilst undergoing fatigue.

8. *Death by Lightning.*—Lightning or an artificial electric current may cause instant death. No visible marks of the effects of the electric current may be left, or the body may be singed or discoloured, or the skin may be perforated at one or two spots.

9. *Wounds.*—The examination of wounds, whether fatal or not, often becomes an important branch of forensic medicine. Wounds are usually divided into *contused*, *lacerated*, *incised*, *punctured*, and *gunshot* wounds. For poisoned wounds see POISONS. Each kind of wound requires to be minutely examined and described, as they are in approved works on surgery. The degree of danger from each should be familiar to the medical jurist; and he should recollect that there is no wound which may not become incidentally fatal from improper treatment, peculiarities of constitution, or accidental inoculation with septic material. Punctured wounds or stabs require minute attention; for there have been instances in which death has been produced by an instrument so small as a pin thrust into a vital part. *Wounds of the head* are always dangerous, especially if the blow has been severe. The person so wounded may die without division of the skin, or fracture of the bones, as happens in what is known as *concussion* of the brain. Contusions which do not divide the skin may fracture the skull; or the inner table of the skull may be fractured without the outer being broken or depressed. Even wounds of the scalp may prove fatal, from inflammation extending towards the brain. Punctured wounds of the head are more dangerous than cuts, as more likely to excite fatal inflammation. When the brain and its membranes are injured, all such wounds are generally fatal. Wounds of the face or organs of sense are often dangerous, always disfiguring, and productive of serious inconvenience. *Wounds of the neck* are always very serious wherever more than the skin is divided. The danger of opening large blood-vessels, or wounding important nerves, is imminent; even the division of a large vein in the neck has proved immediately fatal, from the entrance of air into the vessel, and its speedy conveyance to the heart. A blow on the neck has instantly proved fatal, from injury to an important nerve, generally the pneumogastric or the sympathetic. Dislocations and fractures of the bones of the neck prove instantly fatal. *Wounds of the chest* are always serious when the cavity is penetrated, though persons may recover from wounds of the lungs, and have even survived for some time considerable wounds of the heart. This last is an important fact; because we are not always to consider the spot where the body of a person killed by a wound of the heart, and apparently remaining where he fell, is found as that in which the fatal wound was inflicted. Instances have occurred of persons surviving severe wounds of the heart for several days. Broken ribs are never without danger; and the same may be said of severe contusions of the chest, from the chance of inflammation extending inwards. Wounds penetrating both sides of the chest are generally considered as fatal; but possibly there may be recovery from such. *Wounds of the abdomen*, when they do not completely penetrate, may be considered as simple wounds, unless when inflicted with great force, so as to bruise the contents of the abdominal cavity; in that case they may produce death without breach of surface, from rupture of some viscus, as sometimes happens from blows or kicks upon the belly. Wounds injuring the peritoneum are highly perilous, from the risk of severe inflammation. Wounds of the stomach or intestines, or of the gall-bladder, generally prove mortal, from the effusion of their contents into the peritoneal cavity producing fatal inflammation. Wounds of the liver, spleen, or kidneys are generally soon mortal, from the great vascularity of those organs. Wounds of the extremities, when fatal, may generally be considered so from excessive hæmorrhage, from the consequences of inflammation and gangrene, or from the shock to the system when large portions of the limb are forcibly removed, as in accidents from machinery, and in wounds from firearms.

10. *Poisonous Food.*—Under certain conditions, various articles of diet, especially butcher meat, eggs, milk, butter, cheese, and honey, may become possessed of poisonous properties, and this may arise from a variety of causes besides the introduction of known and specific poisons. Moreover, certain kinds of animal food—fish chiefly—may have definite toxic properties. Food may be more or less poisonous—(1) from unsoundness, either from putridity or decomposition or disease; (2) from the presence of parasites; (3) from mouldiness, or presence of deleterious microscopic fungi; and (4) where the flesh is that of animals which have fed on noxious plants,—and under this head may also be classed poisonous honey, which bees have gathered from poisonous plants. (5) It may be of the nature of poisonous fish, using the term fish in the popular sense. (6) Certain fungi or mushrooms are poisonous. Parasitic diseases would, strictly speaking, come under the first head; but the pre-

ventive measures to be adopted in the use of food infested with parasites will alone be treated of in this place.

(1) *Poisonous Vegetables.*—Unsound or even rotten vegetables and fruits may be consumed, and become fertile sources of varied forms of poisoning, especially in hot summers. The symptoms produced by the ingestion of large quantities of unsound fruit or vegetables are of a diarrhœal character, not often of an alarming severity, except in the cases of the young and feeble. They may, however, sometimes attain a fatal severity. The cause is usually obvious, and the treatment is simple; mild purgatives, as rhubarb or castor oil, with or followed by opiates, to remove peccant matters from the intestines; and stimulants, as ammonia or alcohol, if there be much collapse. Certain fungi or mushrooms are known to be specifically poisonous, such as the *Amanita muscaria*, or fly-fungus, and others. Certain kinds of mushrooms, usually innocuous, are occasionally poisonous or deleterious; and the cause of this is not always clear. Poisonous fungi produce narcotic and irritant symptoms.

(2) *Poisonous, Tainted, or Putrid Meat.*—The obvious characteristics of good sound flesh meat are that its colour is red—neither pale pink nor deep purple; that it is marbled in appearance; firm and elastic to the touch, scarcely moistening the fingers; having a slight and not unpleasant odour; and that when exposed to the air for a day or two it should neither become dry on the surface nor wet and sodden. Sound meat is acid to litmus paper; unsound meat may be neutral or alkaline. Meat may be tainted with physic administered to the animal. It is a common practice, when a fat and valuable animal is unwell, to physic it, and if its recovery be not speedy to slaughter it. The meat of such animals may often be met with in our markets, and may induce illness from the physic with which it is contaminated. The effects of simple putridity are most varied. It is well known that some nations habitually eat putrid meat, and even prefer it to fresh; and the development of rottenness in eggs for the epicure is an art in China. There is no doubt that habit has much to do with the tolerance by the stomach of putrid meat, whether cooked or uncooked. But tainted game, and indeed all kinds of meat in which putrefaction has commenced, may indubitably produce disease. This is chiefly of a diarrhœal character, preceded by rigors, and attended with collapse and, it may be, convulsions and other signs of a profound affection of the nervous system. The effects of such tainted meat are slight as compared with those which are produced by the sausage-poison, developed by a sort of modified putrefaction in certain German sausages. These sausages, when they become musty and soft in their interior, nauseous in odour and flavour, and strongly acid to test paper, acquire a highly poisonous character, and are frequently fatal in their effects. The symptoms produced by the use of poisonous flesh are gastric pain, vomiting, diarrhœa, depression, coldness of the limbs, and weak irregular action of the heart. Fatal cases end in convulsions and oppressed respiration, death ensuing from the third to the eighth day. The nature of the sausage-poison, which is probably akin to that of putrid and indeed all non-specifically tainted meats, has been a matter of considerable controversy. Some have held that the poisonous action is due to the development of rancid fatty acids; others believe that a so-called catalytic body is produced, capable of setting up by contact a similar catalytic action. Others have regarded the sausage-poison as due to the formation of pyrogeneous acids during the drying or smoking of the sausages. The recent discovery by Selmi of a class of poisonous alkaloids or amides, termed *ptomaines*, developed during putrefaction of animal matters, on the one hand, and the discovery by Ballard and Klein, still more recently, that the fatally poisonous properties of hams prepared according to the American method may be due to the presence of a parasitic bacillus, point to one or other of these two latter causes as that of the effects of sausage-poison. Others again have referred the effects to the presence of a microscopic fungus—*Sarcina botulina.*

The poisonous nature of the flesh of animals which have fed on certain plants—for example, hares which have fed on certain species of rhododendron, pheasants on the kalmia shrub, &c.—has been abundantly demonstrated, and need only be referred to here. The honey from bees which have garnered on poisonous plants, as the azalea, may likewise be deleterious; and the fact is of classic interest. The milk even of goats which have browsed on poisonous herbs has also proved poisonous.

(3) *Diseased Meat.*—The poisonous effects of meat affected with certain parasites—trichinæ, cysticerci, trematodes, &c., is an undoubted fact. Great quantities of meat pass through our markets which is undoubtedly the flesh of animals affected with disease, such as foot-and-mouth disease, pleuro-pneumonia, pig typhoid, the so-called scarlatina of swine, sheep-pox, &c.; and the question is quite undecided as to whether such flesh produces any injurious effects. To stop the sale of such meat would be to cut off large sources of our meat supplies. The evils attending the use of such diseased meat, when well cooked, have undoubtedly been exaggerated; but, on the other hand, there is enough evidence to show that the use of certain kinds of diseased meat may be followed by serious results. Thus it is generally admitted that the flesh of animals which have suffered from pleuro-pneumonia and murrain will give rise to boils and carbuncles. Braxy mutton may also produce disease when eaten. Trichinæ will produce trichinosis, flukes, the tape-worm, &c. Hams are occasionally fatally poisonous; and this has been traced to the presence of certain low organisms known as *bacilli.*

(4) *Poisonous Fish.*—Fish is sometimes a poisonous article of food. Cases of poisoning by the so-called shell-fish of the British islands are not unfrequently met with. Generally it is the eating of crabs, lobsters, and mussels which produces such results. These are usually of a distressing rather than of a serious character, nettle-rash being a common symptom. Occasionally, however, fatal results have ensued from the use of mussels. In tropical seas poisonous fish are more plentiful—the golden sardine, the bladder fish, the grey snapper, &c.; and, these being eaten by larger fish, as the barracuda, perch, globe-fish, conger eel, &c., the latter may in turn become poisonous.

Good cookery, that is, exposure to a sufficiently high temperature for a sufficiently lengthened time, is undoubtedly the best measure to adopt short of absolute destruction of unsound and diseased meat. So long as meat is high-priced, and the effects of diseased meat so little understood and so undefined, it will be impossible to induce medical officers of health and sanitary inspectors to seize all the diseased and unsound meat which is daily offered for sale. Notwithstanding all that has been said to the contrary, experienced observers are pretty well agreed that thorough exposure of the meat throughout to the temperature at which albumen is coagulated is destructive to the parasites of flesh. Smoking is less effective. Salting is more effective than smoking; but there is some evidence to show that salting may merely hold the life of organisms in suspense without entirely destroying their vitality; and thus in the conversion of salted pork into hams—a process of re-salting and subsequent drying—the specific germ (a bacillus) has been known to be again rendered harmful. It is not known whether efficient cooking entirely removes the deleterious effects of flesh affected with other than parasitic disease, as for example pleuro-pneumonia.

The curative measures for the results of eating poisonous food cannot be specifically described. They are those which must be arrived at on general principles. Symptoms are to be treated, and the powers of the patient sustained until the deleterious matter is removed by the ordinary channels, or the trichinæ have become encysted.

History of Forensic Medicine.

The true origin of medical jurisprudence is of comparatively recent date, although traces of its principles may be perceived in remote times. Among the ancient Greeks the principles of medical science appear only to have been applied to legislation in certain questions relating to legitimacy. In the writings of Galen we find, however, remarks on the differences between the fœtal and the adult lungs; he also treats of the legitimacy of seven months' children, and discusses feigned diseases. Turning to Rome, we find that the laws of the Twelve Tables fix three hundred days as the extreme duration of utero-gestation. It is doubtful whether the Roman law authorized medical inspections of dead bodies. In the code of Justinian we find *De Statu Hominum*; *De Pœnis et Manumissis*; *De Sicariis*; *De Inspiciendo Ventre Custodiendoque Partu*; *De Muliere quæ peperit undecimo mense*; *De Impotentia*; *De Hermaphroditis*,—titles which show obvious traces of a recognized connexion between medicine and law. It was not, however, by the testimony of living medical witnesses that such questions were to be settled, but on the authority of Hippocrates.

Medical jurisprudence, as a science, dates only from the 16th century. In 1507 the bishop of Bamberg introduced a penal code in which the necessity of medical evidence in certain cases was recognized; and in 1532 the emperor Charles V. persuaded the diet of Ratisbon to adopt an uniform code of German penal jurisprudence, in which the civil magistrate was enjoined in all cases of doubt or difficulty to obtain the evidence of medical witnesses,—as in cases of personal injuries, infanticide, pretended pregnancy, simulated diseases, and poisoning. The true dawn of forensic medicine dates, however, from the publication in 1553 of the *Constitutio Criminalis Carolina* in Germany. A few years later Weiher, a physician, having undertaken to prove that witches and demoniacs are, in fact, persons subject to hypochondriasis and hysteria, and should not be punished, aroused popular indignation, and was with difficulty rescued from the flames by his patron, William duke of Cleves.

At the close of the 16th century Ambrose Paré wrote on monsters, on simulated diseases, and on the art of drawing up medico-legal reports; Pineau also published his treatise on virginity and defloration. About the same time as these stimuli to the study of forensic medicine were being made known in Paris, the first systematic treatise on the science appeared in Sicily in the form of a treatise *De Relationibus Medicorum* by Fidele. Paulo Zacchia, the illustrious Roman medical jurist, moreover, published from 1621 to 1635 a work entitled *Quæstiones Medico-Legales*, which marks a new era in the history of the science,—a work which displays an immense amount of learning and sagacity in an age when chemistry was in its infancy, and physiology very imperfectly understood. The discovery of the circulation of the blood by Harvey soon followed, and gave a new impetus to the study of those branches of forensic medicine having direct relations to physiology; and to Harvey we owe the idea how to apply Galen's observations on the differences between the fœtal and the adult lungs to the elucidation of cases of supposed infanticide. About this time, too, Sebiz published two treatises, on the signs of virginity and on the examination of wounds respectively. In the former he contended that the hymen was the real mark of virginity; but this was denied by Augenio and Gassendi. In 1663 Bartholin, a Danish physician, investigated the period of human uterine gestation, a subject which had engaged the attention of Aristotle. He also proposed the "hydrostatic test" for the determination of live-birth—a test still in use, and applied by observing whether the lungs of an infant float or sink in water. Swammerdam explained the rationale of the process in 1677; but it was not till 1682 that it was first practically applied by Jan Schreyer.

Germany, ever the leader in questions of forensic medicine, introduced the first public lectures on medical jurisprudence. Michaelis gave the first course about the middle of the 17th century in the university of Leipsic; and these were followed by the lectures of Bohn, who also published *De Renunciatione Vulnerum; cui accesserunt Dissertationes binæ de partu enecato, et an quis vivus mortuusve aquis submersus, strangulatus, aut vulneratus fuerit*, and *De Officiis Medici Duplicis, Clinici et Forensis*. Welsch and Amman wrote on the fatality of wounds, and Licetus on monsters.

From the time of Ambrose Paré the mode of conducting investigations in forensic medicine had attracted attention in France; and in 1603 Henry IV. authorized his physician to appoint persons skilled in medicine and surgery to make medico-legal inspections and reports in all cities and royal jurisdictions; in 1692, difficulties having arisen, Louis XIV. created hereditary royal physicians and surgeons for the performance of like duties. These, having become a corrupt and venal body, were suppressed in 1790. The only works on forensic medicine which appeared in France during the 17th century, however, were Gendry's *Sur les Moyens de bien rapporter à Justice*, and Blégny's *Doctrine des Rapports en Chirurgie*. At the beginning of the 18th century the latter was superseded as a text-book by Devaux's *L'art de faire des rapports en Chirurgie*. Valentini followed with two works, which were finally incorporated in his *Corpus Juris Medico-Legale* which appeared in 1722. This work is a vast storehouse of medico-legal information, and a summary of the knowledge of the time.

Professorships for teaching the subject were founded in the German universities early in the 18th century, and numerous treatises on forensic medicine were published. Teichmeyer's *Institutiones Medicinæ Legalis* long formed the text-book of the subject; and Alberti, professor of legal medicine at Halle, in his *Systema* gave to the world a most complete and laborious treatise on the science. His industrious collection of facts renders his works a precious mine of information. Indeed towards the close of last century the Germans were almost the only cultivators of legal medicine. But in France the celebrated case of Villeblanche attracted attention to the subject, and called forth Louis, who in a memoir on utero-gestation attacked with powerful arguments the pretended instances of protracted pregnancy, and paved the way for the adoption in the *Code Napoléon* of three hundred days as the limit of utero-gestation, a period in precise accordance with the ancient Roman law of the Twelve Tables. Louis also wrote on death from hanging, and pointed out the mode by which we may distinguish murder from suicide under such circumstances. It is he who is credited with having been the first in France to publicly teach the just application of medical knowledge to jurisprudence. Foderé's celebrated *Traité de Médecine Légale* appeared in 1798, and marks a new era in the annals of legal medicine.

No British author wrote systematically on forensic medicine till 1788, when Dr Samuel Farr published a short treatise on the *Elements of Medical Jurisprudence*; but this was merely an abridgment of an earlier work of Fazelius. Previous writers, as Mead, Munro, Denman, Percival, and the two Hunters, had, however, dealt with fragments of the subject; nevertheless the science as a whole was little appreciated or recognized in this country during the last century.

In the present century France took the lead; and the institution of three professorships of forensic medicine at the end of the 18th century produced excellent fruits. In 1814 Orfila, a Spaniard by birth, but naturalized in France, published his *Toxicologie*, a work which revolutionized this branch of medical jurisprudence, and first placed the knowledge of poisons upon a scientific basis. Since the time of Orfila, France has never ceased to have one or more living medical jurists, among the most recent of whom we must enumerate Tardieu, whose treatises on abortion, on poisons, on wounds, &c., are justly celebrated. Germany too has industriously pursued the subject, and Casper's great work on forensic medicine will ever remain a classic in the science. In Russia Dragendorff has greatly contributed to our knowledge of poisons.

Though forensic medicine may be said to have been entirely neglected in England till the beginning of the present century, its progress has since been by no means slow or unimportant; and the subject now forms a recognized and obligatory portion of medical study. The first lectures delivered in Great Britain were given in the university of Edinburgh in 1801 by the elder Dr Duncan; and the first professorship was held by his son in 1803. Dr Alfred Swaine Taylor gave the first course of lectures delivered in England, at Guy's Hospital in 1831; and in 1863 the university of London made forensic medicine a separate subject for examination and honours for medical graduates. In 1822 there was not in the English language any treatise of authority either on medical jurisprudence or on any important division of the subject; for it was not till the following year that the useful compendium of Paris and Fonblanque was published; and even half a century ago medical jurisprudence may be said to have been almost in its infancy as compared with what it is now. Since 1829 Great Britain has produced an abundant crop of literature on forensic medicine. Sir Robert Christison's admirable treatise on *Toxicology*, Dr A. S. Taylor's *Principles and Practice of Medical Jurisprudence*, the same author's *Elements of Medical Jurisprudence*, Dr Guy's *Forensic Medicine*, and Ogston's *Lectures on Medical Jurisprudence* are well-known and widely circulated works. The separate memoirs of Taylor, Christison, Guy, and others are also storehouses of facts and deductions in the science.

America, too, has not been behind hand in the race. Wharton and Stillé's *Manual* and Wormley's *Toxicology* are the best-known works of American authors. (T. S.*)

MEDICI. This family is renowned in Italian history for the extraordinary number of statesmen to whom it gave birth, and for its magnificent patronage of letters and art. It emerged from private life and rose to power by means of a very subtle policy that was persistently pursued from generation to generation. The origin of the family is buried in obscurity. Some court historians indeed declare it to have been founded by Perseus, and assert that Benvenuto Cellini's bronze Perseus holding on high the head of Medusa was executed and placed in the Loggia dei Lanzi to symbolize the victory of the Medici over the republic. But this only proves that the real origin of the family is unknown, and equally unknown is the precise signification of the Medicean arms—six red balls on a field of gold.

Early bearers of the name.

The name appears in Florentine chronicles as early as the close of the 12th century, although only casually mentioned in connexion with various offices of the republic. The first of the family to be a distinct figure in history was Salvestro dei Medici, who, in the year 1378, took an active part in the revolt of the Ciompi—so-called because it was led by a wool-carder (*ciompo*), one Michele di Lando, and because the chief share in it was taken by the populace, who held the reins of government for some time, and sought to obtain extended political rights. But, although Michele di Lando was the nominal chief of the revolt, Salvestro dei Medici was its real leader. The latter, although a member of the greater guilds, had joined the lesser and sought to be at their head, in order to lay the foundation of his own power and that of his kindred by attacking the Albizzi, who were the leading men of the greater guilds. The victory of the Ciompi, however, was brief, for the excesses of the lower classes brought about a reaction, in which they were crushed, and Michele di Lando sent into banishment. Nevertheless the lesser guilds had gained some ground by this riot, and Salvestro dei Medici the great popularity at which he had aimed. His policy during that period had traced the sole possible road to power in liberty-loving Florence. And this was the road henceforth pursued by the Medici.

Salvestro.

On Salvestro's death in 1388 the Albizzi repossessed themselves of the government, and conducted the wars of the republic. Vieri dei Medici, who seems to have been the next head of the family, understanding the temper of the times, abstained from becoming a popular leader, and left it to his successors to prosecute the task under easier conditions. Then, in the person of Giovanni, son of Bicci dei Medici (1360–1429), another branch of the family arose, and became from that time forward its representative branch. Indeed this Giovanni may be considered the actual founder of Medicean greatness. He took little part in political affairs, but realized an immense fortune by trade,—establishing banks in Italy and abroad, which in his successors' hands became the most efficient engines of political power. The council of Constance (1414–1418) enabled Giovanni dei Medici to realize enormous profits. Besides, like his ancestor Salvestro, he was a constant supporter of the lesser guilds in Florence. Historians record his frequent resistance to the Albizzi when they sought to oppress the people with heavier taxation, and his endeavours to cause the chief weight to fall upon the richer classes. For this reason he was in favour of the so-called law of *catasto*, which, by assessing the property of every citizen, prevented those in power from arbitrarily imposing taxes that unjustly burdened the people. In this way, and by liberal loans of money to all who were in need of it, he gained a reputation that was practically the foundation-stone of the grand family edifice. Giovanni dei Medici died in 1429 leaving two sons, Cosimo (1389–1464) and Lorenzo (1395–1440). From the former proceeded the branch that held absolute sway for many generations over the nominal republic of Florence, and gave to Italy popes like Leo X. and Clement VII. On the extinction of this elder line in the 16th century, the younger branch derived from Lorenzo, Cosimo's brother, seemed to acquire new life, and for two centuries supplied grand-dukes to Tuscany. Cosimo, surnamed Cosimo the Elder, to distinguish him from the many others bearing the same name, and honoured after his death by the title of *Pater patriæ*, first succeeded in solving the strange problem of becoming absolute ruler of a republic that was keenly jealous of its liberty, without holding any fixed office, without suppressing any previous form of government, and always preserving the appearance and demeanour of a private citizen. Born in 1389, he had already reached the age of forty at the time of his father's death. He had a certain amount of literary culture, and throughout his life showed much taste and an earnest love both for letters and art. But his father had mainly trained him to commerce, for which he had a special liking and aptitude. In fact he was devoted to business to the day of his death, and like his forefathers derived pecuniary advantage from his friendly relations with the papal court. He accompanied Pope John XXIII. to the council of Constance, transacted a vast amount of business in that city, and made very large gains. He then travelled in Germany, and after his return to Florence discharged several ambassadorial missions. At the death of his father he was possessed of a vast fortune and an extended experience, and inherited the leadership of the opposition to the then dominant party of the greater guilds headed by Rinaldo degli Albizzi, Palla Strozzi, and Niccolò da Uzzano. Of gentle and kindly manners, generous in lending and even in giving money whenever he could gain popularity by that means, at critical moments he frequently came to the succour of the Government itself. He was very dexterous in turning his private liberalities to account for the increase of his political prestige, and showed no less acumen and still fewer scruples in making use of his political prestige for purposes of pecuniary profit. Indeed, whenever his own interests were at stake, he showed himself capable of positive villainy, although this was always tempered by calculation. Cosimo proved his skill in these knavish arts during the war between Florence and Lucca. He had joined the Albizzi in urging on this war, and many writers assert that he turned it to much pecuniary advantage by means of loans to the Government and other banking operations. When, however, military affairs went badly, Cosimo joined the discontented populace in invectives against the war and those who had conducted it. This won him an enormous increase of popularity, but the hatred of the Albizzi and their friends augmented in equal degree, and a conflict became inevitable. The Albizzi, who were far more impetuous and impatient than Cosimo, were now bent upon revenge. In 1433 one of their own friends, Bernardo Guadagni, was elected gonfalonier, and thereupon Cosimo dei Medici was called to the palace and summarily imprisoned in the tower. A general assembly of the people was convoked and a "balía" chosen, which changed the Government and sent Cosimo into exile. Undoubtedly the Albizzi party would have preferred a heavier sentence, but they did not dare to attempt their enemy's life, being well aware of the great number of his adherents. Cosimo had some apprehension that he might be poisoned in prison, but Federigo dei Malavolti, captain of the palace guard, showed him the utmost kindness, and, in order to soothe his fears, voluntarily shared his meals. On the 3d October the prisoner was sent to Padua, his allotted place of exile.

Giovanni.

Cosimo the Elder.

The Albizzi speedily saw that they had done either too much or too little. While seeking to keep the government entirely in their own hands, they beheld the continual growth of the Medici party. When it was necessary to make a campaign in Romagna against the mercenary captains commanding the forces of the duke of Milan, it was plainly seen that in banishing Cosimo the republic had lost the only citizen banker in a position to assist it with considerable loans. The Florentines were defeated by Piccinino in 1434, and this event greatly increased the public exasperation against the Albizzi. Meanwhile Cosimo, who had gone to Padua as a private individual, was entertained there like a prince. Then, being permitted to transfer his residence to Venice, he entered on a course of lavish expenditure. He was overwhelmed with letters and appeals from Florence. Finally, on the 1st of September 1434, a signory was elected composed of his friends, and his recall was decreed. Rinaldo degli Albizzi determined to oppose it by force, and rushed to the Piazza with a band of armed men; but his attempt failed, and he left the country to return no more. The Medici were now reinstated in all their former dignities and honours, and Cosimo, on the evening of September 6th, rode past the deserted mansions of the Albizzi and re-entered his own dwelling after an exile of a year. For three centuries, dating from that moment, the whole history of Florence was connected with that of the house of Medici.

Cosimo's first thought was to secure himself against all future risk of removal from Florence, and accordingly he drove the most powerful citizens into exile to all parts of Italy. Nor did he spare even his former political adversary, Palla Strozzi, although the latter had been favourable to him during the recent changes. His rigour in this particular case was universally censured, but Cosimo would tolerate no rivals in the city, and was resolved to abase the great families and establish his power by the support of the lower classes. He was accustomed to say that states could not be ruled by paternosters. Still, when cruelty seemed requisite, he always contrived that the chief odium of it should fall upon others. When Neri Capponi, the valiant soldier and able diplomatist, gained great public favour by his military prowess, and his influence was further increased by the friendship of Baldaccio d'Anghiari, captain of the infantry, Cosimo resolved to weaken his position by indirect means. Accordingly, when in 1441 a partisan of the Medici was elected gonfalonier, Baldaccio was instantly summoned to the palace, imprisoned, murdered, and his body hurled from the window. No one could actually fix this crime upon Cosimo, but the majority believed that he had thus contrived to rid himself of one enemy and cripple another without showing his hand. It was impossible for Cosimo openly to assume the position of tyrant of Florence, nor was it worth his while to become gonfalonier, since the term of office only lasted two months. It was necessary to discover some other way without resorting to violence; he accordingly employed what were then designated "civil methods." He managed to attain his object by means of the "balíe." These magistracies, which were generally renewed every five years, placed in the ballot bags the names of the candidates from whom the signory and other chief magistrates were to be chosen. As soon as a "balía" favourable to Cosimo was formed, he was assured for five years of having the government in the hands of men devoted to his interests. He had comprehended that the art of politics depended rather upon individuals than institutions, and that he who ruled men could also dictate laws. His foreign policy was no less astute. His great wealth enabled him to supply money not only to private individuals, but even to foreign potentates. Philippe de Comines tells us that Cosimo frequently furnished Edward IV. of England with sums amounting to many hundred thousand florins. When Tommaso Parentucelli was still a cardinal, and in needy circumstances, Cosimo made him considerable loans without demanding guarantees of payment. On the cardinal's accession to the tiara as Nicholas V. he was naturally very well disposed towards Cosimo, and employed the Medici bank in Rome in all the affairs of the curia, which brought immense profits to the house. At the time when Francesco Sforza was striving for the lordship of Milan, Cosimo foresaw his approaching triumph, showed him great friendship, and aided him with large sums of money. Accordingly, when Sforza became lord of Milan, Cosimo's power was doubled. Without the title of prince, this merchant showed royal generosity in his expenditure for the promotion of letters and the fine arts. Numerous edifices were raised and public works accomplished with his purse. Besides his palace in the city, he constructed noble villas at Careggi, Fiesole, and other places. He built the basilica of Fiesole, and that of St Lorenzo in Florence, and enlarged the church and monastery of St Mark. Even in distant Jerusalem he endowed a hospice for the use of pilgrims. The artists of the day comprised men like Donatello, Brunelleschi, Ghiberti, Luca della Robbia, and many others, and Cosimo's magnificent commissions not only developed their powers but stimulated other men of wealth to the patronage of art. Without being a scholar, Cosimo had a genuine taste for letters, and gave them much and efficient patronage. He purchased many Greek and Latin manuscripts; he opened the first public library at St Mark's at his own expense, and founded another in the abbey of Fiesole. The Greek refugees from Constantinople found a constant welcome in his palace. During the council of Florence (1439–1442), Gemisthus Pletho spoke to him with enthusiasm of the Platonic philosophy. Cosimo was so deeply attracted by the theme that he decided to have the young Marsilio Ficino trained in philosophy and Greek learning in order to make a Latin translation of the complete works of Plato. And thus a version was produced that is still considered one of the best extant, and that Platonic academy was founded which led to such important results in the history of Italian philosophy and letters. On the 1st of August 1464 Cosimo breathed his last, at the age of seventy-five, while engaged in listening to one of Plato's dialogues.

The concluding years of his life had been years of little happiness for Florence. Being old and infirm, he had left the government to the management of his friends, among whom Luca Pitti was one of the more powerful, and they had ruled with disorder, corruption, and cruelty. The lordship of Florence accordingly did not pass without some difficulty and danger into the hands of Piero, surnamed the Gouty, Cosimo's only surviving legitimate son. Afflicted by gout, and so terribly crippled that he was often only able to use his tongue, the new ruler soon discovered that a plot was on foot to overthrow his power. However, showing far more courage than he was supposed to possess, he had himself borne on a litter from his villa to Florence, defeated his enemies' designs, and firmly re-established his authority. But his success may be mainly attributed to the enormous prestige bequeathed by Cosimo to his posterity. Piero died at the end of five years' reign, on the 3d December 1469, leaving two sons, Lorenzo (1449–92) and Giuliano (1453–78). The younger, the gentler and less ambitious of the pair, was, as we shall presently see, quickly removed from the world. Lorenzo, on the contrary, at once seized the reins of state with a firm grasp, and was, chronologically, the second of the great men bestowed upon Italy by the house of Medici. In literary talent he was immensely superior to Cosimo, but greatly his inferior in the conduct of the commercial affairs of the house, for which he had neither aptitude nor inclination. In politics he had nobler conceptions and higher ambitions, but he was more easily carried away by his passions, less prudent in his revenge, and more disposed to tyranny. He had studied letters from his earliest years under the guidance of Ficino and other leading literati of the day, who were constant habitués of the Medici palace. At the age of eighteen he visited the different courts of Italy in order to gain experience of the world and mankind. At his father's death he was only twenty-one years old, but instantly showed his determination to govern Florence with greater despotism than his father or grandfather. He speedily resorted to the system of the "balíe," and was very dexterous in causing the first to be chosen to suit his purpose. He then proceeded to humiliate the great families and exalt those of little account, and this was the policy he constantly pursued. His younger brother Giuliano, being of a mild and yielding disposition, had only a nominal share in the government.

Piero the Gouty.

Lorenzo the Magnificent.

Lorenzo's policy was not exempt from danger, but, although prosecuted with less caution, it was still the old astute and fortunate policy initiated by Cosimo. But the grandson bestowed no care upon his commercial interests, although squandering his fortune with far greater lavishness. Accordingly he was sometimes driven to help himself from the public purse without ever being able to assist it as Cosimo had done. All this excited blame and enmity against him, while his greed in the matter of the alum mines of Volterra, and the subsequent sack of that unhappy city, were crimes for which there was no excuse. Among his worst enemies were the Pazzi, and, as they formed a very powerful clan, he sought their ruin by competing with them even in business transactions. They were just on the point of inheriting the large property of Giovanni Borromeo when, in order to prevent this, Lorenzo hurriedly caused a law to be passed that altered the right of succession. The hatred of the Pazzi was thereby exasperated to fury. And in addition to these things there ensued a desperate quarrel with Pope Sixtus IV., a man of very impetuous temper, who, on endeavouring to erect a state on the frontiers of the Florentine republic for the benefit of his nephews, found a determined and successful opponent in Lorenzo. Consequently the Pazzi and Archbishop Salviati, another enemy of Lorenzo, aided by the nephews of the pontiff, who was himself acquainted with the whole matter, determined to put an end to the family.

On the 26th April 1478, while Giuliano and Lorenzo were attending high mass in the cathedral of Florence, the former was mortally stabbed by conspirators, but the latter was able to beat back his assailants and escape into the sacristy. His life saved; and, no longer having to share the government with a brother, Lorenzo profited by the opportunity to wreak cruel vengeance upon his foes. Several of the Pazzi and their followers were hanged from the palace windows; others were hacked to pieces, dragged through the streets, and cast into the Arno, while a great many more were condemned to death or sent into exile. Lorenzo seemed willing and able to become a tyrant. But he stopped short of this point. He knew the temper of the city, and had also to look to fresh dangers threatening him from without. The pope had excommunicated him, put Florence under an interdict, and, being seconded by the Neapolitan king, made furious war against the republic. These hostilities speedily assumed alarming proportions, and the Florentines began to tire of submitting to so many hardships in order to support the yoke of a fellow-citizen. Lorenzo's hold over Florence seemed endangered. But he did not lose heart, and, on the contrary, rose superior to the difficulties by which he was encompassed. He boldly journeyed to Naples, to the court of King Ferdinand of Aragon, who was reputed to be as treacherous as he was cruel, and succeeded in obtaining from him an honourable peace, that soon led to a reconciliation with Sixtus. Thus at last Lorenzo found himself complete master of Florence, and was in a position to turn his power to account. But, as the "balíe" changed every five years, it was always requisite, in order to retain his supremacy, that he should be prepared to renew the usual manœuvre at the close of that term and have another elected equally favourable to his aims. This was often a difficult achievement, and Lorenzo showed much dexterity in overcoming all obstacles. In 1480 he compassed the institution of a new council of seventy, which was practically a permanent "balía" with extended powers, inasmuch as it not only elected the chief magistrates, but had also the administration of numerous state affairs. But, this permanent council of his own devoted adherents once formed, his security was firmly established. By this means, the chroniclers tell us, "liberty was buried," but the chief affairs of the state were always conducted by intelligent and experienced men, who promoted the public prosperity. Florence was still called a republic; the old institutions were still preserved, if only in name. Lorenzo was absolute lord of all, and virtually a tyrant. His immorality was scandalous; he kept an army of spies, and frequently meddled in the citizens' most private affairs, and exalted men of the lowest condition to important offices of the state. Yet, as Guicciardini remarks, "if Florence was to have a tyrant, she could never have found a better or more pleasant one." In fact all industry, commerce, and public works made enormous progress. The civil equality of modern states, which was quite unknown to the Middle Ages, was more developed in Florence than in any other city of the world. Even the condition of the peasantry was far more prosperous than elsewhere. And Lorenzo's authority was not confined to Tuscany, but was also very great throughout the whole of Italy. He was on the friendliest terms with Pope Innocent VIII., from whom he obtained the exaltation of his son Giovanni to the cardinalate at the age of fourteen. This boy cardinal was afterwards Pope Leo X. From the moment of the decease of Sixtus IV., the union of Florence and Rome became the basis of Lorenzo's foreign policy. By its means he was able to prevent the hatreds and jealousies of the Sforzas of Milan and the Aragonese of Naples from bursting into the open conflict that long threatened, and after his death actually caused, the beginning of new and irreparable calamities. Hence Lorenzo was styled the needle of the Italian compass.

But the events we have narrated cannot suffice for the full comprehension of this complex character, unless we add the record of his deeds as a patron of letters and his achievements as a writer. His palace was the school and resort of illustrious men. Within its walls were trained the two young Medici afterwards known to the world as Leo X. and Clement VII. Ficino, Poliziano, Pico della Mirandola, and all members of the Platonic academy were its constant habitués. It was here that Pulci gave readings of his *Morgante*, and Michelangelo essayed the first strokes of his chisel. Lorenzo's intellectual powers were of exceptional strength and versatility. He could speak with equal fluency on painting, sculpture, music, philosophy, and poetry. But his crowning superiority over every other Mæcenas known to history lay in his active participation in the intellectual labours that he promoted. Indeed at certain moments he was positively the leading spirit among the literati of his time. He was an elegant prose writer, and was likewise a poet of real originality. At that period Italians were forsaking erudition in order to forward the revival of the national literature by recurring to the primitive sources of the spoken tongue and popular verse. It is Lorenzo's lasting glory to have been the initiator of this movement. Without being—as some have maintained—a poet of genius, he was certainly a writer of much finish and eloquence, and one of the first to raise popular poetry to the dignity of art. In his *Ambra*, his *Caccia del Falcone*, and his *Nencia da Barberino*, he gives descriptions of nature and of the rural life that he loved, with the graphic power of an acute and tasteful observer, joined to an ease of style that occasionally sins by excess of homeliness. Both in his art and in his politics he leant upon the people. The more oppressive his government, the more did he seek in his verses to incite the public to festivities and lull it to slumber by sensual enjoyments. In his *Ballate*, or songs for dancing, and more especially in his carnival songs, a kind of verse invented by himself, Lorenzo displayed all the best qualities and worst defects of his muse. Marvellously and spontaneously elegant, very truthful and fresh in style, fertile in fancy and rich in colour, they are often of a most revolting indecency. And these compositions of one filling a princely station in the city were often sung by their author in the public streets, in the midst of the populace.

Lorenzo left three sons,—Pietro (1471–1503), Giovanni (1475–1521), and Giuliano (1479–1516). He was succeeded by Pietro, whose rule lasted but for two years. Pietro. During this brief term he performed no good deeds, and only displayed inordinate vanity and frivolity. His conduct greatly helped to foment the hatred between Lodovico Sforza and Ferdinand of Naples, which hastened the coming of the French under Charles VIII., and the renewal of foreign invasions. No sooner did the French approach the frontiers of Tuscany than Pietro, crazed with fear, hastened to meet them, and, basely yielding to every demand, accepted terms equally humiliating to himself and the state. But, returning to Florence, he found that the enraged citizens had already decreed his deposition, in order to reconstitute the republic, and was therefore compelled to escape to Venice. His various plots to reinstate himself in Florence were all unsuccessful. At last he went to the south of Italy with the French, was drowned at the passage of the Garigliano in 1503, and was buried in the cloister of Monte Cassino.

The ensuing period was adverse to the Medici, for a republican government was maintained in Florence from 1494 to 1512, and the city remained faithful to its alliance with the French, who were all-powerful in Italy. Cardinal

Giovanni, the head of the family, resided in Rome, playing the patron to a circle of literati, artists, and friends, seeking to increase his popularity, and calmly waiting for better days. The battle of Ravenna wrought the downfall of the fortunes of France in Italy, and led to the rise of those of Spain, whose troops entered Florence to destroy the republic and reinstate the Medici. Pietro had now been dead for some time, leaving a young son, Lorenzo (1492–1519), who was afterwards duke of Urbino. The following year (1513) Cardinal Giovanni was elected pope, and assumed the name of Leo X. He accordingly removed to Rome, leaving his brother Giuliano with his nephew Lorenzo in Florence, and accompanied by his cousin Giulio, who was a natural son of the Giuliano murdered in the conspiracy of the Pazzi, and was soon destined to be a cardinal and ultimately a pope. Meanwhile his kinsmen in Florence continued to govern that city by means of a "balía," although preserving an empty show of republican institutions. And thus, being masters of the whole of central Italy, the Medici enjoyed great authority throughout the country, and their ambition plumed itself for still higher flights. This was the moment when Niccolò Machiavelli, in his treatise *The Prince*, counselled them to accomplish the unity of Italy by arming the whole country, and expelling its foregin invaders.

Cardinal Giovanni (Leo X.). Giuliano. Lorenzo.

Leo X., who is only indirectly connected with the history of Florence, gave his name to the age in which he lived in consequence of his magnificent patronage of art and letters in Rome. But he was merely a clever amateur, and had not the literary gifts of his father Lorenzo. He surrounded himself with versifiers and inferior writers, who enlivened his board and accompanied him wherever he went. He liked to lead a gay and untroubled life, was fond of theatrical performances, satires, and other intellectual diversions. His patronage of the fine arts, his genuine affection for Raphael, and the numerous works he caused to be executed by him and other artists, have served to confer an exaggerated glory on his name. He failed to comprehend the significance of the great religious movement already stirring in Germany, and had not the remotest idea of the grave importance of the Reformation, which indeed he unconsciously promoted by his reckless and shameless sale of indulgences. The whole policy of Pope Leo X. consisted in oscillating between France and Spain, in always playing fast and loose, and deceiving both powers in turn. Yet the evil results of this contemptible policy never seemed to disturb his mind. He finally joined the side of the emperor Charles V., and in 1521, at the time of the defeat of the French by the Spanish troops on the river Adda, he ceased to breathe at his favourite villa of Magliana. Giuliano dei Medici had died during Leo's reign, in 1516, without having ever done anything worthy of record. He was the husband of Philiberta of Savoy, was duke of Nemours, and left a natural son, Ippolito dei Medici (1511–1535), who afterwards became a cardinal. Lorenzo, being of more ambitious temper, was by no means content to remain at the head of the Florence Government hampered by many restrictions imposed by republican institutions, and subject to the incessant control of the pope. In his eagerness to aggrandize his kinsmen, the latter had further decided to give Lorenzo the duchy of Urbino, and formally invested him in its rights, after expelling on false pretences its legitimate lord, Francesco Maria della Rovere. This prince, however, soon returned to Urbino, where he was joyously welcomed by his subjects, and Lorenzo regained possession only by a war of several months, in which he was wounded. In 1519 he also died, worn out by disease and excess. By his marriage with Madeleine de la Tour d'Auvergne, he had one daughter, Caterina dei Medici (1519–89), married in 1533 to Henry, duke of Orleans, afterwards king of France. She played a long and sinister part in the history of that country. Lorenzo also left a natural son named Alessandro, inheriting the frizzled hair and projecting lips of the negro or mulatto slave who had given him birth. His miserable death will be presently related. Thus the only three surviving representatives of the chief branch of the Medici, Cardinal Giulio, Ippolito, and Alessandro were all of illegitimate birth, and left no legitimate heirs.

Cardinal Giulio (Clement VII.).

Cardinal Giulio, who had laboured successfully for the reinstatement of his family in Florence in 1512, had been long attached to the person of Leo X. as his trusted factotum and companion. He had been generally regarded as the mentor of the pope, who had no liking for hard work. But in fact, his frivolity notwithstanding, Leo X. always followed his own inclinations. He had much aptitude for command, and pursued his shuffling policy without any mental anxiety. Giulio, on the contrary, shrank from all responsibility, muddled his brains in weighing the reasons for and against every possible decision, and was therefore a better tool of government in others' hands than he was fit to govern on his own account. When Giuliano and Lorenzo died, the pope appointed the cardinal to the government of Florence. In that post, restricted within the limits imposed by republican institutions, and acting under the continual direction of Rome, he performed his duties fairly well. He caressed the citizens with hopes of extended liberties, which, although never destined to be fulfilled, long served to keep men's minds in a pleasant flutter of expectation; and when the more impatient spirits attempted to raise a rebellion he speedily quenched it in blood. When, after the death of Leo X. and the very brief pontificate of Adrian VI., he was elected pope (1523) under the name of Clement VII., he entrusted the government of Florence to Cardinal Silvio Passerini conjointly with Alessandro and Ippolito, who were still too young to do much on their own account.

The pontificate of Leo X. had been a time of felicity to himself if of disaster to Italy and the church. The reign of Clement, on the contrary, was fatal to himself as well, a result chiefly due to his hesitating temper and continual uncertainty of mind. His policy, like that of Leo X., consisted in perpetual oscillation between France and Spain. By his endeavours to trick all the world, he frequently ended in being tricked himself. In 1525 he was the ally of the French, who then suffered a terrible defeat at Pavia, where their king Francis I. was taken prisoner. The armies of Charles V. triumphantly advanced, without Clement being able to oppose any effectual resistance. Both Rome and Florence were threatened with a fearful catastrophe.

Giovanni delle Bande Nere.

Thus far we have had no occasion to speak of the younger branch of the Medici, descended from Lorenzo, brother to Cosimo the Elder. Always in obscurity, and always held in check by the elder line, it now seemed to acquire new life, and first entered the arena of history when the other was on the point of extinction. In fact the most valiant captain of the papal forces was Giovanni dei Medici, afterwards known by the name of Giovanni delle Bande Nere. His father was Giovanni, son of Pier Francesco, who was the son of Lorenzo, the brother of Cosimo dei Medici. History has little to tell of the elder Giovanni; but his wife Caterina Sforza, of whom he was the third husband, was a woman of more than masculine vigour. Giovanni dei Medici married her in 1497, but died in 1498, leaving her with one son who was christened Lodovico, but afterwards took his father's name of Giovanni (1498–1526). Trained to arms from his earliest years, this youth inherited all the energy of his mother, whose Sforza blood seemed to infuse new life into the younger branch of the Medici. Notwithstanding his extreme youth, he had already achieved the title of the best captain in Italy. He always fought with immense dash and daring, and was devotedly loved and obeyed by his soldiery. He was the only leader who opposed a determined resistance to the imperial forces. He was seriously wounded at Pavia when fighting on the French side. On his recovery he joined the army of the League, and was much enraged by finding that the duke of Urbino, commander of the Venetian and papal forces, would never decide on attacking. When the imperial troops were struggling through the marshes of Mantua, surrounded on every side, and without stores or ammunition, Giovanni could not resign himself to inactivity like his colleagues in command. He was ignorant that the imperialists had just received supplies and artillery from the duke of Ferrara, and therefore daringly attacked them with a small body of men without taking any precautions for defence. One of the first shots fired by the enemy injured him so fatally that he died a few days after. He was married to Maria Salviati, by whom he had one son, Cosimo (1519–1574), born, as we shall see, to lofty fortunes, for he became the first grand-duke of Tuscany, and indeed the founder of the grand-duchy and the new dynasty.

Meanwhile the imperial army pursued its march upon Rome, captured the Eternal City after a few hours' combat, and cruelly sacked it during many days (1527). Thanks to his perpetual shuffling and excessive avarice, the pope found himself utterly forsaken, and, being unable to defend the city, was obliged to seek refuge in the castle of St Angelo, whence he only effected his escape after some months. He then signed a treaty of alliance with the emperor (1529), who sent an army to besiege Florence and restore the Medici, whom the people had expelled in 1527 on the re-establishment of the republic. After an heroic defence, the city was forced to surrender (1530); and, although it was expressly stipulated that the ancient liberties of Florence should be respected, every one foresaw that the conditions would be violated. In fact, pope and emperor immediately began to dispute as to which should be the new lord of the city. Clement VII. had inherited the traditional family dislike for the younger branch of his kin, and so the choice lay between the two bastards Ippolito and Alessandro. The former being a cardinal, the latter was chosen. Alessandro, who already bore the title of duke of Città di Penna, came to Florence in 1531, and by imperial patent was nominated head of the republic. According to the terms of this patent, the former liberty enjoyed under the Medicean rule was to remain intact. But no previous ruler of the city had enjoyed hereditary power confirmed by imperial patent, and such power was incompatible with the existence of a republic. Moreover, Clement VII. showed dissatisfaction with the uncertainty of the power conferred upon his kinsman, and finally succeeded in obtaining additional privileges. On the 4th of April 1532 a parliament was convoked for the last time in Florence, and, as usual, approved every measure proposed for acceptance. Accordingly a new council was formed of two hundred citizens elected for life, forty-eight of which number were to constitute a senate. Alessandro, as duke of the republic, filled the post of gonfalonier, and carried on the government with the assistance of three senators, changed every three months, who took the place of the suppressed signory.

Duke Alessandro.

The duke's chief advisers, and the contrivers of all these arrangements, were Baccio Valori, Francesco Vettori, and above all Francesco Guicciardini,—men, especially the two latter, of lofty political gifts and extensive influence. The mind and character of Duke Alessandro were as yet comparatively unknown. At first he seemed very anxious to win the favour of the people, and disposed to rule with justice and prudence. But soon encountering difficulties that he was unable to overcome, he began to neglect the business of the state, treated his new office as affording the means for increased indulgence in pleasure and vice, and acted as if the sole function of government consisted in lulling the people by festivities and corrupting it by the dissolute life of which he set the example. The question of the moment was the transformation of the old republican régime into a princedom; as an unavoidable result of this change it followed that Florence was no longer to be the ruling city to whose inhabitants alone belonged the monopoly of political office. When the leading Florentine families realized, not only that the republic was destroyed, but that they were reduced to equality with those whom they had hitherto regarded as their inferiors and subjects, their rage was indescribable, and hardly a day passed without the departure of influential citizens who were resolved to achieve the overthrow of their new ruler. They found a leader in Cardinal Ippolito dei Medici, who was then in Rome, embittered by the preference given to Alessandro, and anxious to become his successor with the least possible delay. Under the pressure of terror the duke at once became a tyrant. He garrisoned the different cities, and began the erection in Florence of the Fortezza da Basso, built chiefly at the expense of Filippo Strozzi, who afterwards met his death within its walls.

Cardinal Ippolito.

In 1534 Clement VII. died, and the election fell on Paul III., from whom Cardinal Ippolito hoped to obtain assistance for his designs. Accordingly the principal Florentine exiles were despatched on a mission to the emperor Charles V. with complaints of Alessandro's tyranny and his shameless violation of the terms upon which the city had surrendered. Cardinal Ippolito also represented his own willingness to carry on the government of Florence in a more equitable manner, and promised the emperor a large sum of money. Reply being delayed by the emperor's absence, he became so impatient that he set out, accompanied by several exiles, to meet Charles in Tunis, but on the 10th of August 1535 died suddenly by the way, at Itri, poisoned by order of Alessandro. Such at least was the general belief, and it was confirmed by the same fate befalling other enemies of the duke about the same time. On the emperor's return from Africa, the exiles presented themselves to him in Naples, and the venerable patriot Jacopo Nardi pleaded their cause. Duke Alessandro, being cited to appear, came to Naples accompanied by Francesco Guicciardini, who by speaking in his defence rendered himself odious to all friends of liberty, and irretrievably tarnished his illustrious name. The cardinal being dead, it was hard to find a successor to Alessandro. On this account, and perhaps to some extent through the emperor's personal liking for the duke, the latter rose higher than before in the imperial favour, married Margaret of Austria, the natural daughter of Charles, and returned to Florence with increased power. And now Alessandro indulged unchecked in the lowest excesses of tyranny, and although so recently a bridegroom gave way to increased libertinism. His whole time was passed in vicious haunts and in scandalous adventures. In order to conceal the obscurity of his birth, he left his mother to starve, and it was even asserted that he finally got rid of her by poison.

Lorenzino dei Medici.

His constant associate in this disgraceful routine was his distant kinsman Lorenzo, generally known as Lorenzino dei Medici. Of the younger branch of the Medici, the latter was second cousin of the Cosimo already mentioned as the son of Giovanni delle Bande Nere. He had much culture and literary talent, but led an irregular life, sometimes acting like a madman and sometimes like a villain. He was a writer of considerable elegance, the author of several plays, one of which, the *Aridosio*, was held to be among the best of the age, and he was a worshipper of antiquity. Notwithstanding these tastes, when in Rome he knocked off the heads of some of the finest statues of the age of Adrian, an act by which Clement VII. was so incensed that he threatened to have him hanged. Thereupon Lorenzino fled to Florence, where he became the friend of Duke Alessandro and his partner in the most licentious excesses. They went together to houses of ill-fame, and violated private dwellings and convents. They often showed themselves in public mounted on the same horse. All Florence eyed them with disgust, but no one foresaw the tragedy that was soon to take place.

Assassination of Alessandro. On the evening of January 5th, 1537, after a day passed in the usual excesses, Lorenzino led the duke to his own lodging, and left him there, promising shortly to return with the wife of Leonardo Ginori. Alessandro, worn out by the exertions of the day, fell asleep on the couch while awaiting Lorenzino's return. Before long the latter came accompanied by a desperado known as the Scoronconcolo, who aided him in falling on the sleeper. Roused by their first thrusts, the duke fought for his life, and was only despatched after a violent struggle. The murderers then lifted the body into bed, hid it beneath the clothes, and, Lorenzino having attached a paper to it bearing the words, *vincit amor patriæ, laudumque immensa cupido*, they both fled to Venice. In that city Lorenzino was assassinated some ten years later, in 1548, at the age of thirty-two, by order of Alessandro's successor. Thus he was only about twenty-two at the time he committed the murder. He wrote an *Apologia*, in which he defended himself with great skill and eloquence, saying that he had been urged to the deed solely by love of liberty. For this reason alone he had followed the example of Brutus and played the part of friend and courtier. The tone of this *Apologia* is so straightforward, sometimes even so eloquent and lofty, that we should be tempted to give it credence were it possible to believe the assertions of one who not only by his crime but by the infamy of his previous and subsequent career completely gave the lie to his vaunted nobility of purpose. By Alessandro's death the elder branch of the Medici became extinct, and thus the appearance of the younger line was heralded by a bloody crime.

When the duke's absence from his own palace was discovered on the morning of January 6th, he was at first supposed to have spent the night with one of his mistresses; but soon, some alarm being felt, search was made, and Cardinal Cybo was the first to discover the murder. Enjoining the strictest secrecy, he kept the corpse concealed for three days, and then had it interred in the sacristy of San Lorenzo. Meanwhile he had hastily summoned Alessandro Vitelli and the other captains, so that, by the time Alessandro's death was made public, the city was already filled with troops. The cardinal then convoked the council of forty-eight to decide upon a successor. Alessandro's only issue was a natural son named Giulio, aged five. The cardinal favoured his election, in the hope of keeping the real sovereignty in his own hands. But he speedily saw the impossibility of carrying out a design that was ridiculed by all. On the other hand, Guicciardini, Vettori, and others of the leading citizens favoured the choice of Cosimo, the son of Giovanni delle Bande Nere. He was already in Florence, was aged seventeen, was keen-witted and aspiring, strong and handsome in person, heir to the enormous wealth of the Medici, and, by the terms of the imperial patent, was Alessandro's lawful

Cosimo I. successor. Charles V. approved the nomination of Cosimo, who without delay seized the reins of government with a firm grasp. Like Alessandro, he was named head of the republic; and Guicciardini and others who had worked hardest in his cause hoped to direct him and keep him under their control. But Cosimo soon undeceived them by proving that, his youth notwithstanding, he had a will of his own, and was resolved to rule unshackled by republican forms and unhampered by advisers disposed to act as mentors. The Florentines had now an absolute prince who was likewise a statesman of eminent ability.

On learning the death of Alessandro and the election of Cosimo, the exiles appreciated the necessity for prompt action, as all delay would be fatal to the overthrow of the Medicean rule. They had received money and promises from France; they were strengthened by the adhesion of Filippo Strozzi and Baccio Valori, who had both become hostile to the Medici through the infamous conduct and mad tyranny of Alessandro; and Strozzi brought them the help of his enormous fortune and the prowess of that very distinguished captain, his son Piero. The exiles accordingly met, and assembled their forces at Mirandola. They had about four thousand infantry and three hundred horse; among them were members of all the principal Florentine families; and their leaders were Bernardo Salviati and Piero Strozzi. They marched rapidly, and entered Tuscany towards the end of July 1537. Cosimo on this occasion displayed signal capacity and presence of mind. Fully informed of the exiles' movements by means of his spies, he no sooner learned their approach than he ordered Alessandro Vitelli to collect the best German, Spanish, and Italian infantry at his disposal, and advance against the enemy without delay. On the evening of July 31 Vitelli marched towards Prato with seven hundred picked infantry and a band of one hundred horse, and on the way fell in with other Spanish foot soldiers who joined the expedition. At early dawn the following morning he made a sudden attack on the exiles' advanced guard close to Montemurlo, an old fortress converted into a villa belonging to the Nerli. Having utterly routed them, he proceeded to storm Montemurlo, where Filippo Strozzi and a few of his young comrades had taken refuge and barricaded the gates. Knowing that they must either conquer or die, they made a desperate resistance for some hours, and then, overwhelmed by superior numbers, were obliged to yield themselves prisoners. The main body of the army was still at some distance, having been detained in the mountains by heavy rains and difficult passes, and, on learning the defeat at Montemurlo, its leader refused to advance, and turned back by the way he had come. Alessandro Vitelli then re-entered Florence with his victorious army and his fettered captives. Cosimo had achieved his first triumph.

All the prisoners, who were members of great families, were brought before Cosimo, and were received by him with courteous coldness. Soon, however, a scaffold was erected in the Piazza, and on four mornings in succession four of the prisoners were beheaded. Then the duke saw fit to stay the executions. Baccio Valori, however, and his son and nephew were beheaded on the 20th of August in the courtyard of the Bargello. Filippo Strozzi still survived, confined in the Fortezza da Basso, that had been built at his expense. His family was illustrious, he had numerous adherents, and he enjoyed the protection of the French king. Nevertheless Cosimo only awaited some plausible pretext to rid himself of this dreaded enemy. He brought him to trial and had him put to the question. But this cruelty led to nothing, for Strozzi denied every accusation and bore the torture with much fortitude. On December 18th he was found dead in his prison, with a blood-stained sword by his side, and a slip of paper bearing these words: *exoriare aliquis nostris ex ossibus ultor.* It was believed that, having renounced all hope of his life being spared, Strozzi had preferred suicide to death at the hands of the executioner. Some, however, thought that Cosimo had caused him to be murdered, and adopted this mode of concealing the crime. The young prince's cold-blooded massacre of his captives cast an enduring shadow upon his reign and dynasty. But it was henceforward plain to all that he was a man of stern resolve, who went straight to his end without scruples or half measures. Before long he was regarded by many as the incarnation of Machiavelli's *Prince*, "inasmuch as he joined daring to talent and prudence, was capable of great cruelty, and yet could practise mercy in due season." Guicciardini, who still pretended to act as mentor, and who on account of his many services had a certain influence over him, was obliged to withdraw from public life and busy himself with writing his *History* at his villa of Arcetri. He died in this retreat in 1540, and it was immediately rumoured that the duke had caused him to be poisoned. This shows the estimation in which Cosimo was now held. It was true that he punished with death all who dared to resist his will. By 1540 sentence of death had been pronounced against four hundred and thirty contumacious fugitives, and during his reign one hundred and forty men and six women actually ascended the scaffold, without counting those who perished in foreign lands by the daggers of his assassins. He reduced the old republican institutions to empty forms, by making the magistrates mere creatures of his will. He issued the sternest edicts against the rebels, particularly by the law known as the "Polverina," from the name of its proposer Jacopo Polverini. This law decreed not only the confiscation of the property of exiles, but likewise that of their heirs, even if personally acquired by the latter. Cosimo ruled like the independent sovereign of a great state, and always showed the capacity, firmness, and courage demanded by that station. Only, his state being small and weak, he was forced to rely chiefly upon his personal talent and wealth. It was necessary for him to make heavy loans to the different European sovereigns, especially to Charles V., the most rapacious of them all, and to give enormous bribes to their ambassadors. Besides, he had to carry on wars for the extension of his dominions, and neither his inherited wealth nor the large sums gained by confiscating the estates of rebellious subjects sufficed for all this outlay. He was accordingly compelled to burden the people with taxes, and thus begin at once to diminish its strength.

Cosimo bore a special grudge against the neighbouring republics of Siena and Lucca. Although the latter was small and weak, and the former garrisoned by Spaniards, yet the spectacle of free institutions at the frontiers of his own state served as a continual incitement to subjects disaffected to the new régime. In fact Francesco Burlamacchi, a zealous Lucchese patriot, had conceived the design of re-establishing republican government in all the cities of Tuscany. Cosimo, with the emperor's help, succeeded in having him put to death. Lucca, however, was an insignificant state making no pretence of rivalry, whereas Siena was an old and formidable foe to Florence, and had always given protection to the Florentine exiles. It was now very reluctantly submitting to the presence of a Spanish garrison, and, being stimulated by promises of prompt and efficacious assistance from France, rose in rebellion and expelled the Spaniards in 1552. Cosimo instantly seized the opportunity, wrote to the emperor in terms that appealed to his pride, asked leave to attack Siena, and begged for troops to ensure the success of his enterprise. As no immediate answer arrived, he feigned to begin negotiations with Henry II. of France, and, by thus arousing the imperial jealousy, obtained a contingent of German and Spanish infantry. Then came a long and bloody war. Siena was besieged for fifteen months, and its inhabitants, aided by the valour of Piero Strozzi, who fought under the French flag, made a most heroic resistance, even women and children helping on the walls. But fortune was against them. Piero Strozzi sustained several defeats, and finally the Sienese, having exhausted their ammunition and being decimated by famine and the sword, were obliged to capitulate on honourable terms that were shamelessly violated. By the varied disasters of the siege and the number of fugitives the population was reduced from forty to eight thousand inhabitants. The republicans, still eager to resist, withdrew to Montalcino. Cosimo now ruled the city and territory of Siena in the name of Charles V., who always refused him its absolute possession. After the emperor's abdication, and the succession of Philip II. to the Spanish throne, Cosimo at last obtained Siena and Portoferra by giving up his claim to a sum of 200,000 ducats that he was to have received from Charles V. In 1559 he also captured Montalcino, and thus formed the grand-duchy of Tuscany, but he continued to govern the new state —*i.e.*, Siena and its territories—separately from the old. His rule was intelligent, skilful, and despotic; but his enormous expenses drove him to raise large sums of money by special contrivances unsuited to the country and the people. Hence, notwithstanding the genius of its founder, the grand-duchy held from the first the elements of its future decay. Cosimo preferred to confer office upon men of humble origin in order to have pliable tools, but he also liked to be surrounded by a courtier aristocracy on the Spanish and French pattern. As no Tuscan aristocracy any longer existed, he created new nobles, and tempted foreign ones to come by the concession of various feudal privileges; and, in order to turn this artificial aristocracy to some account, he founded the knightly order of St Stephen, charged with the defence of the coast against pirates, which in course of time won much honour by its prowess. He also established a small standing army for the protection of his frontiers; but, as we have seen, he generally employed German and Spanish troops for his wars, and always had a foreign bodyguard. At the commencement of his reign he opposed the popes in order to maintain the independence of his own state; but later, to obtain help, he truckled to them in many ways, even to the extent of giving up to the Inquisition his own confidant, Piero Carnesecchi, who, being accused of heresy, was beheaded and burnt in 1567. In reward for these acts of submission, the popes showed him friendship, and Pius V. granted him the title of grand-duke, conferring the patent and crown upon him in Rome, although the emperor had always withheld his consent. Finally, however, the latter confirmed the title to Cosimo's successor. The measure most injurious to Tuscany was the fiscal system of taxes, of which the sole aim was to extort the greatest possible amount of money. The consequent damage to industry, commerce, and agriculture was immense, and, added to the devastations caused by the Sienese war, led to their utter ruin. Otherwise Cosimo did not neglect useful measures for the interior prosperity of his state. He was no Mæcenas, but nevertheless restored the Pisan university, enlarged that of Siena, had the public records classified, and also executed public works like the Santa Trinità bridge. During the great inundations of 1557 he turned his whole energy to the relief of the sufferers.

Title of grand-duke.

In 1539 he had espoused Eleonora of Toledo, daughter of the viceroy of Naples, by whom he had several children. Two died in 1562, and their mother soon followed them to the grave. It was said that one of these boys, Don Garcia, had murdered the other, and then been killed by the enraged father. Indeed Cosimo was further accused of having put his own wife to death; but neither rumour had any foundation. He now showed signs of illness and failure of strength. He was not old, but worn by the cares of state and self-indulgence. Accordingly in 1564 he resigned the government to his eldest son, who was to act as his lieutenant, since he wished to remain the virtual head of the state and have power to resume the sceptre on any emergency. In 1570, by the advice of Pius V., he married Camilla Martelli, a young lady of whom he had been long enamoured. In 1574 he died, at the age of fifty-four years and ten months, after a reign of thirty-seven years, leaving three sons and one daughter besides natural children. These sons were Francesco, his successor, who was already at the head of the government, Cardinal Ferdinand, and Piero.

Francesco I.

Francesco I., born in 1541, began to govern as his father's lieutenant in 1564, and was married in 1565 to the archduchess Giovanna of Austria. On beginning to reign on his own account in 1574, he speedily manifested his real character. His training in the hands of a Spanish mother had made him suspicious, false, and despotic. Holding everyone aloof, he carried on the government with the assistance of a few devoted ministers. He compelled his stepmother to retire to a convent, and kept his brothers at a distance from Florence. He loved the privileges of power without its burdens. Cosimo had known how to maintain his independence, but Francesco cast himself like a vassal at Austria's feet. He reaped his reward by obtaining from Maximilian II. the title of grand-duke, for which Cosimo had never been able to win the imperial sanction, but he forfeited all independence. Towards Philip II. he showed even greater submissiveness, supplying him with large sums of money wrung from his over-taxed people. He held entirely aloof from France, in order not to awake the suspicions of his protectors. In short, under his rule the history of Tuscany was reduced to a mere record of local and municipal events. To increase his funds, he traded on his own account, thus creating a monopoly that was ruinous to the country at large, and led to an enormous number of failures. He raised the tax upon corn to so high a rate that few continued to find any profit in growing it, and thus the Maremme, already partly devastated during the war with Siena, were converted into a desert. Even industry declined under this system of government; and, although Francesco founded porcelain manufactories and pietra dura works, they did not rise to any prosperity until after his death. His love of science and letters was the only Medicean virtue that he possessed. He had an absolute passion for chemistry, and passed much of his time in his laboratory. Sometimes indeed he gave audience to his secretaries of state standing before a furnace, bellows in hand. He took some useful measures to promote the rise of a new city at Leghorn, which at that time had only a natural and ill-sheltered harbour. The improvement of Leghorn had been first projected by Cosimo I., and was carried on by all the succeeding Medici. Francesco was a slave to his passions, and was led by them to scandalous excesses and deeds of bloodshed. His example and neglect of the affairs of the state soon caused a vast increase of crime even among the people, and, during the first eighteen months of his reign, there occurred no less than one hundred and sixty-eight murders.

In default of public events, the historians of this period enlarge upon private incidents, generally of a scandalous or sanguinary kind. In 1575 Orazio Pucci, wishing to avenge his father, whom Cosimo had hanged, determined to get up a conspiracy, but, soon recognizing how firmly the Medicean rule had taken root in the country, desisted from the attempt. But the grand-duke, on hearing of the already abandoned plot, immediately caused Pucci to be hanged from the same window of the Palazzo Vecchio, and even from the same iron stanchion, from which his father before him had hung. His companions, who had fled to France and England, were pursued and murdered by the ducal emissaries. Their possessions were confiscated, and the "Polverina" law applied so that the conspirators' heirs were reduced to penury, and the grand-duke gained more than 300,000 ducats.

Next year Isabella dei Medici, Francesco's sister, was strangled in her nuptial bed by her husband, Paolo Giordano Orsini, whom she had betrayed. Piero dei Medici, Francesco's brother, murdered his wife Eleonora of Toledo from the same motive. Still louder scandal was caused by the duke's own conduct. He was already a married man, when, passing one day through the Piazza of St Mark in Florence, he saw an exceedingly beautiful woman at the window of a mean dwelling, and at once conceived a passion for her. She was the famous Bianca Cappello, a Venetian of noble birth, who had eloped with a young Florentine named Pietro Buonaventuri, to whom she was married at the time that she attracted the duke's gaze. He made her acquaintance, and, in order to see her frequently, nominated her husband to a post at court. Upon this, Buonaventuri behaved with so much insolence, even to the nobility, that one evening he was found murdered in the street. Thus the grand-duke, who was thought to have sanctioned the crime, was able to indulge his passion unchecked. On the death of the grand-duchess in 1578 he was privately united to Bianca, and afterwards married her publicly. But she had no children, and this served to poison her happiness, since the next in succession was her bitter enemy, the cardinal Ferdinand. The latter came to Florence in 1587, and was ostentatiously welcomed by Bianca, who was most anxious to conciliate him. On October 18th of the same year, the grand-duke died at his villa of Poggio a Caiano, of a fever caught on a shooting excursion in the Maremme, and the next day Bianca also expired, having ruined her health by drugs taken to cure her sterility. But rumour asserted that she had prepared a poisoned tart for the cardinal, and that, when he suspiciously insisted on the grand-duke tasting it first, Bianca desperately swallowed a slice and followed her husband to the tomb.

Such was the life of Francesco dei Medici, and all that can be said in his praise is that he gave liberal encouragement to a few artists, including Giovanni Bologna, who executed for him the group of the Rape of the Sabines. He was the founder of the Uffizi gallery, of the Medici theatre, and the villa of Pratolino; and during his reign the Della Cruscan academy was instituted.

Ferdinand I.

Ferdinand I. was thirty-eight years of age when, in 1587, he succeeded his brother on the throne. A cardinal from the age of fourteen, he had never taken holy orders. He showed much tact and experience in the management of ecclesiastical affairs. He was the founder of the Villa Medici at Rome, and the purchaser of many priceless works of art, such as the Niobe group and many other statues afterwards transported by him to Florence. After his accession he retained the cardinal's purple until the time of his marriage. He was in all respects his brother's opposite. Affable in his manners and generous with his purse, he chose a crest typical of the proposed mildness of his rule,—a swarm of bees with the motto *Majestate tantum*. He instantly pardoned all who had opposed him, and left his kinsmen at liberty to choose their own place of residence. Occasionally, for political reasons, he committed acts unworthy of his character; but he re-established the administration of justice, and sedulously attended to the business of the state and the welfare of his subjects. Accordingly Tuscany revived under his rule and regained the independence and political dignity that his brother had sacrificed to love of ease and personal indulgence. He favoured commerce, and effectually ensured the prosperity of Leghorn, by an edict enjoining toleration towards Jews and heretics, which led to the settlement of many foreigners in that city. He also improved the harbour and facilitated communication with Pisa by means of the Naviglio, a canal into which a portion of the water of the Arno was turned. He nevertheless retained the reprehensible custom of trading on his own account, keeping banks in many cities of Europe. He successfully accomplished the draining of the Val di Chiana, cultivated the plains of Pisa, Fucecchio, and Val di Nievole, and executed other works of public utility at Siena and Pisa. But his best energies were devoted to the foreign policy by which he sought to emancipate himself from subjection to Spain. On the assassination (1589) of Henry III. of France, Ferdinand supported the claims of the king of Navarre, undeterred by the opposition of Spain and the Catholic League, who were dismayed by the prospect of a Huguenot succeeding to the throne of France. He lent money to Henry IV., and strongly urged his conversion to Catholicism; he helped to persuade the pope to accept Henry's abjuration, and pursued this policy with marvellous persistence until his efforts were crowned with success. Subsequently, however, Henry IV. showed faint gratitude for the benefits conferred upon him, and paid no attention to the expostulations of the grand duke, who then began to slacken his relations with France, and showed that he could guard his independence by other alliances. He gave liberal assistance to Philip III. for the campaign of the latter in Algiers, and to the emperor for the war with the Turks. Hence he was compelled to burden his subjects with enormous taxes, forgetting that while guaranteeing the independence of Tuscany by his loans to foreign powers he was increasingly sapping the strength of future generations. He at last succeeded in obtaining the formal investiture of Siena, which Spain had always considered a fief of her own.

During this grand-duke's reign the Tuscan navy was notably increased, and did itself much honour on the Mediterranean. The war-galleys of the knights of St Stephen were despatched to the coast of Barbary to attack Bona, the headquarters of the corsairs, and they captured the town with much dash and bravery. And in the following year (1608) the same galleys achieved their most brilliant victory in the archipelago over the stronger fleet of the Turks, by taking nine of their vessels, seven hundred prisoners, and a store of jewels of the value of 2,000,000 ducats.

Cosimo II.

Ferdinand I. died in 1609, leaving four sons, of whom the eldest, Cosimo II., succeeded to the throne at the age of nineteen. He was at first assisted in the government by his mother and a council of regency. He had a good disposition, and the fortune to reign during a period when Europe was at peace and Tuscany blessed with abundant harvests. Of his rule there is little to relate. His chief care was given to the galleys of St Stephen, and he sent them to assist the Druses against the Porte. On one occasion he was involved in a quarrel with France. Concino Concini, the Marshal d'Ancre, being assassinated in 1617, Louis XIII. claimed the right of transferring the property of the murdered man to De Luynes. Cosimo opposed the decision, and, refusing to recognize the confiscation decreed by the French tribunals, demanded that Concini's son should be allowed to inherit. Hence followed much ill-feeling and mutual reprisals between the two countries, finally brought to an end by the intervention of the duke of Lorraine.

Like his predecessors, Cosimo II. studied to promote the prosperity of Leghorn, and he deserves honour for abandoning all commerce on his own account. But it was no praiseworthy act to pass a law depriving women of almost all rights of inheritance. By this means many daughters of the nobility were driven into convents against their will. He gave scanty attention to the general affairs of the state. He was fond of luxury, spent freely on public festivities, and detested trouble. Tuscany was apparently tranquil and prosperous; but the decay of which the seeds were sown under Cosimo I. and Ferdinand I. was rapidly spreading, and became before long patent to all and beyond all hope of remedy. The best deed done by Cosimo II. was the protection accorded by him to Galileo Galilei, who had removed to Padua, and there made some of his grandest discoveries. The grand-duke recalled him to Florence in 1610, and nominated him court mathematician and philosopher. Cosimo died in February 1621, after twelve years of a quiet reign marked by no great event. Feeling his end draw near, when he was only aged thirty and all his sons were still in their childhood, he hastened to arrange his family affairs. His mother, Cristina of Lorraine, and his wife, Maddalena of Austria, were nominated regents and guardians to his eldest son Ferdinand II., a boy of ten, and a council of four appointed, whose functions were regulated by law. Accordingly, after Cosimo's death, the young Ferdinand was sent to Rome and Vienna to complete his education, and the government of Tuscany remained in the hands of two jealous and quarrelsome women. Thus the administration of justice and finance speedily went to ruin. Out of submissiveness to the pope, the regents did not dare to maintain their legitimate right to inherit the duchy of Urbino, and in 1623 sanctioned the transfer of that right to the holy see. They conferred exaggerated privileges on the new Tuscan nobility, which became increasingly insolent and worthless. They resumed the practice of trading on their own account, and, without reaping much benefit thereby, did the utmost damage to private enterprise.

Ferdinand II.

In 1627 Ferdinand II., then aged seventeen, returned to Italy and assumed the reins of government; but, being of a very gentle disposition, he decided on sharing his power with the regents and his brothers, and arranged matters in such wise that each was almost independent of the other. He gained the love of his subjects by his great goodness; and, when Florence and Tuscany were cruelly ravaged by the plague in 1630, he showed admirable courage, and carried out many useful measures. But he was totally incapable of energy as a statesman. When the pope made bitter complaints because the board of health had dared to subject certain monks and priests to the necessary quarantine, the grand-duke insisted on his officers asking pardon on their knees for having done their duty. On the death in 1631 of the last duke of Urbino, the pope was allowed to seize the duchy without the slightest opposition on the part of Tuscany. As a natural consequence the pretensions of the Roman curia became increasingly exorbitant; ecclesiastics usurped the functions of the state; and the ancient laws of the republic, together with the regulations decreed by Cosimo I. as a check upon similar abuses, were allowed to become obsolete. On the extinction of the line of the Gonzagas at Mantua in 1627, war broke out between France on the one side and Spain, Germany, and Savoy on the other. The grand-duke, uncertain of his policy, trimmed his sails according to events. Fortunately peace was re-established in 1631. Mantua and Monferrato fell to the duke of Nevers, as France had always desired. But Europe was again in arms for the Thirty Years' War, and Italy was not at peace. Urban VIII. wished to aggrandize his nephews, the Barberini, by wresting Castro and Ronciglione from Odoardo Farnese, duke of Parma and brother-in-law to Ferdinand. Farnese determined to maintain his rights, and marched his army through Tuscany into the territories of the pope, who was greatly alarmed by the attack. Naturally the grand-duke was drawn into the war to defend his own state and his kinsman. His military operations, however, were of the feeblest and often the most laughable character. At last, by means of the French intervention, peace was made in 1644. But, although the pope was forced to yield, he resigned none of his ecclesiastical pretensions in Tuscany. It was during Ferdinand's reign that the septuagenarian Galileo was obliged to appear before the Inquisition in Rome, which treated him with infamous cruelty. On the death of this great and unfortunate man, the grand-duke wished to erect a monument to him, but was withheld by fear of the opposition of the clergy. The dynasty as well as the country now seemed on the brink of decay. Two of the grand duke's brothers had already died childless, and Ippolito, the sole survivor, was a cardinal. Accordingly the only remaining heir was Cosimo III., married to a wife who held him in detestation, and did her best to have her marriage annulled or at least obtain a separation.

Like nearly all his predecessors, Ferdinand II. gave liberal patronage to science and letters, greatly aided therein by his brother Leopold, who had been trained by Galileo Galilei, and who joined with men of learning in founding the celebrated academy *Del Cimento*, of which he was named president. This academy took for its motto the words *Provando e riprovando*, and followed the experimental method of Galileo. Formed in 1657, it was dissolved in 1667 in consequence of the jealousies and dissensions of its members, but during its brief existence won renown by the number and importance of its works.

Cosimo III. Cosimo III. succeeded his father in 1670. He was weak, vain, bigoted, and hypocritical. In 1661 he had espoused Louise d'Orléans, niece of Louis XIV., who, being enamoured of Duke Charles of Lorraine, was very reluctant to come to Italy, and speedily detested both her husband and his country, of which she refused to learn the language. She had two sons and one daughter, but after the birth of her third child, Giovan Gastone, her hatred for her husband increased almost to madness. She first withdrew to Poggio a Caiano, and then, being unable to get her marriage annulled, returned to France, where, although supposed to live in conventual seclusion, she passed the greater part of her time as a welcome visitor at court. Even her testamentary dispositions attested the violence of her dislike to her husband.

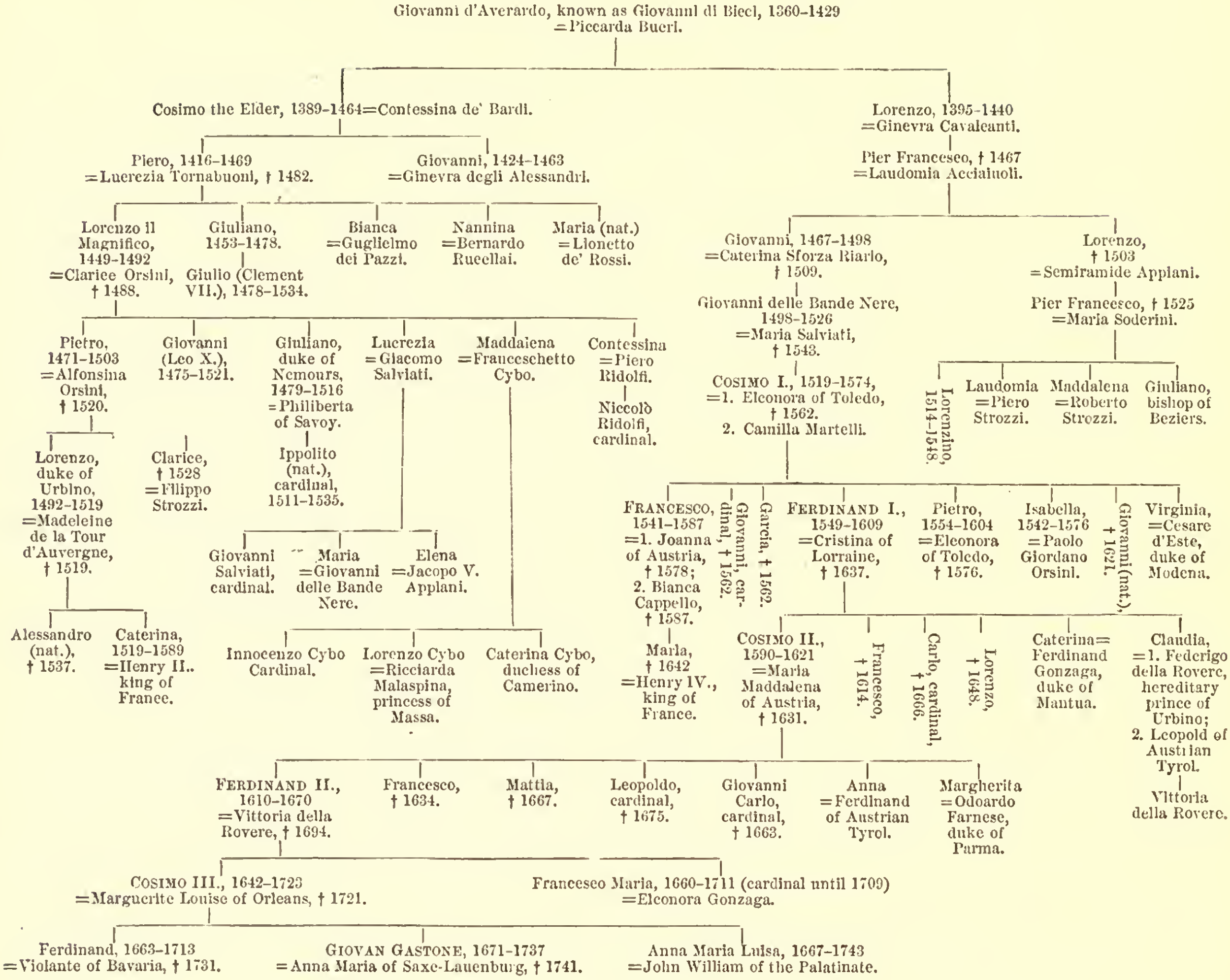
Cosimo's hypocritical zeal for religion compelled his subjects to multiply services and processions, that greatly infringed upon their working hours. He wasted enormous sums in pensioning converts—even those from other countries—and in giving rich endowments to sanctuaries. Meanwhile funds often failed for the payment of Government clerks and soldiers. His court was composed of bigots and parasites; he ransacked the world for dainties for his table, adorned his palace with costly foreign hangings, had foreign servants, and filled his gardens with exotic plants. He purchased from the emperor the title of "Highness" in order to be the equal of the duke of Savoy. He remained neutral during the Franco-Spanish war, and submitted to every humiliation and requisition exacted by the emperor. He had vague notions of promoting agriculture, but accomplished no results. At one time he caused eight hundred families to be brought over from the Morea for the cultivation of the Maremme, where all of them died of fever. But when, after the revocation of the edict of Nantes, French Huguenots offered to apply their labour and capital to the same purpose, the grand-duke's religious scruples refused them refuge. So ruin fell upon Tuscany. Crime and misery increased, and the poor, who only asked for work, were given alms and sent oftener to church. This period witnessed the rise of many charitable institutions of a religious character under the patronage of the grand duke, as for instance the congregation of San Giovanni Battista. But these could not remedy the general decay.

Cosimo's dominant anxiety regarded the succession to the throne. His eldest son Ferdinand died childless in 1713. The pleasure-loving Giovan Gastone was married to Anna Maria of Saxe-Lauenburg, widow of a German prince, a wealthy coarse woman wholly immersed in domestic occupations, and who seemed little likely to give birth to any children. After living with her for some time in a Bohemian village, Giovan Gastone yielded to his dislike to his wife and her country, withdrew to France, and ruined his health by his excesses. After a brief return to Bohemia he finally separated from his wife, by whom he had no family. Thus the dynasty was doomed to extinction. Cosimo had a passing idea of reconstituting the Florentine republic, but, this design being discountenanced by the European powers, he determined to transfer the succession, after the death of Giovan Gastone, to his sister Anna Maria Louisa, who in fact survived him. For this purpose he proposed to annul the patent of Charles V., but the powers objected to this arrangement also, and by the treaty of 1718 the quadruple alliance of Germany, France, England, and Holland decided that Parma and Tuscany should descend to the Spanish Infante Don Carlos. The grand-duke made energetic but fruitless protests.

Giovan Gastone. Cosimo III. had passed his eightieth year at the time of his decease in October 1723, and was succeeded by his son Giovan Gastone, then aged fifty-three. The new sovereign was in bad health, worn out by dissipation, and had neither ambition nor aptitude for rule. His throne was already at the disposal of foreign powers, and his only thought on ascending it was to regain strength enough to pass the remainder of his days in enjoyment. He dismissed the spies, parasites, and bigots that had formed his father's court, abolished the pensions given to converts, suppressed several taxes, and prohibited the organized espionage established in the family circle. He wished to live and let live, and liked the people to be amused. Everything in fact bore a freer and gayer aspect under his reign, and the Tuscans seemed to feel renewed attachment for the dynasty as the moment of its extinction drew near. But the grand-duke was too feeble and incapable to accomplish any real improvement. Surrounded by gay and dissipated young men, he entrusted all the cares of government to a certain Giuliano Dami, who drove a profitable trade by the sale of offices and privileges. In this way all things were in the hands of corrupt individuals; while the grand-duke, compelled to pass the greater part of his time in bed, vainly sought diversion in the company of buffoons, and was only tormented by perceiving that all the world disposed of his throne without even asking his advice. And when, after prolonged opposition, he had resigned himself to accept Don Carlos as his successor, the latter led a Spanish army to the conquest of Naples, an event afterwards leading to the peace of 1735, by which the Tuscan succession was transferred to Francesco II., duke of Lorraine, and husband of Maria Theresa. Giovan Gastone was finally obliged to submit even to this. Spain withdrew her garrisons from Tuscany, and Austrian soldiers took their place and swore fealty to the grand-duke on the 5th of February 1737. He expired on the 9th July of the same year. Such was the end of the younger branch of the Medici, which had found Tuscany a prosperous country, where art, letters, commerce, industry, and agriculture flourished, and left her poor and decayed in all ways, drained by taxation, and oppressed by laws contrary to every principle of sound economy, downtrodden by the clergy, and burdened by a weak and vicious aristocracy.

Capponi, *Storia della Repubblica di Firenze*, Florence, 1875; Roscoe, *Life of Lorenzo dei Medici*, and *Life of Leo X.*; Alfred von Reaumont, *Lorenzo dei Medici, il Magnifico*, Leipsic, 1874; Galluzzi, *Storia del Granducato di Toscana sotto il governo di Casa Medici*, 5 vols., Florence, 1787; A. von Reaumont, *Geschichte Toscanas seit d. Ende d. florent. Freistaates*, 2 vols., Gotha, 1876. (P. V.)

GENEALOGICAL TABLE OF THE MEDICI.



MEDICINE

PART I.—SYNOPTICAL VIEW OF MEDICINE.

MEDICINE, the subject-matter of one of the learned professions, includes, as it now stands, a wide range of scientific knowledge and practical skill. The history of its growth from small beginnings in Greece is traced in the second section of the present article; it remains here to give a synoptical view of medicine, including its scientific or philosophical position, its subdivisions or ramifications as an art and discipline, and its relations to the body politic.

Scientific Position of Medicine.—The science of medicine is the theory of diseases and of remedies. While the notion of disease is necessarily or inevitably correlated with the notion of health, there is no necessary and invariable relation, but, on the other hand, a merely conventional association, between a disease and a remedy. That part of the science of medicine which corresponds to the theory of remedies is not therefore in a position scientifically inferior to the theory of diseases; for each article of the materia medica—apart from a few inert substances—has a certain effect on the organism in health and in disease, which is ascertainable with scientific precision. Those properties and actions of drugs are the subject of pharmacology and toxicology; the circumstances under which the several articles of the materia medica become remedial are the subject of therapeutics, and therapeutics is dependent for its scientific position upon the completeness of the theory of diseases, or pathology.

Disease is the correlative of health, and the word is not capable of a more penetrating definition. From the time of Galen, however, it has been usual to speak of the life of the body either as proceeding in accordance with nature (κατὰ φύσιν, *secundum naturam*) or as overstepping the bounds of nature (παρὰ φύσιν, *præter naturam*). Taking disease to be a deflexion from the line of health, the first requisite of medicine is an extensive and intimate acquaintance with the norm of the body. The normal condition of the body is capable of being determined without ambiguity; it is the absence from its structures and functions of every disease hitherto known. The structure and functions of the body form the subject of anatomy and physiology.

Physiology is, strictly speaking, the science of that which is κατὰ φύσιν, or *secundum naturam*, and it is usual to say that the theory of diseases is based upon physiology. But, although all that was implied in the Hippocratic term φύσις (*natura*) may be claimed as the subject-matter of physiology, yet, in the ordinary connotation of the term, physiology divides the empire with anatomy. To physiology the functions of the body are usually assigned, and to anatomy its form and structure. But, as a matter of fact, the structures and functions of the organism are not separable; structure is correlated to function, whether active, dormant, or extinguished, and in like manner function is the twin notion of structure. In the ultimate analysis neither term means anything without the other, and both together mean life. It is owing mostly to its name that physiology is supposed to have a preponderant interest for the theory of disease; the word anatomy is not well adapted to carry its own half of the structure-and-function dualism. Both in the historical development and in the logical connotation, anatomy is as much associated with the living and moving body as physiology itself; but its etymology has always been against it, and it has become more and more difficult to retain for anatomy anything beyond the technicalities of the dissecting-room. The subject of general anatomy has for the most part disappeared from modern text-books, its place being taken by histology, which deals with the minute structure of the simple tissues, and, in a wider acceptation, with the finer anatomy of all the organs and parts of the body. Histology, like anatomy, has had a somewhat technical or descriptive rôle assigned to it; and it is now mainly under physiology that the processes, activities, or living mechanisms of the body fall to be considered. The development of the body as a whole, and of its several tissues and organs, forms the subject of embryology; many of the physiological types of diseased processes, especially the cellular, are discoverable in the embryological period. For the period of development, no arbitrary separation has been attempted hitherto between structure and function, and embryology is, in theory at least, as much physiological as anatomical. The development of function is a legitimate and even desirable subject of scientific study, and a more distinctive place is probably awaiting it in the future; but so indissoluble does the union of structure and function present itself in the period of genesis and growth that the function has hardly as yet come to be abstracted from the structure, or the structure from the function.

The theory of disease rests, therefore, upon physiology, with its more or less technical adjuncts. Pathology is all that physiology is, with the engrossing and difficult element of perturbation, deflexion, or shortcoming added. By virtue of this element of deviation from the line of health, pathology is a discipline apart, with an abundant literature of its own, and with separate academical institutes and chairs. But pathology is also a discipline apart by virtue of concepts proper to itself. A great part of the theory of disease deals with changes or defects of structure and perturbations or failings of function, which may be intricate or difficult to analyse, but are still well within sight of the line of health. Such are the common diseases of the organs and systems—the inflammations, catarrhs, degenerations, hypertrophies, and functional derangements without lesion of the respiratory, circulatory, nervous, genito-urinary, locomotor, and cutaneous systems. Constitutional or general diseases belong also to the province of perturbations from the physiological course,—such diseases as chlorosis, leukæmia, diabetes, gout, rheumatism, scurvy, rickets, Addison's disease, exophthalmic goitre, and the febrile state. Again, congenital deficiencies or malformations, non-cancerous tumours, and the repairing of injuries exemplify no other laws than those of development and growth.

But with those examples the catalogue of physiological diseases is exhausted. We are left with a vast residue of diseases, which have always bulked largely in the popular mind, and have carried the most terrible associations with them. Such are the pestilences or diseases of peoples:—the plague, sweating sickness, cholera, yellow fever, typhus fever, relapsing fever, typhoid fever, diphtheria, small-pox, measles, scarlet fever, influenza, dengue. Such also are the cancers, consumptions, leprosies, and other loathsome infections. This enormous residue is more than the half of disease, and the definition of disease or the scheme of pathology is brought to a test in finding room within its scientific categories for such maladies as those. The popular imagination in all countries has personified them; medicine in its metaphysical period has regarded them as entities or things in themselves; and it remains to be seen in what way or to what extent medicine in its scientific period will bring them within the category of perturbations of the physiological life.

In considering, for a moment, where to place cancer in the pathological scheme, we shall arrive at a point of view from which the relation of the acute and chronic infections (or contagions) to diseases of the physiological order may be contemplated at least provisionally. Taking cancers, in a generic sense, to mean tumours that have acquired or are possessed of malignancy, we find that such tumours have many points in common with simple tumours,—that they have grown out of the tissues of particular organs or parts under particular (functional) circumstances, and that they may, in general terms, be traced back to that point at which they left the line of health (see PATHOLOGY). The tracing back of tumours along the physiological track is often difficult and laborious; but there is no tumour of the body whose origins are not at length discoverable within the limits of physiological action. That which makes any tumour a cancer is something over and beyond; it is a remarkable acquired property of reproducing its structure in manifold copies, or of infecting the organism of which it is itself a part. The tumour thus becomes a semi-independent power within the body; it may be said, in a political figure, to have acquired *autonomy*, or to have become *imperium in imperio*. A due consideration of such a phenomenon as the infectiveness or cancerousness of some tumours will satisfy one that there are concepts in pathology which carry the investigator entirely beyond physiological bounds or out of sight of the line of health, which bring him face to face with the notion of a disease as a thing in itself, and which thus constitute a peculiar subject-matter. There is nothing that we know among biological phenomena altogether analogous to the semi-independence which an integral part of the body, or condition of the body, manifests towards the organism as a whole, and that, too, strictly in respect of its acquired devious or rebellious habit. The familiar definition of disease, *morbus est vita præter naturam*, which embodies the notion of divergence from the line of health, makes no provision for an acquired autonomy of a morbid state; and that definition has to be supplemented by another, which will recognize the possibility of a disease becoming a thing in itself. The old definition of Van Helmont, *morbus est ens reale subsistens in corpore*, appears to satisfy the requirement; but that definition, although it grew out of the phenomena of disease as observed in fevers, was made too general, and has now associations that are too exclusively ontological and metaphysical. The supplementary definition should be as far as possible in the terms of the principal definition; and we shall provide best in the pathological scheme for such a disease as cancer if, in addition to the formula *morbus est vita præter naturam*, we construct a secondary formula, *morbus est vivum in vivo*.

The notion of autonomy acquired by a morbid state implies, naturally, a pre-autonomous stage of the disease, which had been a mere perturbation of the norm of the body, capable of being measured by the physiological standard. The autonomous stage and the pre-autonomous stage, which may be demonstrated, in individual cases, for cancers, are a philosophical necessity for all other infective diseases that are marked by morphological features, or by structural characters rooted in and growing out of the proper textures of the body. Thus the peculiar skin eruption of small-pox, which is communicable from person to person, along with a distinctive course of fever, must have had pre-autonomous antecedents (not altogether historically vague) in certain casual conditions of the skin and associated constitutional disturbance, which had recurred and become inveterate, and had so attained to a degree of individuality or a point of autonomy at which they began to be propagated as an organic unit. Again, a second group of infections, exemplified by glanders, bovine tubercle, and syphilis, are rooted in deeper textural processes, which must have been at one time (and may still be) set up by the casual operation of ordinary causes, and at length became the occasion of infective mimicry. It is not so easy to picture (and it is not difficult, with a modern dominant school, to ignore) the casual morbid conditions or ordinary physiological perturbations out of which powerful infections like cholera, typhoid fever, or yellow fever may have arisen; but if the rise and consolidation of their autonomy be a subtle or even untraceable history, yet there are diseases, such as dysentery and erysipelas, which are apt to occur both as casual or spontaneous conditions and as specific infections side by side. Ophthalmia is an example of a purulent catarrh which is constantly arising *de novo* in Egypt from local causes in a non-infective manner, and yet has become, on at least one memorable occasion, a powerful and widespread infection for British troops returning from that country and for the home garrisons for many years subsequently. Infective pneumonia in cattle, and more rarely in man, is an analogous case. In such an episode we observe the actual rise of the disease-autonomy. Again, all the infective diseases have degrees of intensity, at one extreme of which there must occur the vanishing point of their infective property; and those gradations of infectiveness are nowhere more noticeable than in the relation of cholera to choleraic diarrhœa. Further, the remarkable group of climatic fevers are not communicable from person to person (see MALARIA); in that respect, and for the reason that the liability of the patient is anything but exhausted by one attack, they are examples of fevers without autonomy. There is not one of the infections that may not be profitably studied from the point of view of its autonomy, and of its more or less obscure pre-autonomous stage. That is a point of view from which even the pestilences and other specific diseases may be regarded as coming within the physiological categories. The large residue of diseases, which are more than perturbations of the physiological life, may still be joined by natural descent to the class of simple perturbations, if we can show for them how their autonomy was acquired, or what was their origin as disease-species.

There is an established place in the history of medicine, and there ought therefore to be room in the definition of disease, for epidemic outbreaks of purely psychical diseased states, such as the dancing madness (*Tanzwuth*), and the boys' crusades; the epidemic diffusion of such morbid states is best approached from the point of view of an acquired autonomy (fixed idea) and an infective mimicry.

The physiological definition of disease, *morbus est vita præter naturam*, affords no place for parasitic diseases. However, the supplementary formula that has been proposed to meet the case of diseases existing autonomously in the body, *morbus est vivum in vivo*, will meet the case of parasitic diseases also. According to many pathologists of the present generation, the whole class of pestilences, fevers, and specific infections generally are caused by certain species of minute parasites invading the body; according to one form of that hypothesis the distinctive characters or specific marks (morphological and other) of those diseases are neither more nor less than the appropriate effects wrought upon the textures and fluids of the body by the respective species of parasites. In this way the great group of infective diseases, which are apt to be the stumbling-block of a scientific definition and logical scheme of disease, are easily disposed of by placing them beside the otherwise insignificant group of parasitic diseases. Whether all or any of those diseases are due in a sense to the invasion of parasites, or wholly caused by parasites, are questions that naturally fall to be settled by a careful sifting of a mass of evidence which has already proved to be peculiarly rich in opportunities for mistake. It may be expected that the facts of infective parasitism and the facts of acquired disease-autonomy will in the end find their place in a common theory of specific diseases, which might be expressed in terms of the physiological formula *morbus est vita præter naturam* with the rider *morbus est vivum in vivo.*

The theory of remedies, which forms the second division of the science of medicine, is chiefly based upon pharmacology or toxicology. If pharmacology be considered as not co-extensive with toxicology, it will be taken to be in great part pharmacographia, or the systematic description of articles of the materia medica—their source, preparation, physical properties, and the like. Toxicology is in its general sense the investigation of the physiological action of drugs, a science which is largely dependent upon experiments on the lower animals; in a more technical sense toxicology relates to the effects of poisons and the art of detecting them (see POISONS). The physiological action of drugs is the key to their therapeutical action. Therapeutics has been defined as "the discovery of the means by which a system of forces competent to eliminate any given perturbation may be introduced into the economy." The adaptation of remedies to diseases is, however, greatly wanting in precision, and continues to be in large part empirical and traditional. It may be objected to the above definition that all diseases are not reducible to the category of "perturbations," and that there is a certain scientific justification for the doctrine of specifics. Besides the articles of the materia medica proper, agencies such as electricity, baths, sea-voyages, and changes of climate generally, enter into the consideration of therapeutics, and two of those form the subject of special departments, viz., electro-therapeutics and hydropathy. Regimen and diet are also important factors in the treatment of disease; according to a contention of Hippocrates, it was in the dietetic needs of mankind that the medical art had its origin.

Subdivisions of Medicine as an Art and Discipline.—The medical art (*ars medendi*) breaks away at once from the unity of the theory of disease. While there is but one body of pathological doctrine for either sex, for every period of life, and for every region and part of the organism, the practical art divides itself into departments and subdepartments. The most fundamental division is into internal and external medicine, or into medicine proper and surgery. The treatment of wounds, injuries, and deformities, with operative interference in general, is the special department of surgical practice (the corresponding parts of pathology, including inflammation, repair, and removable tumours, are sometimes grouped together as surgical pathology); and where the work of the profession is highly subdivided, surgery becomes the exclusive province of the surgeon, while internal medicine remains to the physician. A third great department of practice is formed by obstetric medicine or midwifery, and with obstetrics there is usually associated gynæcology, or the diseases peculiar to women. Diseases of children are the subject of a voluminous separate literature. Dermatology (diseases of the skin) is an important province of practice which, like the diseases of women and children, pertains as much to medicine as to surgery. The greatest of the so-called special departments of practice is ophthalmology (diseases and injuries of the eye). Laryngology is a department that owes its existence mainly to the invention of the laryngoscope, its special province being the treatment of the inflammations (ordinary and specific), tumours, and the like, to which the larynx is liable in common with other parts. Diseases of the ear (otology) form even a more restricted department of practice, owing to the comparative inaccessibility of the chief part of the organ of hearing. The congenital condition of deaf-mutism may or may not be taken as falling within the province of the last-mentioned subdivision. Dentistry or odontology is extremely limited in the range of its subject-matter; but it affords great opportunities for refinements of technical skill, and it is given up to a distinct branch of the profession.

The care of the weak-minded and the insane (psychological medicine) is an integral part of medical practice, inasmuch as it is concerned with diseases of the nervous system and with numerous correlated states of other organs; but it occupies a unique place by reason of the engrossing interest of the subjective phenomena. Habitual drunkenness is also a subject of special treatment.

A state of war, actual or contingent, gives occasion to special developments of medical and surgical practice (military hygiene and military surgery). Wounds caused by projectiles, sabres, &c., are the special subject of naval and military surgery; while under the head of military hygiene we may include the general subject of ambulances, the sanitary arrangements of camps, and the various forms of epidemic camp sickness.

The administration of the civil and criminal law involves frequent relations with medicine, and the professional subjects most likely to arise in that connexion, together with a summary of *causes célèbres*, are formed into the department of medical jurisprudence. It is the practice in Great Britain to call independent medical evidence on both sides of a cause, whether the proceedings be civil or criminal.

The system of life assurance is based upon the co-operation of the medical profession. Heredity, constitution, and diathesis are here the chief subjects of general consideration, while prognosis is the skilled faculty specially called into play.

Relations of Medicine to the Body Politic.—The statutes of the United Kingdom which have direct relation to medicine are (1) those relating to the public health; (2) those relating to lunacy (and habitual drunkenness); (3) those relating to the status of the medical profession, to dentists, and to pharmaceutical chemists; (4) those relating to restrictions on the "practice" of anatomy and physiology. There are, besides, several statutes in which medicine is concerned indirectly,—such as the Poor Laws, the Prisons Acts, the Shipping Acts, the Registration of Births and Deaths Act, the Sale of Food and Drugs Act, the Sale of Poisons Act, the Factory and Workshops Act, the Artisans' Dwellings (Metropolitan) Act, the Rivers Pollution Prevention Act, the Contagious Diseases (Animals) Act (1878), and the Public Health (Water) Act.

1. Most of the statutes relating to the public health in England and Wales were consolidated by an Act of 1875, the Acts relating to the metropolis being excepted; there are separate statutes of about the same period for Ireland and Scotland. The system of administration is by local sanitary authorities, in correspondence with the local government boards in London and Dublin and the board of supervision in Edinburgh. The board in London has a medical department, consisting of a chief medical officer, assistant medical officer, and inspectors, while the Dublin and Edinburgh boards are professionally advised on a somewhat different system. The sanitary authorities throughout the United Kingdom are divided into rural, urban, port, and metropolitan (sanitary and nuisance); they are formed out of pre-existing bodies, either the corporations of cities and towns, the improvement commissioners, or the local authorities. A medical officer of health is attached to most of the several sanitary authorities, or to the combined sanitary authorities of a large district; his duties include making reports on the death-rate and the causes of mortality, the denunciation of nuisances and unwholesome dwellings, workshops, &c., inquiries into the local causes or favouring circumstances of epidemic outbreaks of disease, measures to prevent the spread of contagion (by disinfection, isolation, and otherwise), and other more occasional duties arising under a variety of statutes. Each sanitary authority is required by law to appoint an inspector of nuisances, who practically carries out the instructions of the medical officer when there is one.

The Vaccination Acts (consolidated 1871) are an important part of the public health law of the kingdom; they are administered by the local government board, for the most part through the agency of the medical profession at large, but in some populous parishes also by means of public vaccination stations. Prosecutions under the Acts are instituted by the parochial authorities. The practice formerly (and not unsuccessfully) resorted to of inoculating with the small-pox has been made a criminal offence; but there is still much uncertainty as to the theory of vaccination, and, in particular, as to the relation of vaccinia to variola.

Other statutes which were not consolidated in the Public Health Act of 1875 are the Burials Act, the Contagious Diseases Act, and the Quarantine Act. The first of these is administered by a department of the home office, with a medical inspector. The second (1866 and 1869) relates, under a too general title, to the regulation of prostitution in certain garrison towns, the surgeons under the act being appointed by the board of admiralty or the secretary of state for war, and the administration otherwise carried out by the police.

The quarantine laws stand in the somewhat anomalous position of statutes which it is not thought desirable to repeal, while yet they are stripped bare of all their executive machinery. The Quarantine Act can be set in motion, as occasion arises, by an order of council; not only, however, is there no official medical advice at the disposal of the privy council, upon which action under the act might be taken, but there is not even the framework remaining (except the ghost of a quarantine station on the Motherbank between Portsmouth and the Isle of Wight) of the once considerable quarantine establishment, by which the provisions of the Act might be enforced. On the other hand, port sanitary authorities enjoy certain limited powers under the Public Health Acts of isolating vessels arriving with contagious sickness on board. A quarantine at British ports has not been put in force for many years, opinions being divided as to the abstract efficacy and suitableness of quarantine measures to prevent the importation and diffusion of plague, cholera, or yellow fever (see QUARANTINE).

Numerous instances having occurred of the extensive diffusion of scarlet fever, typhoid fever, and diphtheria by means of milk, the privy council has issued an order, under the Contagious Diseases (Animals) Act of 1878, called the Dairies, Milkshops, and Cowsheds Order, with the object of enforcing extreme cleanliness in the premises and appurtenances of the milk trade, and particularly of guarding against the well-known liability of milk to take up effluvia existing or arising near it. The order of council having remained inoperative, it is proposed to deal with the matter by a new Act of Parliament, to be administered by the local government board. While cows' milk has thus been recognized by the sanitary law as a carrier of certain of the human contagia, the milk of diseased cows, and more especially of tuberculous cows, continues to be sold with impunity, the alleged communication of tubercular disease from the cow to man being difficult to prove to the satisfaction of the legislature. The want of constant supervision of the slaughter-houses is thought by many to be a serious defect in the sanitary law of the country; and there is no doubt that much flesh of diseased animals (especially the tuberculous) is sold merely as inferior meat.

Public Health Law of the United States.—Questions of public health in the United States come under the common law and the statute law. In the larger part of the Union they are subject to the common law only; in a certain number of the States there is statute law; and there has been since 1879 a national board of health and a quarantine law established by Act of Congress. Generally speaking, the public health procedure of the United States suffers from the want of organization. Decisions at common law relate chiefly to nuisances, and to the recovery of damages for loss caused by the same. The first attempt at statute law was an Act of 1866 creating a metropolitan sanitary district and board of health for the city of New York; in 1869 a board of health was created by the State legislature for Massachusetts; the District of Columbia obtained its board of health in 1870; and other States have followed at intervals, so that there are now at least nineteen State boards of health, New York State and Pennsylvania having health boards only for their respective capitals and other individual towns. Besides the municipal boards in those States, there are very few others for towns in the Union, and still fewer for counties. The powers and activity of the boards of health are very various; the Massachusetts board has powers amounting to that of a court, while the function of several of the State boards is hardly more than advisory. The sanitary statutes made by the State legislatures are in some cases very numerous. Wherever questions of quarantine for yellow fever have arisen, as in Louisiana (New Orleans), Georgia, and Alabama, the State board of health has acquired vigour and has enlisted popular support, in the capitals at least; but in most of the States *laissez faire* is the ordinary feeling towards the board and its operations. The medical profession in each State is the most powerful force, and the State medical society is not unfrequently in a semi-official connexion with the sanitary board; on the other hand, it is alleged that the unfortunate sectarian differences in medicine (represented chiefly by homœopathy) have on several occasions prevented the formation of a State board of health, or have tended to paralyse the action of a board already existing. It is a charge also against boards of health, or at least against those in the great political centres, that their efficiency is apt to be impaired by the introduction of irrelevant political considerations in such matters as the making of appointments. The first step towards a national public health law was gained by the Act (approved 3d March 1879) "to prevent the introduction of infectious or contagious diseases into the United States, and to establish a national board of health." The board consists of seven members appointed by the president and of four officials detached from the public departments of State. Its duties are "to obtain information upon all matters affecting the public health, to advise the several departments of the government, the executives of the several States, and the commissioners of the District of Columbia, on all questions submitted to them, or whenever, in the opinion of the board, such advice may tend to the preservation and improvement of the public health." Quarantine was to be a special object of the board's attention, especially the establishment, if possible, of a federal quarantine system which would preserve the legitimate commercial interests of the several States and their seaports. A quarantine law passed in 1879 provides that all vessels coming from any foreign port where contagious or infectious diseases exist shall obtain a bill of health from the consular officer of the United States at the port of sailing. One of the principal functions of the national board of health hitherto has been to institute scientific inquiries into the nature and causation of diseases of national importance, such as malarial fever. Among the acknowledged desiderata in the national sanitary law of the United States are a uniform carrying out of the practice of vaccination—there is no vaccination law in certain States, and in others it is imperfectly applied—and a uniform system of registration of births and deaths. See Bowditch, *Public Hygiene in America, together with a Digest of American Sanitary Law* (by Pickering), Boston, 1877; Billings, Introduction to *Hygiene and Public Health*, edited by Buck (Eng. ed., London), and in the *Transactions of the Internat. Medical Congress*, London, 1880, vol. iv., sect. "Public Health."

Public Health Law of other Countries.—In France there is a council of health for each district, composed of medical practitioners, pharmacists, engineers, and other experts, its function being purely advisory with respect to nuisances, unwholesome dwellings, schools, food, drugs, epidemics, and the like. The executive power rests with the prefect (to be carried out by the police), and is often not put in motion even when advice is tendered. In Paris there are two heads of executive, the prefect of the Seine and the prefect of police. The minister of agriculture and commerce is responsible to the chambers. In Prussia there is a certain amount of bureaucratic care of the public health under the ministry for ecclesiastical, educational, and medical affairs. The minister is advised by a scientific commission (*Wissenschaftliche Deputation für das Medicinalwesen*); and there is a subordinate board for each province, and a medical officer for each district or town (*Kreisphysikus*, or *Stadtphysikus*). Numerous offences against the public health are defined in the code, and penalties fixed (see Eulenberg's work, taken from official sources, *Das Medicinalwesen in Preussen*, Berlin, 1874).

2. The lunacy laws have been fully treated of in a special section of the article INSANITY (*q.v.*). By an Act of 1879 habitual drunkards have been placed in a position somewhat analogous to that of lunatics, and there are now existing certain licensed asylums for their detention.

3. The Acts relating to the status of the medical profession are known as the Medical Acts. The principal measure, passed in 1858, created a body of twenty-four, called the general council of medical education and registration; by a subsequent Act the council received a charter of incorporation, so that it might draw up, and become the publisher and proprietor of, a list and description of officinal drugs, which should be called the British Pharmacopœia, and should supersede previous pharmacopœias. The principal duty of the medical council is to keep a register of qualified medical practitioners. The preamble of the Act by which the medical register was created asserts the desirability of those in want of medical aid being able to distinguish qualified from unqualified practitioners; and those whose names are on the register are alone presumably qualified. To be a registered medical practitioner confers a certain positive legal status (right to sue for fees, hold appointments, give certificates, &c.); but there is nothing in the English law to prevent any person whomsoever from practising medicine and taking fees, provided he does not assume misleading titles. Those who are entitled (on payment of five pounds) to have their names inserted in the medical register are graduates in medicine or surgery of the universities of the United Kingdom, licentiates, members, or fellows of the Royal Colleges of Physicians or Surgeons in London, Dublin, and Edinburgh, licentiates or fellows of the Faculty of Physicians and Surgeons of Glasgow, and licentiates of the Apothecaries' Halls of London and Dublin. The council consists of the representatives of those bodies, of six crown nominees, and the president. The medical council possesses certain judicial and executive powers over the names on its register; if, after due inquiry, a registered practitioner be judged by the medical council to have been guilty of infamous conduct in any professional respect, the medical council may, if they see fit, direct their registrar to erase the practitioner's name from the register. The medical council keeps also a register (unpublished) of medical students; whoever has passed a recognized examination in arts, and has forwarded a certificate signed by a teacher of medicine that he has *bona fide* begun the study of medicine, is entitled to have his name entered in the register of students of medicine, with the date of his commencement. The object of the students' register is merely to provide a common and convenient record of the date of commencement of medical study, and, by implication, of the fact that the examination in arts has been passed.

The medical council owes its title of a "council of education" to certain powers possessed by it of visiting the examinations of the universities and corporations, and certain ill-defined powers of visiting the medical schools. The council may, if they see fit, report to the privy council any deficiencies that they may have discovered in the teaching or examining, and the privy council may proceed to further steps. But, beyond publishing the reports of their visitations, the medical council do not appear to have had occasion to put the machinery in force. The state has not otherwise interfered to prescribe the subject-matter or the minimum standard of medical education, although there has been at least one unsuccessful attempt by the Government of the day to establish a uniform minimum. By an Act of 1876 parliament has interposed to affirm the principle that women are entitled to become registered practitioners of medicine.

Under the Dentists' Act of 1878 the profession of dentistry acquired a legal status corresponding to that of the medical profession, the general medical council having charge of its register also.

Pharmaceutical chemists are now licensed under an Act passed in 1876; since that date licences are granted only to those who pass either the minor or the major examination of the Pharmaceutical Society of Great Britain, a Pharmacy Act for Ireland (1876) having corresponding provisions.

The Medical Profession in other Countries.—In the United States there are usually no restrictions upon the practice of medicine, and in only a few of the States has the medical profession any legal standing. The ordinary medical title is that of doctor of medicine, and that degree is conferred by a large number of institutions after a curriculum of study that varies much in length, and after examinations that are equally various as tests of proficiency. In France the medical profession is divided into two grades: those in the higher grade are all doctors of medicine of the faculties of Paris, Lille, Nancy, Bordeaux, Lyons, or Montpellier; those in the lower grade are *officiers de santé*. In Germany the right to practise is conferred by a state licence granted on passing the *staats-examen*; the examination, which is almost entirely oral and practical, may be passed in stages at any one of the universities in the empire, the professors of anatomy, physiology, and pathological anatomy being practically *ex officio* examiners, while the other examiners are very frequently also professors in the medical faculty. The *staats-examen* is usually passed before the candidate seeks the degree of doctor of medicine; that degree is almost always taken by those who pass the examination for the state licence, and it is usually conferred after a more or less formal examination of the candidate before the medical faculty, and on the approval of his thesis. In Austria, the right to practise is carried by the degree of doctor of medicine; there is no separate state licence, and no examination except that of the medical faculty of the universities (see Billroth's *Lehren and Lernen der medicinischen Wissenschaften*, Berlin, 1876). In most Continental countries there are penalties directed in effect against practising medicine without the state licence, or the university degree equivalent thereto, and in France the law now extends to resident foreign practitioners who have qualified only in their own country. The regulations for the practice of pharmacy in Germany and other Continental countries have long been of a very stringent kind. The training and licensing of midwives is also under state control.

4. Lastly, the state has interposed to restrict the "practice" of anatomy and physiology. By the Anatomy Act of 1832 (amended in 1871) licences are required for schools of anatomy, as well as licences for teachers, "to practise anatomy." Licensed teachers of anatomy are empowered to receive subjects for dissection under certain conditions. The Act is administered by the home office, with a staff of four inspectors of anatomy, one for the metropolis, one for provincial medical schools in England, and one each for Ireland and Scotland. The Act restricting the practice of physiology is the Vivisection Act of 1876; it is intended for the protection of vertebrate animals liable to be employed alive in physiological experiments, and it resorts to a controlling machinery of licence and inspection similar to that of the Anatomy Act, and under the same Government department. (C. C.)

PART II.—HISTORY.

The history of medicine falls naturally under two heads, or might be conceivably written from two different points of view. It might be a history of the medical profession or a history of medical doctrine,—in other words, the history of medicine in its relation to society or in its relation to science. We shall here deal chiefly with the history of medical knowledge, remembering also that the histories of anatomy, of physiology, and of surgery are dealt with in the articles referring to those subjects. But a still more trenchant limitation is necessary to preserve the unity of the subject. Attention can be given to so much only of the history as is directly antecedent to and leads up to the medical science of modern Europe. For this purpose, the history of medicine must start with the earlier period of Greek civilization.

Medicine as Portrayed in the Homeric Poems.—In the state of society pictured by Homer it is clear that medicine has already had a history. We find a distinct and organized profession; we find a system of treatment, especially in regard to injuries, which it must have been the work of long experience to frame; we meet with a nomenclature of parts of the body substantially the same (according to Daremberg) as that employed long afterwards in the writings of Hippocrates; in short, we find a science and an organization which, however imperfect as compared with those of later times, are yet very far from being in their beginning. The Homeric heroes themselves are represented as having considerable skill in surgery, and as able to attend to ordinary wounds and injuries, but there is also a professional class, represented by Machaon and Podalirius, the two sons of Asclepius, who are treated with great respect. It would appear, too, from the *Æthiopis* of Archinus (quoted by Welcker and Haeser) that the duties of these two were not precisely the same. Machaon's task was more especially to heal injuries, while Podalirius had received from his father the gift of "recognizing what was not visible to the eye, and tending what could not be healed." In other words, a rough indication is seen of the separation of medicine and surgery. Asclepius appears in Homer as a Thessalian king, not as a god, though in later times divine honours were paid to him. There is no sign in the Homeric poems of the subordination of medicine to religion which is seen in ancient Egypt and India, nor are priests charged, as they were in those countries, with medical functions,—all circumstances which throw grave doubts on the commonly received opinion that medicine derived its origin in all countries from religious observances.

Although the actual organization of medicine among the Homeric Greeks was thus quite distinct from religion, the worship of Asclepius (or Æsculapius) as the god of healing demands some notice. This cult spread very widely among the Greeks; it had great civil importance, and lasted even into Christian times; but there is no reason to attribute to it any special connexion with the development of the science or profession of medicine. Sick persons repaired, or were conveyed, to the temples of Asclepius in order to be healed, just as in modern times relief is sought by a devotional pilgrimage or from the waters of some sacred spring, and then as now the healing influence was sometimes sought by deputy. The sick person, or his representative, after ablution, prayer, and sacrifice, was made to sleep on the hide of the sacrificed animal, or at the feet of the statue of the god, while sacred rites were performed. In his sleep (incubatio, ἐγκοίμησις) the appropriate remedy was indicated by a dream. Moral or dietetic remedies were more often prescribed than drugs. The record of the cure was inscribed on the columns or walls of the temple; and it has been thought that in this way was introduced the custom of "recording cases," and that the physicians of the Hippocratic school thus learnt to accumulate clinical experience. But the priests of Asclepius were not physicians. Although the latter were often called Asclepiads, this was in the first place to indicate their real or supposed descent from Asclepius, and in the second place as a complimentary title. No medical writing of antiquity speaks of the worship of Asclepius in such a way as to imply any connexion with the ordinary art of healing. The two systems appear to have existed side by side, but to have been distinct, and if they were ever united it must have been before the times of which we have any record. The theory of a development of Greek medicine from the rites of Asclepius, though defended by eminent names, must accordingly be rejected.

Development of Medicine in Greece.—It is only from non-medical writers that anything is known of the development of medicine in Greece before the age of Hippocrates. The elaborate collections made by Daremberg of medical notices in the poets and historians illustrate the relations of the profession to society, but do little to prepare us for the Hippocratic period. Nor is much importance to be attached to the influence of the philosophical sects on medicine except as regards the school of Pythagoras. That philosopher and several of his successors were physicians, but we do not know in what relation they stood to later medical schools. We must therefore hasten onward to the age of Pericles, in which Hippocrates, already called "the Great," was in medicine as complete a representative of the highest efforts of the Greek intellect as were his contemporaries the great philosophers, orators, and tragedians. The medical art as we now practise it, the character of the physician as we now understand it, both date for us from Hippocrates. The justification of this statement is found in the literary collection of writings known by his name. Of these certainly many are falsely ascribed to the historical Hippocrates of Cos; others are almost as certainly rightly so ascribed; others again are clearly works of his school, whether from his hand or not. But which are to be regarded as the "genuine works" is still uncertain, and authorities are conflicting. There are clearly two schools represented in the collection,—that of Cnidus in a small proportion, and that of Cos in far the larger number of the works. The latter was that to which Hippocrates belonged, and where he gave instruction; and accordingly it may be taken that works of this school, when not obviously of a different date, are Hippocratic in doctrine if not in actual authorship.

Hippocratic Medicine.—The first grand characteristic of Hippocratic medicine is the high conception of the duties and status of the physician, shown in the celebrated "Oath of Hippocrates" and elsewhere,—equally free from the mysticism of a priesthood and the vulgar pretensions of a mercenary craft. So matured a professional sentiment may perhaps have been more the growth of time and organization than the work of an individual genius, but certainly corresponds with the character universally attributed to Hippocrates himself. The second great quality is the singular artistic skill and balance with which the Hippocratic physician used such materials and tools as he possessed. Here we recognize the true Greek σωφροσύνη. But this artistic completeness was closely connected with the third cardinal virtue of Hippocratic medicine,—the clear recognition of disease as being equally with life a process governed by what we should now call natural laws, which could be known by observation, and which indicated the spontaneous and normal direction of recovery, by following which alone could the physician succeed. In the fourth place, these views of the "natural history of disease" (in modern language) led to habits of minute observation and accurate interpretation of symptoms, in which the Hippocratic school was unrivalled in antiquity, and has been the model for all succeeding ages, so that even in these days, with our enormous advances in knowledge, the true method of clinical medicine may be said to be the method of Hippocrates.

The actual science of the Hippocratic school was of course very limited. In anatomy and physiology little advance had been made, and so of pathology in the sense of an explanation of morbid processes or knowledge of diseased structures there could be very little. The most valuable intellectual possession was a large mass of recorded observations in individual cases and epidemics of disease. Whether these observations were systematic or individual, and how they were recorded, are points of which we are quite ignorant, as the theory that the votive tablets in the temples supplied such materials must be abandoned.

Though the Hippocratic medicine was so largely founded on observation, it would be an error to suppose that dogma or theory had no place. The dominating theory of disease was the *humoral*, which has never since ceased to influence medical thought and practice. According to this celebrated theory, the body contains four humours,—blood, phlegm, yellow bile, and black bile, a right proportion and mixture of which constitute health; improper proportions or irregular distribution, disease. It is doubtful whether the treatise in which this theory is fully expounded (περὶ φύσιος ἀνθρώπου) is as old as Hippocrates himself; but it was regarded as a Hippocratic doctrine, and, when taken up and expanded by Galen, its terms not only became the common property of the profession, but passed into general literature and common language. Another Hippocratic doctrine, the influence of which is not even yet exhausted, is that of the healing power of nature. Not that Hippocrates taught, as he was afterwards reproached with teaching, that nature is sufficient for the cure of diseases; for he held strongly the efficacy of art. But he recognized, at least in acute diseases, a natural process which the humours went through,—being first of all *crude*, then passing through *coction* or digestion, and finally being expelled by resolution or *crisis* through one of the natural channels of the body. The duty of the physician was to foresee these changes, "to assist or not to hinder them," so that "the sick man might conquer the disease with the help of the physician." The times at which crises were to be expected were naturally looked for with anxiety; and it was a cardinal point in the Hippocratic system to foretell them with precision. Hippocrates, influenced as is thought by the Pythagorean doctrines of number, taught that they were to be expected on days fixed by certain numerical rules, in some cases on odd, in others on even numbers,—the celebrated doctrine of "critical days." This false precision can have had no practical value, but may have enforced habits of minute observation. It follows from what has been said that *prognosis*, or the art of foretelling the course and event of the disease, was a strong point with the Hippocratic physicians. In this they have perhaps never been excelled. Diagnosis, or recognition of the disease, must have been necessarily imperfect, when no scientific nosology, or system of disease, existed, and the knowledge of anatomy was quite inadequate to allow of a precise determination of the seat of disease; but symptoms were no doubt observed and interpreted skilfully. The pulse is not spoken of in any of the works now attributed to Hippocrates himself, though it is mentioned in other works of the collection.

In the treatment of disease, the Hippocratic school attached great importance to diet, the variations necessary in different diseases being minutely defined. Medicines were regarded as of secondary importance, but not neglected, two hundred and sixty-five drugs being mentioned at different places in the Hippocratic works. Blood-letting was known, but not greatly practised. The highest importance was attached to applying all remedies at the right moment, and the general principle enforced of making all influences—internal and external—co-operate for the relief of the patient. The principles of treatment just mentioned apply more especially to the cure of acute diseases; but they are the most salient characteristics of the Hippocratic school. In chronic cases diet, exercise, and natural methods were chiefly relied upon.

The school of Cnidus, as distinguished from that of Cos, of which Hippocrates is the representative, appears to have differed in attaching more importance to the differences of special diseases, and to have made more use of drugs. A treatise on the diseases of women, contained in the Hippocratic collection, and of remarkable practical value, is attributed to this school.

The above sketch of Hippocratic medicine will make it less necessary to dwell upon the details relating to subsequent medical schools or sects in ancient times. The general conception of the physician's aim and task remained the same, though, as knowledge increased, there was much divergence both in theory and practice,—even opposing schools were found to be developing some part of the Hippocratic system. Direct opponents or repudiators of the authority of Hippocrates were rare, all generally appealing to his authority. But, insensibly, the least valuable part of the Hippocratic work, the theory, was made permanent; the most valuable, the practical, neglected.

Post-Hippocratic Medicine.—After Hippocrates the progress of medicine in Greece does not call for any special remark in such a sketch as this, but mention must be made of one great name. Though none of Aristotle's writings are strictly medical, he has by his researches in anatomy and physiology contributed greatly to the progress of medicine. It should also be remembered that he was of an Asclepiad family, and received that partly medical education which was traditional in such families, and also himself is said to have practised medicine as an amateur. Moreover, his works on natural history doubtless furthered the progress among the Greeks of sciences tributary to medicine, though the only specimens of such works which have come down to us from the Peripatetic school are those of Theophrastus, who may be considered the founder of the scientific study of botany. Among his encyclopædic writings were some on medical subjects, of which fragments only have been preserved. The Peripatetic school may have been more favourable to the development of medicine, as of other departments of natural knowledge, than any other; but there is no evidence that any of the philosophical schools had important influence on the progress of medicine. The fruit of Aristotle's teaching and example was seen later on in the schools of Alexandria.

The century after the death of Hippocrates is a time almost blank in medical annals. It is probable that the science, like others, shared in the general intellectual decline of Greece after the Macedonian supremacy; but the works of physicians of the period are almost entirely lost, and were so even in the time of Galen. Galen classes them all as of the dogmatic school; but, whatever may have been their characteristics, they are of no importance in the history of the science.

Alexandrian School of Medicine.—The dispersion of Greek science and intellectual activity through the world by the conquests of Alexander and his successors led to the formation of more than one learned centre, in which medicine among other sciences was represented. Pergamum was early distinguished for its medical school; but in this as in other respects its reputation was ultimately effaced by the more brilliant fame of Alexandria. It is here that the real continuation and development of Hippocratic medicine can be traced.

In one department the Alexandrian school rapidly surpassed its Greek original, namely, in the study of anatomy The dissection of the human body, of which some doubtful traces or hints only are found in Greek times, was assiduously carried out, being favoured or even suggested perhaps by the Egyptian custom of disembowelling and embalming the bodies of the dead. There is no doubt that the organs were also examined by opening the bodies of living persons,—criminals condemned to death being given over to the anatomists for this purpose.

Two eminent names stand in the first rank as leaders of the two earliest schools of medicine which arose in Alexandria, Herophilus and Erasistratus.

Herophilus was a Greek of Chalcedon, a pupil of the schools both of Cos and of Cnidus. He was especially noted for his profound researches in anatomy (see vol. i. p. 802), and in the knowledge and practice of medicine he appears to have been equally renowned. He professed himself a close adherent of Hippocrates, and adopted his theory of the humours. He also made extensive use of drugs, and of bleeding. The reputation of Herophilus is attested by the fact that four considerable physicians wrote works about him and his writings, and he is further spoken of with the highest respect by Galen and Celsus. By the general voice of the medical world of antiquity he was placed only second to Hippocrates.

Erasistratus was the contemporary and rival of Herophilus. Little is known of his life, except that he spent some time at the court of Seleucus Nicator at Antioch before coming to Alexandria, and that he cultivated anatomy late in life, after he had taken up his abode in the latter city. His numerous works are also almost entirely lost, fragments only being preserved by Galen and others. Erasistratus, instead of following Hippocrates as Herophilus did, depreciated him, and seems to have been rather aggressive and independent in his views. He appears to have leaned to mechanical explanations of the symptoms of disease, as was especially the case with inflammation, of which he gave the first rational, though necessarily inadequate, theory.

The two schools composed of the followers of Herophilus and Erasistratus respectively long divided between them the medical world of Alexandria. The names of many prominent members of both sects have been preserved, but it would be useless to repeat them. The Herophilists still reverenced the memory of Hippocrates, and wrote numerous commentaries on his works. They produced many eminent anatomists, but in the end seem to have become lost in theoretical subtleties, and to have maintained too high a standard of literary cultivation. The school of Erasistratus was less distinguished in anatomy than that of Herophilus, but paid more attention to the special symptoms of diseases, and employed a great variety of drugs. It was longer-lived than that of Herophilus, for it still numbered many adherents in the 2d century after Christ, a century after the latter had become extinct.

The Erasistrateans paved the way for what was in some respects the most important school which Alexandria produced, that known as the empiric, which, though it recognized no master by name, may be considered to have been founded by Philinus of Cos (280 B.C.), a pupil of Herophilus; but Serapion, a great name in antiquity, and Glaucias of Tarentum, who traced the empirical doctrine back to the writings of Hippocrates, are also named among its founders. The most striking peculiarity of the empirics was that they rejected anatomy, regarding it as useless to inquire into the causes of things, and thus, as they contended, being the more minute in their observation of the actual phenomena of disease. They professed that their whole practice was based upon experience, to which word they gave a special meaning. Three sources, and three only, could experience draw from:—observation, history (*i.e.*, recorded observation), and judgment by analogy. These three bases of knowledge were known as the "tripod" of the empirics. It should not, however, be forgotten that the empirics read and industriously commented on the works of Hippocrates. They were extremely successful in practical matters, especially in surgery and in the use of drugs, and a large part of the routine knowledge of diseases and remedies which became traditional in the times of the Roman empire is believed to have been derived from them. In the 2d century the school became closely connected with the philosophical sect of the Sceptics, whose leader, Sextus, was an empirical physician. It lived and flourished far beyond this time, when transplanted to Rome, not less than in its native Alexandria, and appears to be recognizable even up to the beginning of the Middle Ages.

If we look at the work of the Alexandrian schools in medicine as a whole, we must admit that the progress made was great and permanent. The greatest service rendered to medicine was undoubtedly the systematic study of anatomy. It is clear that the knowledge of function (physiology) did not by any means keep pace with the knowledge of structure, and this was probably the reason why the important sect of the empirics were able entirely to dispense with anatomical knowledge. The doctrines of Hippocrates, though lightly thought of by the Erasistrateans, still were no doubt very widely accepted, but the practice of the Hippocratic school had been greatly improved in almost every department,—surgery and obstetrics being probably those in which the Alexandrian practitioners could compare most favourably with those of modern times. We have now to trace the fortunes of this body of medical doctrine and practice when transplanted to Rome, and ultimately to the whole Roman world.

Roman Medicine.—The Romans cannot be said to have at any time originated or possessed an independent school of medicine. They had from early times a very complicated system of superstitious medicine, or religion, related to disease and the cure of disease, borrowed, as is thought, from the Etruscans; and, though the saying of Pliny that the Roman people got on for six hundred years without doctors was doubtless an exaggeration, and not, literally speaking, exact, it must be accepted for the broad truth which it contains. When a medical profession appears, it is, so far as we are able to trace it, as an importation from Greece.

The first Greek physician whose name is preserved as having migrated to Rome was Archagathus, who came over from the Peloponnesus in 218 B.C.; but there were probably others before him. When Greece was made a Roman province, the number of such physicians who sought their fortunes in Rome must have been very large. The bitter words of M. Porcius Cato, who disliked them as he did other representatives of Greek culture, are evidence of this. The most eminent of these earlier Greek physicians at Rome was Asclepiades, the friend of Cicero (born 124 B.C. at Prusa in Bithynia). He came to Rome as a young man, and soon became distinguished both for his medical skill and his oratorical power. He introduced a system which, so far as we know, was his own, though founded upon the Epicurean philosophical creed; on the practical side it conformed pretty closely to the Stoic rule of life, thus adapting itself to the leanings of the better stamp of Romans in the later times of the republic. According to Asclepiades all diseases depended upon alterations in the size, number, arrangement, or movement of the "atoms," of which, according to the doctrine of Epicurus, the body consisted. These atoms were united into passages (πόροι) through which the juices of the body were conveyed. This doctrine, of which the developments need not further be followed, was important chiefly in so far that it was perfectly distinct from, and opposed to, the humoral pathology of Hippocrates. In the treatment of disease Asclepiades attached most importance to diet, exercise, passive movements or frictions, and the external use of cold water,—in short, to a modified athletic training. He rejected the *vis medicatrix naturæ*, pointing out that nature in many cases not only did not help but marred the cure. His knowledge of disease and surgical skill were, as appears from the accounts given by Celsus and Cœlius Aurelianus, very considerable. Asclepiades had many pupils, who adhered more or less closely to his doctrines, but it was especially one of them, Themison, who gave permanence to the teachings of his master by framing out of them, with some modifications, a new system of medical doctrine, and founding on this basis a school which lasted for some centuries in successful rivalry with the Hippocratic tradition, which, as we have seen, was up to that time the prevailing influence in medicine.

This system was known as methodism, its adherents as the methodici or methodists. Its main principles were that it was useless to consider the causes of a disease, or even the organ affected by the disease, and that it was sufficient to know what was common to all diseases, viz., their common qualities (communitates, κοινότητες). Of these there were three possible forms—(1) relaxation, (2) contraction of the minute passages or πόροι, and (3) a mixed state, partly lax, partly constricted. The signs of these morbid states were to be found in the general constitution of the body, especially in the excretions. Besides this it was important only to consider whether the disease was acute or chronic, whether it was increasing, declining, or stationary. Treatment of disease was directed not to any special organ, nor to producing the crises and critical discharges of the Hippocratic school, but to correcting the morbid common condition or "community," relaxing the body if it was constricted, causing contraction if it was too lax, and in the "mixed state" acting according to the predominant condition. This simple rule of treatment was the system or "method" from which the school took its name.

The methodists agreed with the empirics in one point, in their contempt for anatomy; but, strictly speaking, they were dogmatists, though with a dogma different from that of the Hippocratic school. Besides Themison, its systematic founder, the school boasted many physicians eminent in their day, among whom Thessalus of Tralles, a half-educated and boastful pretender, was one of the most popular. He reversed the Hippocratic maxim "art is long," promising his scholars to teach them the whole of medicine in six months, and had inscribed upon his tomb ἰατρονίκης, as being superior to all living and bygone physicians.

In the 2d century a much greater name appears among the methodists, that of Soranus of Ephesus, a physician mentioned with praise even by Tertullian and Augustine, who practised at Rome in the reigns of Trajan and Hadrian. Soranus is known by a work, still extant in the Greek original, on the diseases of women, and also by the Latin work of Cœlius Aurelianus, three centuries later, on acute and chronic diseases, which is based upon, if not, as some think, an actual translation of, the chief work of Soranus, and which is the principal source of our knowledge of the methodic school. The work on diseases of women is the only complete work on that subject which has come down to us from antiquity, and shows remarkable fulness of practical knowledge in relation to its subject. It is notable that an important instrument of research, the speculum, which has been reinvented in modern times, was used by Soranus; and specimens of still earlier date, showing great mechanical perfection, have been found among the ruins of Pompeii. The work on acute and chronic diseases is also full of practical knowledge, but penetrated with the theories of the methodists.

The methodic school lasted certainly for some centuries, and influenced the revival of medical science in the Middle Ages, though overshadowed by the greater reputation of Galen. It was the first definite product of Greek medicine on Roman soil, but was destined to be followed by others, which kept up a more or less successful rivalry with it, and with the Hippocratic tradition.

The so-called pneumatic school was founded by Athenæus, in the 1st century after Christ. According to its doctrines the normal as well as diseased actions of the body were to be referred to the operation of the pneuma or universal soul. This doctrine, crudely transferred from philosophical speculation, was intended to reconcile the humoral (or Hippocratic) and solidist (or methodic) schools; but the methodists seem to have claimed Athenæus as one of themselves.

The conflicts of the opposing schools, and the obvious deficiencies of each, led many physicians to try and combine the valuable parts of each system, and to call themselves eclectics. Among these were found many of the most eminent physicians of Græco-Roman times. It may be sufficient to name Rufus of Ephesus, and Archigenes, who is mentioned by Juvenal.

Although no system or important doctrine of medicine was originated by the Roman intellect, and though the practice of the profession was probably almost entirely in the hands of the Greeks, the most complete picture which we have of medical thought and activity in Roman times is due to a Latin pen, and to one who was, in all probability, not a physician. A. Cornelius Celsus, a Roman patrician, who lived probably in the first century, appears to have studied medicine as a branch of general knowledge. Whether he was a practising physician or not has been a matter of controversy. The conclusion supported by most evidence seems to be that he practised on his friends and dependants, but not as a remunerative profession. His well-known work, *De Medicina*, was one of a series of treatises intended to embrace all knowledge proper for a man of the world. It was not meant for the physicians, and was certainly little read by them, as Celsus is quoted by no medical writer, and when referred to by Pliny is spoken of as an author, not a physician. There is no doubt that his work is chiefly a compilation; and Daremberg, with other scholars, has traced a large number of passages of the Latin text to the Greek originals from which they were translated. In the description of surgical operations the vagueness of the language seems sometimes to show that the author had not performed such himself; but in other parts, and especially in his historical introduction, he speaks with more confidence; and everywhere he compares and criticizes with learning and judgment. The whole body of medical literature belonging to the Hippocratic and Alexandrian times is ably summarized, and a knowledge of the state of medical science up to and during the times of the author is thus conveyed to us which can be obtained from no other source. The work of Celsus is thus for us only second in importance to the Hippocratic writings and the works of Galen; but it is valuable rather as a part of the history of medicine than as the subject of that history. It forms no link in the general chain of medical tradition, for the simple reason that the influence of Celsus (putting aside a few scanty allusions in mediæval times) commenced in the 15th century, when his works were first discovered in manuscript or committed to the press. Since then, however, he has been almost up to our own times the most popular and widely-read of all medical classics, partly for the qualities already indicated, partly because he was one of the few of those classics accessible to readers of Latin, and partly also because of the purity and classical perfection of his language.

Of Pliny, another encyclopædic writer, a few words must be said, though he was not a physician. In his *Natural History* we find as complete a summary of the popular medicine of his time as Celsus gives of the scientific medicine. Pliny disliked doctors, and lost no opportunity of depreciating regular medicine; nevertheless he has left many quotations from, and many details about, medical authors which are of the highest value. He is useful to us for what he wrote about the history of medicine, not for what he contributed. Like Celsus, he had little influence on succeeding medical literature or practice.

We now come to the writer who, above all others, gathered up into himself the divergent and scattered threads of ancient medicine, and out of whom again the greater part of modern European medicine has flowed. Galen (see vol. i. 803 and x. 23) was a man furnished with all the anatomical, medical, and philosophical knowledge of his time; he had studied all kinds of natural curiosities, and had stood in near relation to important political events; he possessed enormous industry, great practical sagacity, and unbounded literary fluency. He had, in fact, every quality necessary for an encyclopædic writer, or even for a literary and professional autocrat. He found the medical profession of his time split up into a number of sects, medical science confounded under a multitude of dogmatic systems, the social status and moral integrity of physicians degraded. He appears to have made it his object to reform these evils, to reconcile scientific acquirements and practical skill, to bring back the unity of medicine as it had been understood by Hippocrates, and at the same time to raise the dignity of medical practitioners.

Galen was as devoted to anatomical and, so far as then understood, physiological research as to practical medicine. He worked enthusiastically at dissection, though, the liberty of the Alexandrian schools no longer existing, he could dissect only animals, not the human body. In his anatomical studies Galen had a twofold object,—a philosophical, to show the wisdom of the Creator in making everything fit to serve its purpose, and a practical, to aid the diagnosis, or recognition, of disease. The first led him into a teleological system so minute and overstrained as to defeat its own end; the second was successfully attained by giving greater precision and certainty to medical and surgical practice in difficult cases. His general physiology was essentially founded upon the Hippocratic theory of the four elements, with which he combined the notion of spirit (pneuma) penetrating all parts, and mingled with the humours in different proportions. It was on this field that he most vehemently attacked the prevailing atomistic and materialistic views of the methodic school, and his conception of the pneuma became in some respects half metaphysical. His own researches in special branches of physiology were important, but do not strictly belong to our present subject.

The application of physiology to the explanation of diseases, and thus to practice, was chiefly by the theory of the temperaments or mixtures which Galen founded upon the Hippocratic doctrine of humours, but developed with marvellous and fatal ingenuity. The normal condition or temperament of the body depended upon a proper mixture or proportion of the four elements—hot, cold, wet, and dry. From faulty proportions of the same arose the *intemperies* ("distempers"), which, though not diseases, were the occasions of disease. Equal importance attached to faulty mixtures or dyscrasiæ of the blood. By a combination of these morbid predispositions with the action of deleterious influences from without all diseases were produced. Galen showed extreme ingenuity in explaining all symptoms and all diseases on his system. No phenomenon was without a name, no problem without a solution. And, though it was precisely in his fine-spun subtlety that he departed farthest from scientific method and practical utility, it was this very quality which seems in the end to have secured his popularity and established his pre-eminence in the medical world.

Galen's use of drugs was influenced largely by the same theories. In drugs were to be recognized the same elementary qualities—hot, cold, moist, dry, &c.—as in the human body; and, on the principle of curing by contraries, the use of one or other was indicated. The writings of Galen contain less of simple objective observation than those of several other ancient physicians, all being swept into the current of dogmatic exposition. But there is enough to show the thoroughness and extent of his practical knowledge. Unfortunately it was neither this nor his zeal for research that chiefly won him followers, but the completeness of his theoretical explanations, which fell in with the mental habits of succeeding centuries, and were such as have flattered the intellectual indolence of all ages. But the reputation of Galen grew slowly; he does not appear to have enjoyed any pre-eminence over other physicians of his time, to most of whom he was strongly opposed in opinion. In the next generation he began to be esteemed only as a philosopher; gradually his system was implicitly accepted, and it enjoyed a great though not exclusive predominance till the fall of Roman civilization. When the Arabs possessed themselves of the scattered remains of Greek culture, the works of Galen were more highly esteemed than any others except those of Aristotle. Through the Arabs the Galenical system found its way back again to Western Europe. Even when Arabian medicine gave way before the direct teaching of the Greek authors rescued from neglect, the authority of Galen was increased instead of being diminished; and he assumed a position of autocracy in medical science which was only slowly undermined by the growth of modern science in the 17th and 18th centuries.

But the history of medicine in Roman times is by no means the same thing as the history of the fate of the works of Galen. For some centuries the methodic school was popular at Rome, and produced one physician, Cœlius Aurelianus, who must be pronounced, next to Celsus, the most considerable of the Latin medical writers. His date was in all probability the end of the 4th or beginning of the 5th century. The works bearing his name are, as has been said, entirely based upon the Greek of Soranus, but are important both because their Greek originals are lost, and because they are evidence of the state of medical practice in his own time. The popularity of Cœlius is evidenced by the fact that in the 6th century an abridgment of his larger work was recommended by Cassiodorus to the Benedictine monks for the study of medicine.

Before quitting this period the name of Aretæus of Cappadocia must be mentioned. So little is known about him that even his date cannot be fixed more closely than as being between the second half of the 1st century and the beginning of the 3d. His works have been much admired for the purity of the Greek style, and his accurate descriptions of disease; but, as he quotes no medical author, and is quoted by none before Alexander of Aphrodisias at the beginning of the 3d century, it is clear that he belonged to no school and founded none, and thus his position in the chain of medical tradition is quite uncertain. Alexander of Aphrodisias, who lived and wrote at Athens in the time of Septimius Severus, is best known by his commentaries on Aristotle, but also wrote a treatise on fevers, still extant.

Ancient Medicine after Galen.—The Byzantine school of medicine, which closely corresponds to the Byzantine literary and historical schools, followed closely in Galen's footsteps, and its writers were chiefly compilers and encyclopædists. The earliest is Oribasius (326–403), whose date and position are fixed by his being the friend and court physician of Julian the Apostate. He was a Greek of Pergamum, educated in Alexandria, and long resident in Byzantium. His great work Συναγωγαὶ ἰατρικαί, of which only about one-third has been preserved, was a medical encyclopædia founded on extracts from Hippocrates, Galen, Dioscorides, and certain Greek writers who are otherwise very imperfectly known. The work is thus one of great historical value but of no originality. The next name which requires to be mentioned is that of Aetius (550 A.D.), a compiler who closely followed Oribasius, but with inferior powers, and whose work also has an historical but no original value. A higher rank among medical writers is assigned to Alexander of Tralles (525–605), whose doctrine was that of an eclectic. His practical and therapeutical rules are evidently the fruit of his own experience, though it would be difficult to attribute to him any decided advance in medical knowledge. But the most prominent figure in Byzantine medicine is that of Paul of Ægina (Paulus Ægineta), who lived probably in the early part of the 7th century. His skill, especially in surgery, must have been considerable, and his Ἰατρικά gives a very complete picture of the achievements of the Greeks in this department. Another work, on obstetrics, now lost, was equally famous, and procured for him, among the Arabs, the name of "the Obstetrician." His reputation lasted through the Middle Ages, and was not less in the Arabian schools than in the West. In this respect Paulus is a most important influence in the development of medicine. His great work on surgery was early translated into Arabic, and became the foundation of the surgery of Abulcasis, which in turn (to anticipate) was one of the chief sources of surgical knowledge to Europe in the Middle Ages. The succeeding period of Byzantine history was so little favourable to science that no name worthy of note occurs again (though many medical works of this period are still extant) till the 13th century, when we meet with a group of writers;—Demetrius Pepagomenus, Nicolaus Myrepsus, and Johannes, called Actuarius, who flourished under the protection of the Palæologi. The work of the last has some independent merit; but all are interesting as showing a fusion of Greek and Arabian medicine, the latter having begun to exercise even in the 11th century a reflex influence on the schools of Byzantium. Something was borrowed even from the school of Salerno, and thus the close of Byzantine medicine is brought into connexion with the dawn of science in modern Europe.

In the West the period after Galen affords little evidence of anything but a gradual though unvarying decline in Roman medicine. Cœlius Aurelianus, already referred to as the follower of Soranus, must be mentioned as showing the persistence of the methodic school. An abridgment of one of his writings, with the title of *Aurelius*, became the most popular of all Latin medical works. As a writer he was worthy of a better period of medical literature. Little else was produced in these times but compilations, of the most meagre kind, chiefly of the nature of herbals, or domestic receipt-books; among the authors of which it may be sufficient to name Serenus Sammonicus (3d century), Gargilius Martialis (3d century), and Marcellus Empiricus (5th century). Certain compilations still extant bear the falsely-assumed names of eminent writers, such as Pliny and Hippocrates. A writer with the (perhaps assumed) name of Apuleius Platonicus produced a herbal which held its ground till the 15th century at least, and was in the 9th translated into Anglo-Saxon. These poor compilations, together with Latin translations of certain works of Galen and Hippocrates, formed a medical literature, meagre and unprogressive indeed, but of which a great part survived through the Middle Ages till the discovery of printing and revival of learning. It is important to remember that this obscure stream of tradition flowed on, only partially affected by the influx of Arabian, or even the early revival of purer classical learning.

Arabian Medicine.—The rise of the Mohammedan empire, which influenced Europe so deeply both politically and intellectually, made its mark also in the history of medicine. As in the parallel case of the Roman conquest of Greece, the superior culture of the conquered race asserted its supremacy over their Arab conquerors. After the Mohammedan conquests became consolidated, and learning began to flourish, schools of medicine, often connected with hospitals and schools of pharmacy, arose in all the chief seats of Moslem power. At Damascus Greek medicine was zealously cultivated with the aid of Jewish and Christian teachers. In Baghdad, under the rule of Hárún el Rashíd and his successors, a still more flourishing school arose, where numerous translations of Greek medical works were made. The names of Mesua, or Yahyá ibn Másawaih (*ob.* 243 A.H., 857–8 A.D.), celebrated for his knowledge of drugs, and Honein ibn Ishak el 'Ibádí (*ob.* 873) or Joannitius, the translator and commentator of Hippocrates and Galen, belong to this period. Certain writings of Joannitius, translated into Latin, were popular in the Middle Ages in Europe, and were printed in the 16th century. At the same time the Arabs became acquainted with Indian medicine, and Indian physicians lived at the court of Baghdad. The Islamite rulers in Spain were not long behind those of the East in encouraging learning and medical science, and developed culture to a still higher degree of perfection. In that country much was due to the Jews, who had already established schools in places which were afterwards the seats of Moslem dominion. From the 10th to the 13th century was the brilliant period of Arabian medicine in Spain.[1]

The classical period of Arabian medicine begins with Rhazes (Abú Bakr Mohammed ibn Zakaríyá el-Rází, 313 A.H., 925–26 A.D.), a native of Ray in the province of Dailam (Persia), who practised with distinction at Baghdad; he followed the doctrines of Galen, but learnt much from Hippocrates. He was the first of the Arabs to treat medicine in a comprehensive and encyclopædic manner, surpassing probably in voluminousness Galen himself, though but a small proportion of his works are extant. Rhazes is deservedly remembered as having first described small-pox and measles in an accurate manner. Haly, *i.e.*, 'Alí ibn el-'Abbás (*ob.* 994), a Persian, wrote a medical text-book, known as the "Royal Book," which was the standard authority among the Arabs up to the time of Avicenna, and was more than once translated into Latin and printed. Other writers of this century need not be mentioned here; but the next, the 11th century, is given as the probable though uncertain date of a writer who had a great influence on European medicine, Mesua the younger of Damascus, whose personality is obscure, and of whose very existence some historians have doubted, thinking that the name was assumed by some mediæval Latin writer. The work *De Simplicibus*, which bears his name, was for centuries a standard authority on what would now be called materia medica, was printed in twenty-six editions in the 15th century and later, and was used in the formation of the first London pharmacopœia, issued by the College of Physicians in the reign of James I. Either to the 10th or the 11th century must be referred the name of another Arabian physician who has also attained the position of a classic, Abu'l Kásim, or Abulcasis, of El-Zahra, near Cordova in Spain. His great work, *Altasríf*, a medical encyclopædia, is chiefly valued for its surgical portion (already mentioned), which was translated into Latin in the 12th century, and was for some centuries a standard if not the standard authority on surgery in Europe. Among his own countrymen the fame and position of Abulcasis were soon eclipsed by the greater name of Avicenna (Ibn Síná).

Avicenna (see vol. iii. p. 152 *sq.*) has always been regarded as the chief representative of Arabian medicine. He wrote on philosophy also, and in both subjects acquired the highest reputation through the whole of Eastern Islam. In Mohammedan Spain he was less regarded, but in Europe his works even eclipsed and superseded those of Hippocrates and Galen. His style and expository power are highly praised, but the subject-matter shows little originality. The work by which he is chiefly known, the celebrated "canon," is an encyclopædia of medical and surgical knowledge, founded upon Galen, Aristotle, the later Greek physicians, and the earlier Arabian writers, singularly complete and systematic, but is thought not to show the practical experience of its author. As in the case of Galen, the formal and encyclopædic character of Avicenna's works was the chief cause of his popularity and ascendency, though in modern times these very qualities in a scientific or medical writer would rather cause him to become more speedily antiquated.

In the long list of Arabian medical writers none can here be mentioned except the great names of the Hispano-Moorish school, a school both philosophically and medically antagonistic to that of Avicenna. Of these the earliest is Avenzoar, or Abumeron, that is, Abú Merwán 'Abd el-Malik Ibn Zohr (1113–62), a member of a family which gave several distinguished members to the medical profession. His chief work, *Al-Teysír* (facilitatio), is thought to show more practical experience than the writings of Avicenna, and to be less based upon dialectical subtleties. It was translated into Latin, and more than once printed, as were some of his lesser works, which thus formed a part of the contribution made by the Arabians to European medicine. His friend and pupil AVERROES of Cordova (*q.v.*), so well known for his philosophical writings, was also an author in medical subjects, and as such widely read in Latin. The famous Rabbi MAIMONIDES (*q.v.*) closes for us the roll of medical writers of the Arabian school. His works exist chiefly in the original Arabic or in Hebrew translations; only some smaller treatises have been translated into Latin, so that no definite opinion can be formed as to their medical value. But, so far as is known, the independent and rationalistic spirit which the two last-named writers showed in philosophy did not lead them to take any original point of view in medicine.

The works of the Arabian medical writers who have now been mentioned form a very small fraction of the existing literature. Three hundred medical writers in

[1] See Dozy, *Cat. Cod. Or. Lug. Bat.*, ii. 296.

Arabic are enumerated by Wüstenfeld, and other historians have enlarged the list (Haeser), but only three have been printed in the original; a certain number more are known through old Latin translations, and the great majority still exist in manuscript. It is thus evident that the circumstance of having been translated (which may have been in some cases almost an accident) is what has chiefly determined the influence of particular writers on Western medicine. But it is improbable that further research will alter the general estimate of the value of Arabian medicine. There can be no doubt that it was in the main Greek medicine, modified to suit other climates, habits, and national tastes, and with some important additions from Oriental sources. The greater part is taken from Hippocrates, Galen, Dioscorides, and later Greek writers. The Latin medical writers were necessarily unknown to the Arabs; and this was partly the cause that even in Europe Galenic medicine assumed such a preponderance, the methodic school and Celsus being forgotten or neglected. In anatomy and physiology the Arabians distinctly went back; in surgery they showed no advance upon the Greeks; in practical medicine nothing new can be traced, except the description of certain diseases (*e.g.*, small-pox and measles) unknown or imperfectly known to the Greeks; the only real advance was in pharmacy and the therapeutical use of drugs. By their relations with the further East, the Arabs became acquainted with valuable new remedies which have held their ground till modern times; and their skill in chemistry enabled them to prepare new chemical remedies, and form many combinations of those already in use. They produced the first pharmacopœia, and established the first apothecaries' shops. Many of the names and many forms of medicines now used, and in fact the general outline of modern pharmacy, except so far as modified by modern chemistry, started with the Arabs. Thus does Arabian medicine appear as judged from a modern standpoint; but to mediæval Europe, when little but a tradition remained of the great ancient schools, it was invested with a far higher degree of originality and importance.

It is now necessary to consider what was the state of medicine in Europe after the fall of the Western empire and before the influence of Arabian science and literature began to be felt. This we may call the pre-Arabian or Salernitan period.

Medicine in the Early Middle Ages: School of Salerno.—In medical as in civil history there is no real break. A continuous thread of learning and practice must have connected the last period of Roman medicine already mentioned with the dawn of science in the Middle Ages. But the intellectual thread is naturally traced with greater difficulty than that which is the theme of civil history; and in periods such as that from the 5th to the 10th century in Europe it is almost lost. The chief homes of medical as of other learning in these disturbed times were the monasteries. Though the science was certainly not advanced by their labours, it was saved from total oblivion, and many ancient medical works were preserved either in Latin or vernacular versions. The "Anglo-Saxon Leechdoms" of the 11th century, published in the Master of the Rolls series of mediæval chronicles and memorials, admirably illustrate the mixture of magic and superstition with the relics of ancient science which constituted monastic medicine. Similar works, in Latin or other languages, exist in manuscript in all the great European libraries. It was among the Benedictines that the monastic study of medicine first received a new direction, and aimed at a higher standard. The study of Hippocrates, Galen, and other classics was recommended by Cassiodorus (6th century), and in the original mother-abbey of Monte Cassino medicine was studied; but there was not there what could be called a medical school; nor had this foundation any connexion (as has been supposed) with the famous school of Salerno.

The origin of this, the most important source of medical knowledge in Europe in the early Middle Ages, is involved in obscurity. It is known that Salerno, a Roman colony, in a situation noted in ancient times for its salubrity, was in the 6th century at least the seat of a bishopric, and at the end of the 7th century of a Benedictine monastery, and that some of the prelates and higher clergy were distinguished for learning, and even for medical acquirements. But it has by recent researches been clearly established that the celebrated *Schola Salernitana* was a purely secular institution. All that can with certainty be said is that a school or collection of schools gradually grew up in which especially medicine, but also, in a subordinate degree, law and philosophy were taught. In the 9th century Salernitan physicians were already spoken of, and the city was known as *Civitas Hippocratica.* A little later we find great and royal personages resorting to Salerno for the restoration of their health, among whom was William of Normandy, afterwards the Conqueror. The number of students of medicine must at one time have been considerable, and in a corresponding degree the number of teachers. Among the latter many were married, and their wives and daughters appear also in the lists of professors. The most noted female professor was the celebrated Trotula in the 11th century. The Jewish element appears to have been important among the students, and possibly among the professors. The reputation of the school was great till the 12th or 13th century, when the introduction of the Arab medicine was gradually fatal to it. The foundation of the university of Naples, and the rise of Montpellier, also contributed to its decline.

The teachings of the Salernitan doctors are pretty well known through existing works, some of which have only recently been discovered and published. The best-known is the anonymous rhyming Latin poem on health, *Regimen Sanitatis Salerni*, professedly written for the use of the "king of England," supposed to mean Robert, son of William the Conqueror; it had an immense reputation in the Middle Ages, and was afterwards many times printed, and translated into most European languages. This was a popular work intended for the laity; but there are others strictly professional. Among the writers it may be sufficient to mention here Gariopontus; Copho, who wrote the *Anatome Porci*, a well-known mediæval book; Joannes Platearius, first of a family of physicians bearing the same name, whose *Practica*, or medical compendium, was afterwards several times printed; and Trotula, believed to be the wife of the last-named. All of these fall into the first period before the advent of Arabian medicine. In the transitional period, when the Arabian school began to influence European medicine, but before the Salernitans were superseded, comes Nicolaus Præpositus, who wrote the *Antidotarium*, a collection of formulæ for compound medicines, which became the standard work on the subject, and the foundation of many later compilations. An equally popular writer was Gilles de Corbeil (Ægidius Corboliensis), at one time a teacher at Salerno, afterwards court physician to Philip Augustus of France, who composed several poems in Latin hexameters on medical subjects. Two of them, on the urine and the pulse respectively, attained the position of medical classics.

None of these Salernitan works rise much above the rank of compilations, being founded on Hippocrates, Galen, and later Greek writers, with an unmistakable mixture of the doctrines of the methodists. But they often show much practical experience, and exhibit the naturalistic method of the Hippocratic school. The general plan of treatment is dietetic rather than pharmaceutical, though the art of preparing drugs had reached a high degree of complexity at Salerno. Anatomy was as little regarded as it was in the later ancient schools, the empiric and methodic, but demonstrations of the parts of the body were given on swine. Although it cannot be said that the science of medicine was advanced at Salerno, still its decline was arrested at a time when every other branch of learning was rapidly falling into decay; and there can be no doubt that the observation of patients in hospitals, and probably clinical instruction, were made use of in learning and teaching. The school of Salerno thus forms a bridge between the ancient and the modern medicine, more direct though less conspicuous than that circuitous route, through Byzantium, Baghdad, and Cordova, by which Hippocrates and Galen, in Arabian dress, again entered the European world. Though the glory of Salerno had departed, the school actually existed till it was finally dissolved by an edict of the emperor Napoleon I. in the year 1811.

Introduction of Arabian Medicine: The Scholastic Period.—About the middle of the 11th century the Arabian medical writers began to be known by Latin translations in the Western world. Constantinus Africanus, a monk, was the author of the earliest of such versions (1050 A.D.); his labours were directed chiefly to the less important and less bulky Arabian authors, of whom Haly was the most noted; the real classics were not introduced till later. For some time the Salernitan medicine held its ground, and it was not till the conquest of Toledo by Alphonso of Castile that any large number of Western scholars came in contact with the learning of the Spanish Moors, and systematic efforts were made to translate their philosophical and medical works. Jewish scholars, often under the patronage of Christian bishops, were especially active in the work. In Sicily also the Oriental tendencies of Frederick Barbarossa and Frederick II. worked in the same direction. Gerard of Cremona, a physician of Toledo (1114–87), made translations, it is said by command of Barbarossa, from Avicenna and others. It is needless to point out the influence of the crusades in making Eastern ideas known in the Western world. The influence of Arabian medicine soon began to be felt even in the Hippocratic city of Salerno, and in the 13th century is said to have held an even balance with the older medicine. After this time the foreign influence predominated; and by the time that the Aristotelian dialectic, in the introduction of which the Arabs had so large a share, prevailed in the schools of Europe, the Arabian version of Greek medicine reigned supreme in the medical world. That this movement coincided with the establishment of some of the older European universities is well known. The history of medicine in the period now opening is closely combined with the history of scholastic philosophy. Both were infected with the same dialectical subtlety, which was, from the nature of the subject, especially injurious to medicine.

At the same time, through the rise of the universities, medical learning was much more widely diffused, and the first definite forward movement was seen in the school of Montpellier, where a medical faculty existed early in the 12th century, afterwards united with faculties of law and philosophy. The medical school owed its foundation largely to Jewish teachers, themselves educated in the Moorish schools of Spain, and imbued with the intellectual independence of the Averroists. Its rising prosperity coincided with the decline of the school of Salerno. Montpellier became distinguished for the practical and empirical spirit of its medicine, as contrasted with the dogmatic and scholastic teaching of Paris and other universities. In Italy, Bologna and Padua were earliest distinguished for medical studies,—the former preserving more of the Galenical tradition, the latter being more progressive and Averroist. The northern universities contributed little,—the reputation even of Paris being of later growth.

The supremacy of Arabian medicine lasted till the revival of learning, when the study of the medical classics in their original language worked another revolution. The medical writers of this period, who chiefly drew from Arabian sources, have been called Arabists (though it is difficult to give any clear meaning to this term), and were afterwards known as the neoterics.

The medical literature of this period is extremely voluminous, but essentially second-hand, consisting mainly of commentaries on Hippocrates, Galen, Avicenna, and others, or of compilations and *compendia* still less original than commentaries. Among these may be mentioned the *Conciliator* of Peter of Abano (1250–1315), the *Aggregator* of Jacob de Dondi (1298–1359), both of the school of Padua, and the *Pandectæ Medicinæ* of the Salernitan Matthæus Sylvaticus (*ob.* 1342), a sort of medical glossary and dictionary. But for us the most interesting fact is the first appearance of Englishmen as authors of medical works having a European reputation, distinguished, according to the testimony of Haeser, by a practical tendency characteristic of the British race, and fostered in the school of Montpellier.

The first of these works is the *Compendium Medicinæ*, also called *Laurea* or *Rosa Anglicana*, of Gilbert (Gilbertus Anglicus, about 1290), said to contain good observations on leprosy. A more important work, the *Practica seu Lilium Medicinæ*, of Bernard Gordon, a Scottish professor at Montpellier (written in the year 1307), was more widely spread, being translated into French and Hebrew, and printed in several editions. Of these two physicians the first probably, the latter certainly, was educated and practised abroad, but John Gaddesden, the author of *Rosa Anglica seu Practica Medicinæ* (between 1305 and 1317), was a graduate in medicine of Merton College, Oxford, and court physician. His compendium is entirely wanting in originality, and perhaps unusually destitute of common sense, but it became so popular as to be reprinted up to the end of the 16th century. Works of this kind became still more abundant in the 14th and in the first half of the 15th century, till the wider distribution of the medical classics in the original put them out of fashion.

In surgery this period was far more productive than in medicine, especially in Italy and France, but the limits of our subject only permit us to mention Gulielmus de Saliceto of Piacenza (about 1275), Lanfranchi of Milan (died about 1306), the French surgeon, Guy de Chauliac (about 1350), and the Englishman, John Ardern (about 1350). In anatomy also the beginning of a new epoch was made by Mondino de Liucci, or Mundinus (1275–1326), and his followers. Some advance was made in chemistry by the celebrated Arnold de Villanova (1235–1312), whose medical writings (if the *Breviarium Practicæ* be rightly ascribed to him) rise above the rank of compilations. Finally, in the 13th and especially the 14th century, we find, under the name of *consilia*, the first mediæval reports of medical cases which are preserved in such a form as to be intelligible. Collections of *consilia* were published, among others, by Gentilis Fulgineus before 1348, by Bartolomeo Montagnana (died in 1470), and by Baverius de Baveriis of Imola (about 1450). The last-named, we can say from experience, contains much that is interesting and readable.

Period of the Revival of Learning.—The impulse which all departments of intellectual activity received from the revival of Greek literature in Europe was felt by medicine among the rest. Not that the spirit of the science, or of its corresponding practice, was at once changed. The basis of medicine through the Middle Ages had been literary and dogmatic, and it was literary and dogmatic still; but the medical literature now brought to light, including as it did the more important works of Hippocrates and Galen, many of them hitherto unknown, and in addition the forgotten element of Latin medicine, especially the work of Celsus, was in itself far superior to the second-hand compilations and incorrect versions which had formerly been accepted as standards. The classical works, though still regarded with unreasoning reverence, were found to have a germinative and vivifying power that carried the mind out of the region of dogma, and prepared the way for the scientific movement which has been growing in strength up to our own day.

Two of the most important results of the revival of learning were indeed such as are excluded from the scope of this brief sketch, namely, the reawakening of anatomy, which to a large extent grew out of the study of the works of Galen, and the investigation of medicinal plants, to which a fresh impulse was given by the revival of Dioscorides and other ancient naturalists. The former brought with it necessarily a more accurate conception of physiology, and thus led up to the great discovery of Harvey, which was the turning-point in modern medicine. The latter gave rise, on the one hand, to the modern science of botany, on the other to a more rational knowledge of drugs and their uses. At the same time, the discovery of America, and increased intercourse with the East, by introducing a variety of new plants, greatly accelerated the progress both of botany and pharmacology.

But it was not in these directions that improvement was first looked for. It was at first very naturally imagined that the simple revival of classical and especially of Greek literature would at once produce the same brilliant results in medicine as in literature and philosophy. The movement of reform started, of necessity, with scholars rather than practising physicians,—more precisely with a group of learned men, whom we may be permitted, for the sake of a name, to call the medical humanists, equally enthusiastic in the cause of letters and of medicine. From both fields they hoped to expel the evils which were summed up in the word barbarism. Nearly all mediæval medical literature was condemned under this name; and for it the humanists proposed to substitute the originals of Hippocrates and Galen, thus leading back medicine to its fountain-head. Since a knowledge of Greek was still confined to a small body of scholars, and a still smaller proportion of physicians, the first task was to translate the Greek classics into Latin. To this work several learned physicians, chiefly Italians, applied themselves with great ardour. Among the earliest were Nicolaus Leonicenus of Vicenza (1428–1524), Giovanni de Monte or Montanus (1498–1552), and many others in Italy. In northern Europe should be mentioned Gulielmus Copus (1471–1532) and Günther of Andernach (1487–1584) better known as Guinterius Andernacensis, both for a time professors at Paris; and, among the greatest, Thomas Linacre (about 1460–1524; see LINACRE). A little later Janus Cornarius or Hagenbut (1500–58) and Leonard Fuchs (1501–66) in Germany, and John Kaye or Caius (1510–72) in England, carried on the work. Symphorien Champier (Champerius or Campegius) of Lyons (1472–1539), a contemporary of Rabelais, and the patron of Servetus, wrote with fantastic enthusiasm on the superiority of the Greek to the Arabian physicians, and possibly did something to enlist in the same cause the two far greater men just mentioned. Rabelais not only lectured on Galen and Hippocrates, but edited some works of the latter; and Servetus, in a little tract *Syruporum universa ratio*, defended the practice of Galen as compared with that of the Arabians. The great Aldine press made an important contribution to the work, by *editiones principes* of Hippocrates and Galen in the original. Thus was the campaign opened against the mediæval and Arabian writers, till finally Greek medicine assumed a predominant position, and Galen took the place of Avicenna. The result was recorded in a formal manner by the Florentine Academy, sometime shortly before 1535: "quæ, excusso Arabicæ et barbaræ servitutis medicæ jugo, ex professo se Galenicam appellavit et profligato barbarorum exercitu unum totum et solum Galenum, ut optimum artis medicæ authorem, in omnibus se sequuturam pollicita est." Janus Cornarius, from whom this is quoted, laments, however, that the Arabians still reigned in most of the schools of medicine, and that the Italian and French authors of works called *Practica* were still in high repute. The triumph of Galenism was therefore not complete by the middle of the 16th century. It was probably most so, and earliest, in the schools of Italy and in those of England, where the London College of Physicians might be regarded as an offshoot of the Italian schools. Paris was the stronghold of conservatism, and Germany was stirred by the teachings of one who must be considered apart from all schools—Paracelsus. The nature of the struggle between the rival systems may be well illustrated by a formidable controversy about the rules for bleeding in acute diseases. This operation, according to the Arabian practice, was always performed on a vein at a distance from the organ affected. The Hippocratic and also Galenic rule, to let blood from, or near to, the diseased organ, was revived by Brissot (1470–1522), a professor in the university of Paris. His attempt at reform, which was taken to be, as in effect it was, a revolt against the authority of the Arabian masters, led to his expulsion from Paris, and the formal prohibition by the parliament of his method. Upon this apparently trifling question arose a controversy which lasted many years, occupied several universities, and led to the interposition of personages no less important than the pope and the emperor, but which is thought to have largely contributed to the final downfall of the Arabian medicine.

Paracelsus and Chemical Medicine.—Contemporary with the school of medical humanists, but little influenced by them, lived in Germany a man of strange genius, of whose character and importance the most opposite opinions have been expressed. The first noticeable quality in Paracelsus (*c.* 1490–1541) is his revolutionary independence of thought, which was supported by his immense personal arrogance. Himself well trained in the learning and medical science of the day, he despised and trampled upon all traditional and authoritative teachings. He began his lectures at Basel by burning the books of Avicenna and others; he afterwards boasted of having read no books for ten years; he protested that his shoe buckles were more learned than Galen and Avicenna. On the other hand, he spoke with respect of Hippocrates, and wrote a commentary on his *Aphorisms*. In this we see a spirit very different from the enthusiasm of the humanists for a purer and nobler philosophy than the scholastic and Arabian versions of Greek thought. There is no record of Paracelsus's knowledge of Greek, and as, at least in his student days, the most important works of Greek medicine were very imperfectly known, it is probable he had little first-hand acquaintance with Galen or Hippocrates, while his breach with the humanists is the more conspicuous from his lecturing and writing chiefly in his native German.

Having thus made a clean sweep of nearly the whole of the dogmatic medicine, what did Paracelsus put in its place? Certainly not pure empiricism, or habits of objective observation. He had a dogma of his own,—one founded, according to his German expositors, on the views of the

Neo-Platonists, of which a few disjointed specimens must here suffice. The human body was a "microcosm" which corresponded to the "macrocosm," and contained in itself all parts of visible nature,—sun, moon, stars, and the poles of heaven. To know the nature of man and how to deal with it, the physician should study, not anatomy, which Paracelsus utterly rejected, but all parts of external nature. Life was a perpetual germinative process controlled by the indwelling spirit or Archeus; and diseases, according to the mystical conception of Paracelsus, were not natural, but spiritual. Nature was sufficient for the cure of most diseases; art had only to interfere when the internal physician, the man himself, was tired or incapable. Then some remedy had to be introduced which should be antagonistic, not to the disease in a physical sense, but to the spiritual seed of the disease. These remedies were *arcana*,—a word corresponding partly to what we now call specific remedies, but implying a mysterious connexion between the remedy and the "essence" of the disease. Arcana were often shown to be such by their physical properties, not only by such as heat, cold, &c., but by fortuitous resemblances to certain parts of the body; thus arose the famous doctrine of "signatures," or signs indicating the virtues and uses of natural objects, which was afterwards developed into great complexity. Great importance was also attached to chemically prepared remedies as containing the essence or spiritual quality of the material from which they were derived. The actual therapeutical resources of Paracelsus included a large number of metallic preparations, in the introduction of some of which he did good service, and, among vegetable preparations, the tincture of opium, still known by the name he gave it, laudanum. In this doubtless he derived much advantage from his knowledge of chemistry, though the science was as yet not disentangled from the secret traditions of alchemy, and was often mixed up with imposture.

German historians of medicine attach great importance to the revolt of Paracelsus against the prevailing systems, and trace in his writings anticipations of many scientific truths of later times. That his personality was influential, and his intrepid originality of great value as an example in his own country, is undeniable. As a national reformer he has been not inaptly compared to Luther. But his importance in the universal history of medicine we cannot estimate so highly. The chief immediate result we can trace is the introduction of certain mineral remedies, especially antimony, the use of which became a kind of badge of the disciples of Paracelsus. The use of these remedies was not, however, necessarily connected with a belief in his system, which seems to have spread little beyond his own country. Of the followers of Paracelsus some became mere mystical quacks and impostors. Others, of more learning and better repute, were distinguished from the regular physicians chiefly by their use of chemical remedies. In France the introduction of antimony gave rise to a bitter controversy which lasted into the 17th century, and led to the expulsion of some men of mark from the Paris faculty. In England "chemical medicine" is first heard of in the reign of Elizabeth, and was in like manner contemned and assailed by the College of Physicians and the Society of Apothecaries. But it should be remembered that all the chemical physicians did not call Paracelsus master. The most notorious of that school in England, a certain Anthony, never quotes Paracelsus, but relies upon Arnold de Villanova and Raymund Lully. From this time, however, it is always possible to trace a school of chemical practitioners, who, though condemned by the orthodox Galenists, held their ground, till in the 17th century a successor of Paracelsus arose in the celebrated Van Helmont.

Consequences of the Revival of Ancient Medicine.—The revival of Galenic and Hippocratic medicine, though ultimately it conferred the greatest benefits on medical science, did not immediately produce any important or salutary reform in practical medicine. The standard of excellence in the ancient writers was indeed far above the level of the 16th century; but the fatal habit of taking at second hand what should have been acquired by direct observation retarded progress more than the possession of better models assisted it, so that the fundamental faults of mediæval science remained uncorrected.

Nevertheless some progress has to be recorded, even if not due directly to the study of ancient medicine. In the first place the 15th and 16th centuries were notable for the outbreak of certain epidemic diseases, which were unknown to the old physicians. Of these the chief was the "sweating sickness" or "English sweat," especially prevalent in, though not confined to, the country whence it is named. Among many descriptions of this disease, that by John Kaye or Caius, already referred to, was one of the best, and of great importance as showing that the works of Galen did not comprise all that could be known in medicine. The spread of syphilis, a disease equally unknown to the ancients, and the failure of Galen's remedies to cure it, had a similar effect.

In another direction the foundations of modern medicine were being laid during the 16th century, namely, by the introduction of clinical instruction in hospitals. In this Italy, and especially the renowned school of Padua, took the first step, where De Monte (Montanus), already mentioned as a humanist, gave clinical lectures on the patients in the hospital of St Francis, which may still be read with interest. Pupils flocked to him from all European countries; Germans are especially mentioned; a Polish student reported and published some of his lectures; and the Englishman Kaye was a zealous disciple, who does not, however, seem to have done anything towards transplanting this method of instruction to his own country. Inspections of the dead, to ascertain the nature of the disease, were made, though not without difficulty, and thus the modern period of the science of morbid anatomy was ushered in.

Medicine in the 17th century.—The medicine of the early part of the 17th presents no features to distinguish it from that of the preceding century. The practice and theory of medicine were mainly founded upon Hippocrates and Galen, with ever-increasing additions from the chemical school. But the development of mathematical and physical science soon introduced a fundamental change in the habits of thought with respect to medical doctrine.

These discoveries not only weakened or destroyed the respect for authority in matters of science, but brought about a marked tendency to mechanical explanations of life and disease. When Harvey by his discovery of the circulation furnished an explanation of many vital processes which was reconcileable with the ordinary laws of mechanics, the efforts of medical theorists were naturally directed to bringing all the departments of medicine under similar laws. It is often assumed that the writings and influence of Bacon did much towards introducing a more scientific method into medicine and physiology. But, without discussing the general philosophical position or historical importance of Bacon, it may safely be said that his direct influence can be little traced in medical writings of the first half of the 17th century. Harvey, as is well known, spoke slightingly of the great chancellor, and it is not till the rapid development of physical science in England and Holland in the latter part of the century, that we find Baconian principles explicitly recognized.

The dominant factors in the 17th century medicine were the discovery of the circulation by Harvey (published in 1628), the mechanical philosophy of Descartes and the contemporary progress of physics, the teaching of Van Helmont and the introduction of chemical explanations of morbid processes, and finally, combined of all these, and inspiring them, the rise of the spirit of inquiry and innovation, which may be called the scientific movement. Before speaking in detail of these, we may note that by other influences, quite independent of theories, important additions were made to practical medicine. The method of clinical instruction in hospitals, commenced by the Italians, was introduced into Holland, where it was greatly developed, especially at Leyden, in the hands of the celebrated Sylvius. It is noteworthy that concurrently with the rise of clinical study the works of Hippocrates were more and more valued, while Galen began to sink into the background.

At the same time the discovery of new diseases, unknown to the ancients, and the keener attention which the great epidemics of plague caused to be paid to those already known, led to more minute study of the natural history of disease. The most important disease hitherto undescribed was rickets, first made known by Arnold de Boot, a Frisian who practised in Ireland, in 1649, and afterwards more fully in the celebrated work of Glisson in 1651. The plague was carefully studied by Diemerbroek (*De Peste*, 1646) and others. Hodges, of London, in 1665 seems to have been the first who had the courage to make a post-mortem inspection of a plague patient. Bennet wrote an important work on consumption in 1654. During the same period many new remedies were introduced, the most important being cinchona bark, brought to Spain in the year 1640. The progress of pharmacy was shown by the publication of *Dispensatories* or *Pharmacopœiæ*, such as that of the Royal College of Physicians of London in 1618. This, like the earlier German works of the same kind (on which it was partly founded), contains both the traditional (Galenical) and the modern or chemical remedies.

Van Helmont.—The medicine of the 17th century was especially distinguished by the rise of systems; and we must first speak of an eccentric genius who endeavoured to construct a system for himself, as original and opposed to tradition as that of Paracelsus. Van Helmont (1578–1644) was a man of noble family in Brussels, who, after mastering all other branches of learning as then understood, devoted himself with enthusiasm to medicine and chemistry. By education and position a little out of the regular lines of the profession, he took up in medicine an independent attitude. Well acquainted with the doctrines of Galen, he rejected them as thoroughly as Paracelsus did, and borrowed from the latter some definite ideas as well as his revolutionary spirit. The archeus of Paracelsus appears again, but with still further complications,—the whole body being controlled by the *archeus influus*, and the organ of the soul and its various parts by the *archei insiti*, which are subject to the central archeus. Many of the symptoms of diseases were caused by the passions and perturbations of the archeus, and medicines acted by modifying the *ideas* of the same archeus. These and other notions cannot be here stated at sufficient length to be intelligible. It is enough to say that on this fantastic basis Helmont constructed a medical system which had some practical merits, that his therapeutical methods were mild and in many respects happy, and that he did service by applying newer chemical methods to the preparation of drugs. He thus had some share, though a share not generally recognized, in the foundation of the iatro-chemical school, now to be spoken of. But his avowed followers formed a small and discredited sect, which, in England at least, can be clearly traced in the latter part of the century.

Discovery of the Circulation of the Blood.—The influence of Harvey's discovery began to be felt before the middle of the century. Its merits were recognized by Descartes, among the first, nine years after its publication. For the history of the discovery, and its consequences in anatomy and physiology, we must refer to the article HARVEY. In respect of practical medicine, much less effect was at first noticeable. But this example, combined with the Cartesian principles, set many active and ingenious spirits to work to reconstruct the whole of medicine on a physiological or even a mechanical basis,—to endeavour to form what we should now call physiological or scientific medicine. The result of this was not to eliminate dogma from medicine, though it weakened the authority of the old dogma. The movement led rather to the formation of schools or systems of thought, which under various names lasted on into the 18th century, while the belief in the utility or necessity of schools and systems lasted much longer. The most important of these were the so-called iatro-physical or mechanical and the iatro-chemical schools.

Iatro-Physical School.—The iatro-physical school of medicine grew out of physiological theories. Its founder is held to have been Borelli of Naples (1608–79), whose treatise *De motu animalium*, published in 1680, is regarded as marking an epoch in physiology. The tendency of the school was to explain the actions and functions of the body on physical and especially on mechanical principles. The movements of bones and muscles were referred to the theory of levers; the process of digestion was regarded as essentially a process of trituration; nutrition and secretion were shown to be dependent upon the tension of the vessels, and so forth. The developments of this school belong rather to the history of physiology, where they appear, seen in the light of modern science, as excellent though premature endeavours in a scientific direction. But the influence of these theories on practical medicine was not great. The more judicious of the mechanical or physical school refrained, as a judicious modern physiologist does, from too immediate an application of their principles to daily practice. Mechanical theories were introduced into pathology, in explanation of the processes of fever and the like, but had little or no influence on therapeutics. The most important men in this school after Borelli were Steno (1638–86), Baglivi (1673–1707), and Bellini (1643–1704). An English physician, Cole (1660–1700), is also usually ranked with them. One of the most elaborate developments of the system was that of Pitcairn, a Scottish physician who became professor at Leyden (1652–1713), to be spoken of hereafter.

Iatro-Chemical School. — The so-called iatro-chemical school stood in a much closer relation to practical medicine than the iatro-physical. The principle which mainly distinguished it was not merely the use of chemical medicines in addition to the traditional, or, as they were called in distinction, "Galenical" remedies, but a theory of pathology or causation of disease entirely different from the prevailing "humoral" pathology. Its chief aim was to reconcile the new views in physiology and chemistry with practical medicine. In some theoretical views, and in the use of certain remedies, the school owed something to Van Helmont and Paracelsus, but took in the main an independent position. The founder of the iatro-chemical school was Francis de le Boë, called Sylvius (1614–72), belonging to a French family settled in Holland. Sylvius was for fourteen years professor of medicine at Leyden, where he attracted students from all quarters of Europe. He made a resolute attempt to reconstruct medicine on the two bases of the doctrine of the circulation of the blood and the new views of chemistry. Fermentation, which was supposed to take place in the stomach, played an important part in the vital processes. Chemical disturbances of these processes, called *acridities*, &c., were the cause of fevers and other diseases. Sometimes acid sometimes alkaline properties predominated in the juices and secretions of the body, and produced corresponding disturbances. In nervous diseases disturbances of the vital "spirits" were most important. Still in some parts of his system Sylvius shows an anxiety to base his pathology on anatomical changes. The remedies he employed were partly Galenical, partly chemical. He was very moderate in the use of bleeding.

The doctrines of Sylvius became widely spread in Holland and Germany; less so in France and Italy. In England they were not generally accepted till adopted with some modifications by Thomas Willis the great anatomist (1622–75), who is the chief English representative of the chemical school. Willis was as thorough-going a chemist as Sylvius. He regarded all bodies, organic and inorganic, as composed of the three elements—spirit, sulphur, and salt, the first being only found abundantly in animal bodies. The "intestine movement of particles" in every body, or fermentation, was the explanation of many of the processes of life and disease. The sensible properties and physical alterations of animal fluids and solids depended upon different proportions, movements, and combinations of these particles. The elaborate work *Pharmaceutice Rationalis*, based on these materials, had much influence in its time, though it was soon forgotten. But some parts of Willis's works, such as his descriptions of nervous diseases, and his account (the earliest) of diabetes, are classical contributions to scientific medicine. In the application of chemistry to the examination of secretions Willis made some important steps. The chemical school met with violent opposition, partly from the adherents of the ancient medicine, partly from the iatro-mechanical school. Towards the end of the 17th century appeared an English medical reformer who sided with none of these schools, but may be said in some respects to have surpassed and dispensed with them.

Sydenham and Locke.—Thomas Sydenham (1624–89) was educated at Oxford and at Montpellier. He was well acquainted with the works of the ancient physicians, and probably fairly so with chemistry. Of his knowledge of anatomy nothing definite can be said, as he seldom refers to it. His main avowed principle was to do without hypothesis, and study the actual diseases in an unbiassed manner. As his model in medical methods, Sydenham repeatedly and pointedly refers to Hippocrates, and he has not unfairly been called the English Hippocrates. He resembled his Greek master in the high value he set on the study of the "natural history of disease"; in the importance he attached to "epidemic constitution," that is, to the influence of weather and other natural causes in modifying disease; and further in his conception of the healing power of nature in disease, a doctrine which he even expanded beyond the teaching of Hippocrates. According to Sydenham, a disease is nothing more than an effort of nature to restore the health of the patient by the elimination of the morbific matter. The extent to which his practice was influenced by this and other *a priori* conceptions prevents us from classing Sydenham as a pure empiric, but he had the rare merit of never permitting himself to be enslaved even by his own theories. Still less was his mind warped by either of the two great systems, the classical and the chemical, which then divided the medical world. Sydenham's influence on European medicine was very great. His principles were welcomed as a return to nature by those who were weary of theoretical disputes. He introduced a milder and better way of treating fevers, especially small-pox, and gave strong support to the use of specific medicines, especially Peruvian bark. He was an advocate of bleeding, and often carried it to excess. Another important point in Sydenham's doctrine is his clear recognition of many diseases as being what would be now called *specific*, and not due merely to an alteration in the primary qualities or humours of the older schools. From this springs his high appreciation of specific medicines.

One name should always be mentioned along with Sydenham—that of his friend John Locke. The great sensational philosopher was a thoroughly trained physician, and practised privately. He shared and defended many of Sydenham's principles, and in the few medical observations he has left shows himself to be even more thorough-going than the "English Hippocrates." It is deeply to be regretted in the interests of medicine that he did not write more. It is, however, reasonable to suppose that his commanding intellect often makes itself felt in the words of Sydenham. One sentence of Locke's in a letter to W. Molyneux sums up the practical side of Sydenham's teaching.

> "You cannot imagine how far a little observation carefully made by a man not tied up to the four humours [Galen], or sal, sulphur, and mercury [Paracelsus], or to acid and alcali [Sylvius and Willis] which has of late prevailed, will carry a man in the curing of diseases though very stubborn and dangerous; and that with very little and common things, and almost no medicine at all."

We thus see that, while the great anatomists, physicists, and chemists, men of the type of Willis, Borelli, and Boyle, were laying foundations which were later on built up into the fabric of scientific medicine, little good was done by the premature application of their half-understood principles to practice. The reform of practical medicine was effected by men who aimed at, and partly succeeded in, rejecting all hypothesis and returning to the unbiassed study of natural processes, as shown in health and disease.

Sydenham showed that these processes might be profitably studied and dealt with without explaining them; and, by turning men's minds away from explanations and fixing them on facts, he enriched medicine with a *method* more fruitful than any discoveries in detail. From this time forth the reign of canonical authority in medicine was at an end, though the dogmatic spirit long survived.

The 18th century.—The medicine of the 18th century is notable, like that of the latter part of the 17th, for the striving after complete theoretical systems. The influence of the iatro-physical school was by no means exhausted; and in England, especially through the indirect influence of Newton's great astronomical generalizations, it took on a mathematical aspect, and is sometimes known as iatro-mathematical. This phase is most clearly developed in Pitcairn (1652–1713), who, though a determined opponent of metaphysical explanations, and of the chemical doctrines, gave to his own rude mechanical explanations of life and disease almost the dogmatic completeness of a theological system. His countryman and pupil, George Cheyne, who lived some years at Bath, published a new theory of fevers on the mechanical system, which had a great reputation. Their English contemporaries and successors, Freind, Cole, and Mead, leaned also to mechanical explanations, but with a distrust of systematic theoretical completeness, which was perhaps partly a national characteristic, partly the result of the teaching of Sydenham and Locke. Freind (1675–1728) in his *Emmenologia* gave a mechanical explanation of the phenomena of menstruation. He is also one of the most distinguished writers on the history of medicine. Cole (see above) published mechanical hypotheses concerning the causation of fevers which closely agree with those of the Italian iatro-mechanical school. More distinguished in his own day than any of these was Richard Mead (1673–1754), one of the most accomplished and socially successful physicians of modern times. Mead was the pupil of the equally popular and successful John Radcliffe

(1650–1714), who had acquired from Sydenham a contempt for book learning, and belonged to no school in medicine but the school of common sense. Radcliffe left, however, no work requiring mention in a history of medicine. Mead, a man of great learning and intellectual activity, was an ardent advocate of the mathematical doctrines. "It is very evident," he says, "that all other means of improving medicine have been found ineffectual, by the stand it was at for two thousand years, and that, since mathematicians have set themselves to the study of it, men already begin to talk so intelligibly and comprehensibly, even about abstruse matters, that it is to be hoped that mathematical learning will be the distinguishing mark of a physician and a quack." His *Mechanical Account of Poisons*, in the first edition (1702), gave an explanation of the effects of poisons, as acting only on the blood. Afterwards he modified his hypothesis, and referred the disturbances produced to the "nervous liquor," which he supposed to be a quantity of the "universal elastic matter" diffused through the universe, by which Newton explained the phenomena of light, *i.e.*, what was afterwards called the luminiferous ether. Mead's treatise on *The Power of the Sun and Moon over Human Bodies* (1704), equally inspired by Newton's discoveries, was a premature attempt to assign the influence of atmospheric pressure and other cosmical causes in producing disease. His works contain, however, many original experiments, and excellent practical observations. James Keill (1673–1719) applied Newtonian and mechanical principles to the explanation of bodily functions with still greater accuracy and completeness; but his researches have more importance for physiology than for practical medicine.

Boerhaave.—None of these men founded a school,—a result due in part to their intellectual character, in part to the absence in England of medical schools equivalent in position and importance to the universities of the Continent. An important academical position was, on the other hand, one of the reasons why a physician not very different in his way of thinking from the English physicians of the age of Queen Anne was able to take a far more predominant position in the medical world. Hermann Boerhaave (1668–1738) was emphatically a great teacher. He was for many years professor of medicine at Leyden, where he lectured five hours a day, and excelled in influence and reputation, not only his greatest forerunners, Montanus of Padua and Sylvius of Leyden, but probably every subsequent teacher. The hospital of Leyden, though with only twelve beds available for teaching, became the centre of medical influence in Europe. Many of the leading English physicians of the 18th century studied there; Van Swieten, a pupil of Boerhaave, transplanted the latter's method of teaching to Vienna, and founded the noted Vienna school of medicine. As the organizer, and almost the constructor, of the modern method of clinical instruction, the services of Boerhaave to the progress of medicine were immense, and can hardly be overrated. In his teaching, as in his practice, he avowedly followed the method of Hippocrates and Sydenham, both of whom he enthusiastically admired. In his medical doctrines he must be pronounced an eclectic, though taking his stand mainly on the iatro-mechanical school. The best known parts of Boerhaave's system are his doctrines of inflammation, obstruction, and "plethora." By the last-named especially he was long remembered. His object was to make all the anatomical and physiological acquisitions of his age, even microscopical anatomy, which he diligently studied, available for use in the practice of medicine. He thus differed from Sydenham, who took almost as little account of modern science as of ancient dogma. Boerhaave may be in some respects compared to Galen, but again differed from him in that he always abstained from attempting to reduce his knowledge to a uniform and coherent system. Boerhaave attached great importance to the study of the medical classics, but rather treated them historically than quoted them as canonical authorities. It almost follows from the nature of the case that the great task of Boerhaave's life, a synthesis of ancient and modern medicine, and the work in which this is chiefly contained, his celebrated *Institutions*, could not have any great permanent value. Nearly the same thing is true even of the *Aphorisms*, in which, following the example of Hippocrates, he endeavoured to sum up the results of his long experience.

Hoffmann and Stahl.—We have now to speak of two writers in whom the systematic tendency of the 18th century showed itself most completely.

Friedrich Hoffmann (1660–1742), like Boerhaave, owed his influence, and perhaps partly his intellectual characteristics, to his academical position. He was in 1693 appointed the first professor of medicine in the university of Halle, then just founded by the elector Frederick III. Here he became, as did his contemporary and rival Stahl, a popular and influential teacher, though their university had not the European importance of Leyden. Hoffmann's "system" was apparently intended to reconcile the opposing "spiritual" and "materialistic" views of nature, and is thought to have been much influenced by the philosophy of Leibnitz. His medical theories rest upon a complete theory of the universe. Life depended upon a universally diffused ether, which animals breathe in from the atmosphere, and which is contained in all parts of the body. It accumulates in the brain, and there generates the "nervous fluid" or *pneuma*,—a theory closely resembling that of Mead on the "nervous liquor," unless indeed Mead borrowed it from Hoffmann. On this system are explained all the phenomena of life and disease. Health depends on the maintenance of a proper "tone" in the body,—some diseases being produced by excess of tone, or "spasm"; others by "atony," or want of tone. But it is impossible here to follow its further developments. Independently of his system, which has long ceased to exert any influence, Hoffmann made some contributions to practical medicine; and his great knowledge of chemistry enabled him to investigate the subject of mineral waters. He was equally skilful in pharmacy, but lowered his position by the practice, which would be unpardonable in a modern physician, of trafficking in secret remedies. Some of these are even to this day sold for the benefit of the orphanage at Halle.

George Ernest Stahl (1660–1734) was for more than twenty years professor of medicine at Halle, and thus a colleague of Hoffmann, whom he resembled in constructing a complete theoretical system, though their systems had little or nothing in common. Stahl's chief aim was to oppose materialism. For mechanical conceptions he substituted the theory of "animism,"—attributing to the soul the functions of ordinary animal life in man, while the life of other creatures was left to mechanical laws. The symptoms of disease were explained as efforts of the soul to rid itself from morbid influences, the soul acting reasonably with respect to the end of self-preservation. The anima thus corresponds partly to the "nature" of Sydenham, while in other respects it resembles the archeus of Van Helmont. Animism in its completeness met with little acceptance during the lifetime of its author, but influenced some of the iatro-physical school. Stahl was the author of the theory of "phlogiston" in chemistry, which in its day had great importance.

Haller and Morgagni.—From the subtleties of rival systems it is a satisfaction to turn to two movements in the medicine of the 18th century which, though they did not extinguish the spirit of system-making, opened up paths of investigation by which the systems were ultimately superseded. These are physiology in the modern sense, as dating from Haller, and pathological anatomy, as dating from Morgagni.

Albrecht von Haller (1708–77) was a man of even more encyclopædic attainments than Boerhaave. He advanced chemistry, botany, anatomy, as well as physiology, and was incessantly occupied in endeavouring to apply his scientific studies to practical medicine, thus continuing the work of his great teacher Boerhaave. Besides all this he was probably more profoundly acquainted with the literature and bibliography of medicine than any one before or since. Haller occupied in the new university of Göttingen (founded 1737) a position corresponding to that of Boerhaave at Leyden, and in like manner influenced a very large circle of pupils. The appreciation of his work in physiology belongs to the history of that science; we are only concerned here with its influence on medicine. Haller's definition of irritability as a property of muscular tissue, and its distinction from sensibility as a property of nerves, struck at the root of the prevailing hypothesis respecting animal activity. It was no longer necessary to suppose that a half conscious "anima" was directing every movement. Moreover, Haller's views did not rest on *a priori* speculation, but on numerous experiments. He was among the first to investigate the action of medicines on healthy persons. Unfortunately the lesson which his contemporaries learnt was not the importance of experiment, but only the need of contriving other "systems" less open to objection; and thus the influence of Haller led directly to the theoretical subtleties of Cullen and John Brown, and only indirectly and later on to the general anatomy of Bichat. The great name of Haller does not therefore occupy a very prominent place in the history of practical medicine.

The work of Giovanni Battista Morgagni (1682–1771) had and still preserves a permanent importance beyond that of all the contemporary theorists. In a series of letters *De sedibus et causis morborum per anatomen indagatis*, published when he was in his eightieth year, he describes the appearances met with at the post-mortem examination as well as the symptoms during life in a number of cases of various diseases. It was not the first work of the kind. Bonet had published his *Sepulcretum* in 1679; and observations of post-mortem appearances had been made by Montanus, Tulp, Vieussens, Valsalva, Lancisi, Haller, and others. But never before was so large a collection of cases brought together, described with such accuracy, or illustrated with equal anatomical and medical knowledge. Morgagni's work at once made an epoch in the science. Morbid anatomy now became a recognized branch of medical research, and the movement was started which has lasted till our own day.

The contribution of Morgagni to medical science must be regarded as in some respects the counterpart of Sydenham's. The latter had, in neglecting anatomy, neglected the most solid basis for studying the natural history of disease; though perhaps it was less from choice than because his practice, as he was not attached to a hospital, gave him no opportunities. But it is on the combination of the two methods, that of Sydenham and of Morgagni, that modern medicine rests; and it is through these that it has been able to make steady progress in its own field, independently of the advance of physiology or other sciences.

The method of Morgagni found many imitators, both in his own country and in others. In England the first important name in this field is at the same time that of the first writer of a systematic work in any language on morbid anatomy, Matthew Baillie (1761–1823), who published his treatise in 1793.

Cullen and Brown.—It remains to speak of two systematic writers on medicine in the 18th century, whose great reputation prevents them from being passed over, though their real contribution to the progress of medicine was not great—Cullen and Brown.

William Cullen (1712–90) was a most eminent and popular professor of medicine at Edinburgh. The same academical influences as surrounded the Dutch and German founders of systems were doubtless partly concerned in leading him to form the plan of a comprehensive system of medicine. Cullen's system was largely based on the new physiological doctrine of irritability, but is especially noticeable for the importance attached to nervous action. Thus even gout was regarded as a "neurosis." These pathological principles of Cullen are contained in his *First Lines of the Practice of Physic*, an extremely popular book, often reprinted and translated. More importance is to be attached to his *Nosology or Classification of Diseases*. The attempt to classify diseases on a natural-history plan was not new, having been commenced by Sauvages and others, and is perhaps not a task of the highest importance. Cullen drew out a classification of great and needless complexity, the chief part of which is now forgotten, but several of his main divisions are still preserved.

It is difficult to form a clear estimate of the importance of the last systematizer of medicine, John Brown (1735–88), for, though in England he has been but little regarded, the wide though short-lived popularity of his system on the Continent shows that it must have contained some elements of brilliancy, if not originality. His theory of medicine professed to explain the processes of life and disease, and the methods of cure, upon one simple principle,—that of the property of "excitability," in virtue of which the "exciting powers," defined as being (1) external forces and (2) the functions of the system itself, call forth the vital phenomena "sense, motion, mental function, and passion." All exciting powers are stimulant, the apparent debilitating or sedative effect of some being due to a deficiency in the degree of stimulus; so that the final conclusion is that "the whole phenomena of life, health as well as disease, consist in stimulus and nothing else." Brown recognized some diseases as *sthenic*, others as *asthenic*, the latter requiring stimulating treatment, the former the reverse; but his practical conclusion was that 97 per cent. of all diseases required a "stimulating" treatment. In this he claimed to have made the most salutary reform because all physicians from Hippocrates had treated diseases by depletion and debilitating measures with the object of curing by elimination. It would be unprofitable to attempt a complete analysis of the Brunonian system; and it is difficult now to understand why it attracted so much attention in its day. To us at the present time it seems merely a dialectical construction, having its beginning and end in definitions, the words power, stimulus, &c., being used in such a way as not to correspond to any precise physical conceptions, still less to definite material objects or forces. One recommendation of the system was that it favoured a milder system of treatment than was at that time in vogue; Brown may be said to have been the first advocate of the modern stimulant or feeding treatment of fevers. He advocated the use of "animal soups" or beef tea. Further he had the discernment to see that certain symptoms, such as convulsions and delirium, which were then commonly held always to indicate inflammation, were often really signs of weakness.

The fortunes of Brown's system (called, from having been originally written in Latin, the Brunonian) form one of the strangest chapters in the history of medicine. In Scotland, Brown so far won the sympathy of the students that riotous conflicts took place between his partisans and opponents. In England his system took little root. In Italy, on the other hand, it received enthusiastic support, and, naturally, a corresponding degree of opposition. The most important adherent to Brown's system was Rasori (1763-1837), who taught it as professor at Pavia, but afterwards substituted his own system of contra-stimulus. The theoretical differences between this and the "stimulus" theory need not be expounded. The practical difference in the corresponding treatment was very great, as Rasori advocated a copious use of bleeding and of depressing remedies, such as antimony. Joseph Frank, a German, professor at Pavia, afterwards of Vienna, the author of an encyclopædic work on medicine now forgotten, embraced the Brunonian system, though he afterwards introduced some modifications, and transplanted it to Vienna. Many names are quoted as partisans or opponents of the Brunonian system in Italy, but scarcely one of them has any other claim to be remembered. In Germany the new system called forth, a little later, no less enthusiasm and controversial heat. Girtanner first began to spread the new ideas (though giving them out as his own), but Weikard was the first avowed advocate of the system. Röschlaub (1768-1835) modified Brown's system into the theory of excitement (*Erregungstheorie*), which for a time was extremely popular in Germany. The enthusiasm of the younger Brunonians in Germany was as great as in Edinburgh or in Italy, and led to serious riots in the university of Göttingen. In America the system was enthusiastically adopted by a noted physician, Benjamin Rush, of Philadelphia, who was followed by a considerable school. France was not more influenced by the new school than England. In both countries the tendency towards positive science and progress by objective investigation was too marked for any theoretical system to have more than a passing influence. In France, however, the influence of Brown's theories is very clearly seen in the writings of Broussais, who, though not rightly classed with the system-makers, since his conclusions were partly based upon anatomical investigation, resembled them in his attempt to unite theory and practice in one comprehensive synthesis. The explanation of the meteoric splendour of the Brunonian system in other countries seems to be as follows. In Italy the period of intellectual decadence had set in, and no serious scientific ardour remained to withstand the novelties of abstract theory. In Germany the case was somewhat different. Intellectual activity was not wanting, but the great achievements of the 18th century in philosophy and the moral sciences had fostered a love of abstract speculation; and some sort of cosmical or general system was thought indispensable in every department of special science. Hence another generation had to pass away before Germany found herself on the level, in scientific investigation, of France and England.

Before the theoretic tendency of the 18th century was quite exhausted, it displayed itself in a system which, though in some respects isolated in the history of medicine, stands nearest to that of Brown,—that, namely, of Hahnemann (see HOMŒOPATHY). Hahnemann (1753-1844) was in conception as revolutionary a reformer of medicine as Paracelsus. He professed to base medicine entirely on a knowledge of symptoms, regarding all investigation of the causes of symptoms as useless. While thus rejecting all the lessons of morbid anatomy and pathology, he put forward views respecting the causes of disease which hardly bear to be seriously stated. All chronic maladies result either from three diseases—psora (the itch), syphilis, or sycosis (a skin disease), or else are maladies produced by medicines. Seven-eighths of all chronic diseases are produced by itch driven inwards.[1] (It is fair to say that these views were published in one of his later works.) In treatment of disease Hahnemann rejected entirely the notion of a *vis medicatrix naturæ*, and was guided by his well-known principle "similia similibus curantur," which he explained as depending on the law that in order to get rid of a disease some remedy must be given which should substitute for the disease an action dynamically similar, but weaker. The original malady being thus got rid of, the vital force would easily be able to cope with and extinguish the slighter disturbance caused by the remedy. Something very similar was held by Brown, who taught that "indirect debility" was to be cured by a lesser degree of the same stimulus as had caused the original disturbance. Generally, however, Hahnemann's views contradict those of Brown, though moving somewhat in the same plane. In order to select remedies which should fulfil the indication of producing symptoms like those of the disease, Hahnemann made many observations of the action of drugs on healthy persons. He did not originate this line of research, for it had been pursued if not originated by Haller, and cultivated systematically by Tommasini, an Italian "contra-stimulist;" but he carried it out with much elaboration. His results, nevertheless, were vitiated by being obtained in the interest of a theory, and by singular want of discrimination. Hahnemann's doctrines met with much opposition on the part of the medical profession, and he was hence led to state his case to the "lay" public as a sort of court of appeal; and thus matters of science were made the theme of much popular controversy. This expedient, in which Hahnemann had been in a small degree anticipated by Brown, contributed largely to the success of his system. The appeal flattered a prevalent belief in the right of private judgement, even in technical and learned subjects. Hahnemann was thus able to take up the position (and not without justification) of a victim of professional prejudice. The anomalous position into which professional scorn and extra-professional popularity brought him produced a distinct deterioration in the character of his work. In his second period he developed the extraordinary theory of "potentiality" or dynamization,—namely, that medicines gained in strength by being diluted, if the dilution was accompanied by shaking or pounding, which was supposed to "potentialize" or increase the potency of the medicine. On this extraordinary principle Hahnemann ordered his original tinctures to be reduced in strength to one-fiftieth; these first dilutions again to one-fiftieth; and so on, even till the thirtieth dilution, which he himself used by preference, and to which he ascribed the highest "potentiality." It is hardly necessary to point out that even the lower dilutions involve quantities which no analysis can weigh, measure, or even recognize. The still greater eccentricities of Hahnemann's later works need not be recounted. From a theoretical point of view Hahnemann's is one of the abstract systems, pretending to universality, which modern medicine neither accepts nor finds it worth while to controvert. In the treatment of disease his practical innovations came at a fortunate time, when the excesses of the depletory system had only partially been superseded by the equally injurious opposite extreme of Brown's stimulant treatment. Hahnemann's use of mild and often quite inert remedies contrasted favourably with both of these. Further he did good by insisting upon simplicity in prescribing, when it was the custom to give a number of drugs, often heterogeneous and inconsistent, in the same prescription. But these indirect benefits were quite independent of the truth or falsity of his theoretical system.

Positive Progress in the 18th Century.—In looking back on the repeated attempts in the 18th century to construct a universal system of medicine, it is impossible not to

[1] The itch is really an affection produced by the presence in the skin of a species of mite (*Acarus scabiei*), and when this is destroyed or removed the disease is at an end.

regret the waste of brilliant gifts and profound acquirements which they involved. It was fortunate, however, that the accumulation of positive knowledge in medicine did not cease. While Germany and Scotland, as the chief homes of abstract speculation, gave birth to most of the theories, progress in objective science was most marked in other countries,—in Italy first, and afterwards in England and France. We must retrace our steps a little to enumerate several distinguished names which, from the nature of the case, hardly admit of classification.

In Italy the tradition of the great anatomists and physiologists of the 17th century produced a series of accurate observers and practitioners. Among the first of these were Antonio Maria Valsalva (1666–1723), still better known as an anatomist; Giovanni Maria Lancisi (1654–1720), also an anatomist, the author of a classical work on the diseases of the heart and aneurisms; and Ippolito Francisco Albertini (1662–1738), whose researches on the same class of diseases were no less important.

In France Jean Baptiste Sénac (1693-1770) wrote also an important work on the affections of the heart. Sauvages, otherwise F. B. de Lacroix (1706–67), gave under the title *Nosologia Methodica* a natural-history classification of diseases; Jean Astruc (1684–1766) contributed to the knowledge of general diseases. But the state of medicine in that country till the end of the 18th century was unsatisfactory as compared with some other parts of Europe.

In England the brilliancy of the early part of the century in practical medicine was hardly maintained to the end, and presented indeed a certain contrast with the remarkable and unflagging progress of surgery in the same period. The roll of the College of Physicians does not furnish many distinguished names. Among these should be mentioned John Fothergill (1712–80), who investigated the "putrid sore throat" now called diphtheria, and the form of neuralgia popularly known as tic douloureux. A physician of Plymouth, John Huxham (1694-1768), made researches on epidemic fevers, in the spirit of Sydenham and Hippocrates, which are of the highest importance. William Heberden (1710-1801), a London physician, called by Samuel Johnson *ultimus Romanorum*, "the last of our learned physicians," left a rich legacy of practical observations in the *Commentaries* published after his death. More important in their results than any of these works were the discoveries of EDWARD JENNER (*q.v.*), respecting the prevention of small-pox by vaccination, in which he superseded the partially useful but dangerous practice of inoculation, which had been introduced into England in 1721. The history of this discovery need not be told here, but it may be pointed out that, apart from its practical importance, it has had great influence on the scientific study of infectious diseases. The name of John Pringle (1707–82) should also be mentioned as one of the first to study epidemics of fevers occurring in prisons and camps. His work entitled *Observations on the Diseases of an Army* was translated into many European languages, and became the standard authority on the subject.

In Germany the only important school of practical medicine was that of Vienna, as revived by Van Swieten (1700–72), a pupil of Boerhaave, under the patronage of Maria Theresa. Van Swieten's commentaries on the aphorisms of Boerhaave are thought more valuable than the original text. Other eminent names of the same school are Anton de Haen (1704–76), Anton Störck (1731-1803), Maximilian Stoll (1742-88), and John Peter Frank (1745–1821), father of Joseph Frank beforementioned as an adherent of the Brownian system, and like his son carried away for a time by the new doctrines. This, the old "Vienna School," was not distinguished for any notable discoveries, but for success in clinical teaching, and for its sound method of studying the actual facts of disease during life and after death, which largely contributed to the establishment of the "positive medicine" of the 19th century.

One novelty, however, of the first importance is due to a Vienna physician of the period, Leopold Avenbrugger (1722–1809), the inventor of the method of recognizing diseases of the chest by percussion. Avenbrugger's method was that of *direct* percussion with the tips of the fingers, not that which is now used, of *mediate* percussion with the intervention of a finger or plessimeter; but the results of his method were the same, and its value nearly as great. Avenbrugger's great work, the *Inventum Novum*, was published in 1761. The new practice was received at first with contempt and even ridicule, and afterwards by Stoll and Peter Frank with only grudging approval. It did not receive due recognition till 1808, when Corvisart translated the *Inventum Novum* into French, and Avenbrugger's method rapidly attained a European reputation. Surpassed, but not eclipsed, by the still more important art of auscultation introduced by Laennec, it is hardly too much to say that this simple and purely mechanical invention has had more influence on the development of modern medicine than all the "systems" evolved by the most brilliant intellects of the 18th century.

Early Part of the 19th Century.—It is not possible to carry the history of medicine, in a sketch such as this, beyond the early years of the 19th century, both because the mass of details becomes so large as to require more minute treatment, and because it is difficult as we approach our own times to preserve the necessary historical perspective. It was, however, in this period that what we regard as the modern school of medicine was formed, and took the shape which it has preserved to our own days. The characteristic of the modern school is the adoption in medicine of the methods of research of physical science, and the gradually declining importance attached to theory and abstract reasoning,—hypotheses, though not neglected, being used as means of research rather than as ultimate conclusions. Its method may therefore be called the positive method, or that of rational empiricism. The growth of the new school was first seen in two European countries, in France and England, and must be separately followed in the two. Germany entered the field later.

Rise of the Positive School in France.—The reform of medicine in France must be dated from the great intellectual awakening caused by the Revolution, but more definitely starts with the researches in anatomy and physiology of Marie François Xavier Bichat (1771–1802). The importance in science of Bichat's classical works, especially of the *Anatomie générale*, cannot be estimated here; we can only point out their value as supplying a new basis for pathology or the science of disease. Among the most ardent of his followers was François Joseph Victor Broussais (1772–1838), whose theoretical views, partly founded on those of Brown and partly on the so-called vitalist school of Bordeu and Barthez, differed from these essentially in being avowedly based on anatomical observations. Broussais's chief aim was to find an anatomical basis for all diseases, but he is especially known for his attempt to explain all fevers as a consequence of irritation or inflammation of the intestinal canal (gastro entérite). A number of other maladies, especially general diseases and those commonly regarded as nervous, were attributed to the same cause. It would be impossible now to trace the steps which led to this wild and long since exploded theory. It led, among other consequences, to an enormous misuse of bleeding. Leeches were his favourite instruments, and so much so that he is said to have used 100,000 in his own hospital wards during one year. He was equalled if not surpassed in this excess by his follower Bouillaud, known for his important work on heart diseases. Broussais's system, to which he gave the name of "Médecine Physiologique" did much indirect good, in fixing attention upon morbid changes in the organs, and thus led to the rise of the strongly opposed anatomical and pathological school of Corvisart, Laennec, and Bayle.

Jean Nicolas Corvisart (1755–1821) has already been mentioned as the translator and introducer into France of Avenbrugger's work on percussion. He introduced some improvements in the method, but the only real advance was the introduction of mediate percussion by Piorry in 1828. The discovery had, however, yet to be completed by that of auscultation, or listening to sounds produced in the chest by breathing, the movements of the heart, &c. The combination of these methods constitutes what is now known as *physical diagnosis*. René Théophile Hyacinthe Laennec (1781–1826) was the inventor of this most important perhaps of all methods of medical research. Except for some trifling notices of sounds heard in certain diseases, this method was entirely new. It was definitely expounded in an almost complete form in his work *De l'auscultation médiate*, published in 1819. Laennec attached undue importance to the use of the stethoscope, and laid too much weight on specific signs of specific diseases; otherwise his method in its main features has remained unchanged. The result of his discovery was an entire revolution in the knowledge of diseases of the chest; but it would be a mistake to forget that an essential factor in this revolution was the simultaneous study of the condition of the diseased organs as seen after death. Without the latter, it is difficult to see how the information conveyed by sounds could ever have been verified. This increase of knowledge is therefore due, not to auscultation alone, but to auscultation combined with morbid anatomy. In the case of Laennec himself this qualification takes nothing from his fame, for he studied so minutely the relations of post-mortem appearances to symptoms during life that, had he not discovered auscultation, his researches in morbid anatomy would have made him famous. The pathologico-anatomical method was also followed with great zeal and success by Gaspard Laurent Bayle (1774–1816), whose researches on tubercle, and the changes of the lungs and other organs in consumption, are the foundation of most that has been done since his time. It was of course antecedent to the discovery of auscultation. Starting from these men arose a school of physicians who endeavoured to give to the study of symptoms the same precision as belonged to anatomical observations, and by the combination of both methods made a new era in clinical medicine. Among these were Chomel (1788–1858), Louis (1787–1872), Cruveilhier (1791–1874), and Andral (1797–1876). Louis, by his researches on pulmonary consumption and typhoid fever, had the chief merit of refuting the doctrines of Broussais. In another respect also he aided in establishing an exact science of medicine by the introduction of the numerical or statistical method. By this method only can the fallacies which are attendant on drawing conclusions from isolated cases be avoided; and thus the chief objection which has been made to regarding medicine as an inductive science has been removed. Louis's method was improved and systematized by Gavarret; and its utility is now universally recognized. Space does not permit us to trace further the history of this brilliant period of French medicine, during which the superiority of the school of Paris could hardly be contested. We can only mention the names of Bretonneau (1771–1862), Rostan (1790–1866), D'Alibert (1766–1837), Rayer (1793–1867), and Trousseau (1801–1866), the eloquent and popular teacher.

English Medicine from 1800 *to* 1840.—The progress of medicine in England during this period displays the same characteristics as at other times, viz., a gradual and uninterrupted development, without startling changes such as are caused by the sudden rise or fall of a new school. Hardly any theoretical system is of English birth; Erasmus Darwin (1731–1802), the grandfather of the great Charles Darwin, alone makes an exception. In his *Zoonomia* (1794) he expounded a theory of life and disease which had some resemblance to that of Brown, though arrived at (he says) by a different chain of reasoning.

Darwin's work shows, however, the tendency to connect medicine with physical science, which was an immediate consequence of the scientific discoveries of the end of the 18th century, when Priestley and Cavendish in England exercised the same influence as Lavoisier in France. The English school of medicine was also profoundly stirred by the teachings of the two brothers William and John Hunter, especially the latter,—who must therefore be briefly mentioned, though their own researches were chiefly concerned with subjects lying a little outside the limits of this sketch. William Hunter (1718–1783) was known in London as a brilliant teacher of anatomy and successful obstetric physician; his younger brother and pupil, John Hunter (1728–1793), was also a teacher of anatomy, and practised as a surgeon. His immense contributions to anatomy and pathology cannot be estimated here, but his services in stimulating research and training investigators belong to the history of general medicine. They are sufficiently evidenced by the fact that Jenner and Baillie were his pupils.

The same scientific bent is seen in the greater attention paid to morbid anatomy (which dates from Baillie), and the more scientific method of studying diseases. An instance of the latter is the work of Robert Willan (1757–1812) on diseases of the skin,—a department of medicine in which abstract and hypothetical views had been especially injurious. Willan, by following the natural-history method of Sydenham, at once put the study on a sound basis; and his work has been the starting point of the most important modern researches. About the same time William Charles Wells (1757–1817), a scientific investigator of remarkable power, and the author of a celebrated essay on dew, published observations on alterations in the urine, which, though little noticed at the time, were of great value as assisting in the important discovery made some years afterwards by Bright.

These observers, and others who cannot be mentioned here, belong to the period when English medicine was still little influenced by the French school. Shortly after 1815, however, when the Continent was again open to English travellers, many English doctors studied in Paris, and the discoveries of their great French contemporaries began to be known. The method of auscultation was soon introduced into this country by pupils of Laennec. John Forbes in 1824, and William Stokes of Dublin in 1825, published treatises on the use of the stethoscope. Forbes also translated the works of Laennec and Avenbrugger, and an entire revolution was soon effected in the knowledge of diseases of the chest. James Hope and Peter Mere Latham further developed this subject, and the former was also known for his researches in morbid anatomy. The combination of clinical and anatomical research led, as in the hands of the great French physicians, to important discoveries by English investigators. The discovery by Richard Bright (1789–1858) of the disease of the kidneys known by his name, has proved to be one of the most momentous of this century. It was published in *Reports of*

Medical Cases, 1827–31. Thomas Addison takes, somewhat later, a scarcely inferior place. The remarkable physiological discoveries of Bell and Marshall Hall for the first time rendered possible the discrimination of diseases of the spinal cord. Several of these physicians were also eminent for their clinical teaching,—an art in which Englishmen had up till then been greatly deficient.

Although many names of scarcely less note might be mentioned among the London physicians of the early part of the century, we must pass them over to consider the progress of medicine in Scotland and Ireland. In Edinburgh the admirable teaching of Cullen had raised the medical faculty to a height of prosperity of which his successor, James Gregory (1758–1821), was not unworthy. His nephew, William Pulteney Alison (1790–1859), was even more widely known. These great teachers maintained in the northern university a continuous tradition of successful teaching, which the difference in academical and other circumstances rendered hardly possible in London. Nor was the northern school wanting in special investigators, such as John Abercrombie, known for his work on diseases of the brain and spinal cord published in 1828, and many others. Turning to Ireland, it should be said that the Dublin school in this period produced two physicians of the highest distinction. Robert James Graves (*c.* 1800–1853) was a most eminent clinical teacher and observer, whose lectures are regarded as the model of clinical teaching, and indeed served as such to the most popular teacher of the Paris school in the middle of this century, Trousseau. William Stokes (1804–1878) was especially known for his works on diseases of the chest and of the heart, and for his clinical teaching.

German Medicine from 1800 *to* 1840.—Of the other countries of Europe, it is now only necessary to mention Germany. Here the chief home of positive medicine was still for a long time Vienna, where the "new Vienna school" continued and surpassed the glory of the old. Joseph Skoda (born 1805) extended, and in some respects corrected, the art of auscultation as left by Laennec. Karl Rokitansky (1804–1878), by his colossal labours, placed the science of morbid anatomy on a permanent basis, and enriched it by numerous discoveries of detail. Most of the ardent cultivators of this science in Germany in the next generation were his pupils. In the other German schools, though some great names might be found, as Romberg (1795–1873), the founder of the modern era in the study of nervous diseases, the general spirit was scholastic and the result barren, till the teaching of one man, whom the modern German physicians generally regard as the regenerator of scientific medicine in their country, made itself felt. Johann Lucas Schönlein (1793–1864) was first professor at Würzburg, afterwards at Zurich, and for twenty years at Berlin (from 1839–1859). Schönlein's positive contributions to medical science were not large; but he made in 1839 one discovery, apparently small, but in reality most suggestive, namely, that the contagious disease of the head called favus is produced by the growth in the hair of a parasitic fungus. In this may be found the germ of the startling modern discoveries in parasitic diseases. His systematic doctrines founded the so-called "natural history school;" but his real merit was that of the founder or introducer of a method. In the words of Haeser, "Schönlein has the incontestable merit of having been the first to establish in Germany the exact method of the French and the English, and to impregnate this method with the vivifying spirit of German research." The name of Schönlein thus brings us to the threshold of the modern German school of medicine,—the most scientific and exact in Europe, and in its spirit strikingly in contrast with the theoretical subtlety of German systematists in the last century.

Literature.—The earliest work of authority on the history of medicine is that of Daniel le Clerc (*Histoire de la Médecine*, Geneva, 1696; Amsterdam, 1704, 1723, &c.), which ends with Galen. Freind's *History of Physick* (London, 1725–26, 2 vols.) carries on the subject from Galen to the beginning of the 16th century. The first complete history is that of Kurt Sprengel (*Versuch einer pragmatischen Geschichte der Arzneikunde*, Halle, 1792; 3d edition, Halle, 1821–28, 5 vols.; also in French, Paris, 1815). Beside these may be mentioned Hecker, *Geschichte der Heilkunde*, Berlin, 1822, and *Gesch. der neueren Heilkunde*, Berlin, 1839; Ch. Daremberg, *Histoire des sciences médicales*, Paris, 1870, 2 vols.; Edward Meryon, *History of Medicine*, London, 1861 (left unfinished, vol. i. only having appeared). The most recent and complete text-book is Haeser's *Lehrbuch der Geschichte der Medicin und der Epidemischen Krankheiten* (3d edition, Jena, 1875–79, 3 vols., in course of completion), to which the preceding sketch is very largely indebted.

In special departments of the subject the authorities are the following:—For classical medicine: Celsus, *De Medicina*; Littré, *Œuvres d'Hippocrate*, Paris, 1839–61, 10 vols. (especially vol. i.); Francis Adams, *Genuine Works of Hippocrates translated, with a Preliminary Discourse*, London (Syd. Soc.), 1849, and *Paulus Ægineta, translated, with a Commentary*, London (Syd. Soc.), 1844; Daremberg, *La Médecine dans Homère*, Paris, 1865, and *La Médecine entre Homère et Hippocrate*, Paris, 1869; and W. A. Greenhill's articles "Galen," "Hippocrates," &c., in Smith's *Classical Dictionary*, 1844. For Arabian medicine: Wüstenfeld, *Geschichte der Arabischen Aerzte und Naturforscher*, Göttingen, 1840; and Lucien Leclerc, *Histoire de la Médecine Arabe*, Paris, 1876, 2 vols. For Salernitan medicine: *Collectio Salernitana*, edited by De Renzi, Daremberg, &c., Naples, 1852, 5 vols.; *Regimen Sanitatis*, with introduction by Sir A. Croke, Oxford, 1830; and Daremberg, *L'École de Salerne*, Paris, 1861. For medicine in England: John Aikin, *Biographical Memoirs of Medicine in Great Britain, to the time of Harvey*, London, 1780; *Lives of British Physicians*, London, 1830 (chiefly by Dr Macmichael, partly by Dr Bisset Hawkins and Dr H. H. Southey); and Munk, *Roll of the Royal College of Physicians of London*, 2d ed., 1878, 3 vols. For the modern schools: Hirschel, *Geschichte des Brown'schen Systems und der Erregungs Theorie*, Leipsic, 1846; Bouchut, *Histoire de la Médecine et des Doctrines Médicales*, 2 vols., Paris, 1873 (comparison of ancient and modern schools); Buckle, *History of Civilization in England*, 1858–61. (J. F. P.)

MEDINA, or rather EL-MEDÍNA (the city), or MEDÍNAT RASÚL ALLÁH (the city of the apostle of God), a town of the Hijáz in Arabia, in 25° N. lat., 40 E. long.,[1] the refuge of Mohammed on his flight from Mecca, and a renowned place of Moslem pilgrimage, consecrated by the possession of his tomb. The name El-Medína goes back to the Koran (*sur.* xxxiii. 60); the old name was Yathrib, the Lathrippa of Ptolemy and Iathrippa of Stephanus Byzantius.

Medina stands in a sort of basin at the northern extremity of an elevated plain, on the western skirt of the mountain range which divides the Red Sea coast-lands from the central plateau of Arabia. At an hour's distance to the north it is dominated by Mount Ohod, an outlying spur of the great mountains, which is now visited by the pious as the scene of the well-known battle (see MOHAMMED), and the site of the tomb and mosque of the Prophet's uncle Hamza. To the east the plain is bounded by a long line of hills eight or ten hours distant, over which the Nejd road runs. A number of torrent courses (of which W. Kanát to the north, at the foot of Mount Ohod, and W. 'Akík, some miles to the south, are the most important) descend from the mountains, forming considerable streams and pools after rain, and converge in the

[1] This can only be viewed as a very rough estimate. The road from Yanbu' on the Red Sea, which runs somewhat north of east, is by Burton's estimate 132 miles. From Medina to Mecca by the inland or high road he makes 248 miles. The usual road near the coast by Rábigh and Kholeys and thence to W. Fátima cannot be very different in length. Caravans traverse it in about ten or eleven days.

neighbourhood of the town to unite farther west at a place called Zaghába, whence they descend to the sea through the "mountains of the Tiháma"—the rough country between Medina and its port of Yanbuʿ—under the name of W. Idam. Southwards from Medina the plain extends unbroken, but with a slight rise, as far as the eye can reach. The convergence of torrent courses in the neighbourhood of Medina makes this one of the best-watered spots in northern Arabia. The city lies close to one of the great volcanic centres of the peninsula, which was in violent eruption as late as 1266 A.D., when the lava stream approached within an hour's distance of the walls, and dammed up W. Ḳanát. The result of this and older prehistoric eruptions has been to confine the underground water, so important in Arabian tillage, which can be reached at any point of the oasis by sinking deep wells. Many of the wells are brackish, and the natural fertility of the volcanic soil is in many places impaired by the salt with which it is impregnated; but the date palm grows well everywhere, and the groves, interspersed with gardens and corn-fields, which surround the city on all sides except the west, have been famous from the time of the Prophet. Thus situated, Medina was originally a city of agriculturists, not like Mecca a city of merchants; nor, apart from the indispensable trade in provisions, has it ever acquired commercial importance like that which Mecca owes to the pilgrimage.[1] Landowners and cultivators are still a chief element in the population of the city and suburbs. The latter, who are called Nawákhila, and more or less openly profess the Shíʿa opinions, form a sort of separate caste, marrying only among themselves. The townsmen proper, on the other hand, are a very motley race.[2] The mechanical arts, which the true Arab despises, are chiefly practised by foreigners. New settlers remain behind with each pilgrimage; and the many offices of profit connected with the mosque, the stipends paid by the sultan to every inhabitant, and the gains to be derived by pilgrim-cicerones (Muzawwirs) or by those who make it a business to say prayers at the Prophet's mosque for persons who send a fee from a distance, as well as the alms which the citizens are accustomed to collect when they go abroad, especially in Turkey, keep up an idle population greatly in excess of that which the district would naturally support in the present defective state of agriculture. The population of the city and suburbs may be from 16,000 to 20,000 souls.

The city proper is surrounded by a solid stone wall,[3] with towers and four massive gateways of good architecture, forming an irregular oval running to a kind of angle at the north-west, where stands the castle, held by a Turkish garrison. The houses are good stone buildings similar in style to those of Mecca; the streets are narrow but clean, and in part paved.[4] There is a copious supply of water conducted from a tepid source at the village of Ḳubá, 2 miles south, and distributed in underground cisterns in each quarter.[5] The glory of Medina, and the only important building, is the mosque of the Prophet, in the eastern part of the city, a spacious enclosed court between 400 and 500 feet in length from north to south, and two-thirds as much in breadth. The minarets and the lofty dome above the sacred graves are imposing features, but the circuit is hemmed in by houses or narrow lanes, and is not remarkable except for the principal gate (Báb el-Salám) at the southern end of the west front, facing the sacred graves, which is richly inlaid with marbles and fine tiles, and adorned with golden inscriptions. This gate leads into a deep portico, with ten rows of pillars, running along the southern wall. Near the further end of the portico, but not adjoining the walls, is a sort of doorless house or chamber hung with rich curtains, which is supposed to contain the graves of Mohammed, Abubekr, and ʿOmar. To the north of this is a smaller chamber of the same kind, draped in black, which is said to represent the house or tomb of Fátima. Both are enclosed within an iron railing, so closely interwoven with brass wire-work that a glimpse of the so-called tombs can only be got through certain apertures where intercessory prayer is addressed to the prophet, and pious salutations are paid to the other saints.[6] The portico in front of the railing is not ineffective, at least by night light. It is paved with marble, and in the eastern part with mosaic, laid with rich carpets; the southern wall is clothed with marble pierced with windows of good stained glass, and the great railing has a striking aspect; but an air of tawdriness is imparted by the vulgar painting of the columns, especially in the space between the tomb and the pulpit, which has received, in accordance with a tradition of the Prophet, the name of the Garden (rauḍa), and is decorated with barbaric attempts to carry out this idea in colour.[7] The throng of visitors passing along the south wall from the Báb el-Salám to salute the tombs is separated from the Garden by a wooden partition about 8 feet high, painted in arabesques. The other three sides of the interior court have porticos of less depth and mean aspect, with three or four rows of pillars. Within the court are the well of the Prophet and some palm trees said to have been planted by Fátima.

The original mosque was a low building of brick roofed with palm branches, and much smaller than the present structure. The wooden pulpit from which Mohammed preached appears to have stood on the same place with the present pulpit in the middle of the south portico. The dwelling of the Prophet and the huts of his women adjoined the mosque. Mohammed died in the hut of ʿÁisha, and was buried where he died; Abubekr and ʿOmar were afterwards buried beside him. Now in 711 A.D. the mosque, which had previously been enlarged by ʿOmar and ʿOthmán, was entirely reconstructed on a grander scale and in Byzantine style by Greek and Coptic artificers at the command of the caliph Walíd and under the direction of ʿOmar ibn ʿAbd elʿAzíz. The enlarged plan included the huts above named, which were pulled down. Thus the place of the Prophet's burial was brought within the mosque; but the recorded discontent of the city at this step shows that the feeling which regards the tomb as the great glory of the mosque, and the pilgrimage to it as the most meritorious that can be undertaken except that to Mecca, was still quite unknown. It is not even certain

[1] The pilgrimage to Medina, though highly meritorious, is not obligatory, and it is not tied to a single season, so that there is no great concourse at one time, and no fair like that of Mecca.

[2] A small number of families in Mecca still claim to represent the ancient Anṣár, the "defenders" of Mohammed. But in fact the old population emigrated *en masse* after the sack of Medina by Muslim in 683, and passed into Spain in the armies of Músá. In the 13th century one old man of the Khazraj and one old woman of the Aus tribe were all that remained of the old stock in Medina (Makkarí, i. 187; Dozy, *Mus. d'Espagne*, i. 111). The aristocratic family of the Beni Ḥoseyn, who claim descent from the martyr of Kerbela, and so from the Prophet, have apparently a better established pedigree.

[3] According to Ibn Khallikán (Slane's transl., iii. 927) the walls are of the 12th century, the work of Jamál el-Dín el-Ispaháni.

[4] The Baláṭ or great paved street of Medina, a very unusual feature in an Eastern town, dates from the 1st century of Islám. See Wüstenfeld's abstract of Samhúdí, p. 115.

[5] Ḳubá is famous as the place where the prophet lived before he entered Medina, and the site of the first mosque in which he prayed. It lies amidst orchards in the richest part of the oasis

[6] The space between the railing and the tomb is seldom entered except by the servants of the mosque. It contains the treasures of the mosque in jewels and plate, which were once very considerable but have been repeatedly plundered, last of all by the Wahhábís in the beginning of the present century.

[7] The word *rauḍa* also means a mausoleum, and is applied by Ibn Jubair to the tomb itself. Thus the tradition that the space between the pulpit and tomb was called by the Prophet one of the gardens of Paradise probably arose from a mistake.

what was done at this time to mark off the graves. Ibn 'Abd Rabbih, in the beginning of the 10th century (*'Ikd*, Cairo ed., iii. 366), describes the enclosure as a hexagonal wall, rising within three cubits of the ceiling of the portico, clothed in marble for more than a man's height, and above that height daubed with the unguent called khalúk. This may be supplemented from Iṣṭakhrí, who calls it a lofty house without a door. That there are no gravestones or visible tombs within is certain from what is recorded of occasions when the place was opened up for repairs. Ibn Jubair (p. 193 *sq.*) and Samhúdí speak of a small casket adorned with silver, fixed in the eastern wall, which was supposed to be opposite the head of the Prophet, while a silver nail in the south wall indicated the point to which the corpse faced, and from which the salutation of worshippers was to be addressed (Burton misquotes). The European fable of the coffin suspended by magnets is totally unknown to Moslem tradition. The smaller chamber of Fáṭima is pretty modern. In the time of Ibn Jubair and of Ibn Baṭúṭa (unless the latter, as is so often the case, is merely copying his predecessor) there was only a small marble trough north of the rauḍa (or grave) which "is said to be the house of Fáṭima or her grave, but God only knows." It is more probable that Fáṭima was buried in the Baḳí, where her tomb was also shown in the 12th century (Ibn Jubair, p. 198 *sq.*).

The mosque was again extended by El-Mahdí (781 A.D.), and was burned down in 1256. Of its appearance before the fire we have two authentic accounts by Ibn 'Abd Rabbih early in the 10th century, and by Ibn Jubair, who visited it in 1184. The old mosque had a much finer and more regular appearance than the present one; the interior walls were richly adorned with marble and mosaic arabesques of trees and the like, and the outer walls with stone marquetry; the pillars of the south portico (seventeen in each row) were in white plaster with gilt capitals, the other pillars were of marble. Ibn 'Abd Rabbih speaks of eighteen gates, of which in Ibn Jubair's time, as at present, all but four were walled up. There were then three minarets. After the fire which took place just at the time of the fall of the caliphate, the mosque long lay in a miserable condition. Its repair was chiefly due to the Egyptian sultans, especially to Ḳáit Bey, whose restoration after a second fire in 1481 amounted almost to a complete reconstruction. Of the old building nothing seems to have remained but some of the columns and part of the walls; and, as the minarets have also been rebuilt and two new ones added, the architectural character is now essentially Egyptian. The great dome above the tomb, the railing round it, and the pulpit, all date from Ḳáit Bey's restoration.

The suburbs, which occupy as much space as the city proper, and are partly walled in, lie south-west of the town, from which they are separated by an open space, the halting-place of caravans. Through the suburbs runs the watercourse called W. Buṭḥán, a tributary of W. Ḳanát, which the Yanbu' road crosses by a stone bridge. The suburbs are the quarter of the peasants. Thirty or forty families with their cattle occupy a single courtyard (ḥósh), and form a kind of community often at feud with its neighbours. The several clans of Medina must have lived in much the same way at the time of the Prophet. The famous cemetery called Baḳí' el-Gharḳad, the resting-place of a multitude of the "companions" of the Prophet, lies immediately to the west of the city. It once contained many monuments, the chief of which are described by Ibn Jubair. Burckhardt in 1815 found it a mere waste, but some of the mosques have since been rebuilt.

History.—The story of the Amalekites in Yathrib and of their conquest by the Hebrews in the time of Moses is purely fabulous, see Nöldeke, *Ueber die Amalekiter*, 1864, p. 36. The oasis, when it first comes into the light of history, was held by Jews, among whom emigrants from Yemen afterwards settled. From the time of the flight of Mohammed (622 A.D.) till the Omayyads removed the seat of empire from Medina to Damascus, the town springs into historic prominence as the capital of the new power that so rapidly changed the fate of the East. Its fall was not less rapid and complete, and since the battle of Ḥarra and the sack of the city in 683 it has never regained political importance. The history of Medina in this period will be told in the articles MOHAMMED and MOHAMMEDAN EMPIRE. Mohammed invested the country round Medina with an inviolable character like that of the Ḥaram round Mecca; but this provision has never been observed with strictness. After the fall of the caliphs, who maintained a governor in Medina, the native emírs enjoyed a fluctuating measure of independence, interrupted by the aggressions of the sherifs of Mecca, or controlled by an intermittent Egyptian protectorate. The Turks after the conquest of Egypt held Medina for a time with a firmer hand; but their rule grew weak, and was almost nominal long before the Wahhábís took the city in 1804. A Turko-Egyptian force retook it in 1812, and the Turks still maintain a pasha with a military establishment, while the cadi and chief agha of the mosque (a eunuch) are sent from Constantinople. But the internal government is largely in Arab hands, and is said to be much better than that of Mecca.

Sources.—Medina has been described from personal observation by Burckhardt, who visited it in 1815, and Burton, who made the pilgrimage in 1853. Sadlier on his journey from Ḳaṭíf to Yanbu' (1819) was not allowed to enter the holy city. Burckhardt was prevented by ill health from examining the city and country with his usual thoroughness. Little is added to our information by the report of 'Abd el-Razzáḳ, who performed the pilgrimage in 1878, on a medical commission from the English Government. The chief Arabic authority besides Ibn 'Abd Rabbih and Ibn Jubair is Samhúdí, of whose history Wüstenfeld published an abstract in the Göttingen *Abhandlungen*, vol. ix., 1861. It goes down to the end of the 15th century. The topography of the country about Medina is interesting both historically and geographically; Bekrí, Yáḳút, and other Arabic geographers supply much material on this topic, but completer European accounts are wanting to permit of its full utilization. Medina now offers a more promising, but also a more perilous, field for an explorer than Mecca. (W. P. S.)

MEDINA SIDONIA, a town of Spain, in the province of Cadiz, and about 21 miles by road westward from that city, stands at a height of 600 feet above the sea-level, on an isolated hill surrounded by a cultivated plain. Apart from its picturesque airy situation it has nothing to interest the traveller; the streets are narrow, steep, and dirty, and its buildings and ruins are unimportant. The occupations of the inhabitants are connected chiefly with the agriculture and cattle-breeding carried on in the surrounding district; bricks and pottery are also made to some extent. The population in 1877 was 12,234.

Medina Sidonia has been identified by some with the *Asiao* of Pliny, but it is uncertain whether Jerez is not more probably the locality referred to by that name. Under the Visigoths the place was erected into a bishopric (Assidonia), and attained some importance; in the beginning of the 8th century it was taken by Tarik. In the time of Edrisi the province of Shadúna or Shidona included, among other towns, Seville and Carmona; later Arab geographers place Shadúna in the province of Seville. The town gives its title to the ducal house of Guzman el Bueno, the hero of Tarifa (1292).

MEDITERRANEAN SEA. The southern shores of Europe are separated from the northern shores of Africa by the Mediterranean Sea. It extends in a generally east and west direction from longitude 5° 21′ W. to 36° 10′ E. Its length from Gibraltar to its eastern extremity in Syria is about 2100 miles. Its breadth is very various, being 400 miles from the mouth of the Rhone to the Algerian coast, 500 miles from the Gulf of Sidra to the entrance to the Adriatic, and 250 miles from the mouth of the Nile to the south coast of Asia Minor. From the very indented nature of its coasts, the general mass of the water is much cut up into separate seas, which have long borne distinctive names, as the Adriatic, the Ægean, the Sea of Marmora, the Black Sea, &c. The area of the whole system, including the Sea of Azoff, is given by Admiral Smythe as 1,149,287 square miles. If we deduct that of the Black Sea and Sea of Azoff, 172,506 square miles, we have for the area of the Mediterranean proper 976,781, or, roughly speaking, a million of square miles.

The Mediterranean is sharply divided into two great principal basins, the western and the eastern or Levant basin. The western possesses a comparatively smooth and unindented coast-line. It is bounded on the south by the coast of Africa and the north coast of Sicily, and it is further enclosed by the coasts of Spain, France, and Italy, which form a roughly arc-shaped coast-line. There are comparatively few small islands in this basin, though some of the more important large ones occur in it. The eastern basin is by far the larger of the two, and extends from Cape Bon to the Syrian coast, including as important branches the Adriatic and the Ægean. The latter is connected directly, through the Hellespont, the Sea of Marmora, and the Bosphorus, with the Black Sea. The entrance to the western basin and to the sea generally from the ocean is through the Straits of Gibraltar in 36° N. lat. If this parallel be drawn out through the sea it will be found that the western basin lies almost wholly to the northward, and the main body of the eastern one to the southward of it, the mean latitude of the western basin being about 39° 30′, and that of the eastern basin 35°. They communicate with each other by the channels separating Sicily from Italy and from Africa. The former is known as the Strait of Messina, and is of insignificant size, the latter is a wide channel apparently without any distinctive name, and generally shallow. The greatest depth on the shallowest ridge reaching from the African to the Sicilian coast is under 200 fathoms, and agrees very closely with the corresponding depth at the entrance to the Straits of Gibraltar.

Depth.—So far as is at present known, the maximum depth is pretty nearly alike in the two basins, being 2040 fathoms in the western and 2150 fathoms in the eastern. Many lines of soundings have been run in the Mediterranean for telegraph purposes, and they afford a very good idea of the general configuration of the bottom. Between Marseilles and Algiers the depth ranges generally from 1200 to 1600 fathoms; between Naples and Sardinia from 1500 to 2000; between Alexandria and Rhodes from 1200 to 1600; and between Alexandria and Cyprus from 900 to 1100. The basin of the Mediterranean really begins about 50 miles to the westward of Gibraltar. It is here that the shallowest ridge stretches across from Africa to Spain; the maximum depth on it is probably not more than 180, and certainly less than 200 fathoms. From this ridge the bottom slopes quickly westward into the depths of the Atlantic, and gently eastward into the Mediterranean. The depth nowhere reaches 1000 fathoms until beyond Alboran Island, 120 miles east of Gibraltar. This is a small low island separated from the mainland on all sides by water of more than 400 fathoms; it must therefore be considered an oceanic as distinguished from a continental island.[1] Further to the north, and off the coast of Valencia, we have the Balearic Islands,—namely, Majorca, Minorca, Iviza, and Formentera. These also must be considered oceanic islands, and indeed two groups of oceanic islands. Iviza and Formentera are isolated both from the Spanish coast and from the other two islands by water of over 300 fathoms depth; Majorca and Minorca are connected by a bank with no more than 50 fathoms of water on it. Thirty miles east of Minorca there are more than 1400 fathoms; beyond that there are no soundings between the Baleares and the large and important group of Corsica and Sardinia. These islands are continental, being connected with the Italian mainland by the bank on which Elba occurs, and which is covered by little over 50 fathoms of water. The Straits of Bonifacio, which separate Corsica from Sardinia, are also quite shallow, so that Corsica and Sardinia may be looked on as a secondary peninsula attached to the Tuscan shore of Italy by a shallow bank not more than 15 or 20 miles broad, the deep water coming close up all round it. Almost the same may be said of Sicily, including the Malta group, but excluding the Lipari group, which is purely volcanic. From Cape Passaro, in the south-east end of Sicily, a line can be drawn connecting it with the town of Tripoli, and without passing over water of more than 300 fathoms. As has already been said, the west end of Sicily is connected with the coast of Tunis by a ridge in no part covered by more than 200 fathoms of water. Between these two ridges lies a small but comparatively deep basin of 600 to 700 fathoms. At the western extremity of it lies the mountainous island of Pantellaria. The bank on which Malta is situated stretches for nearly 100 miles in a southerly direction from Cape Passaro in Sicily. Opposite, on the African shore, is a similar bank of much larger dimensions, on which are the small islands Lampion and Lampedusa belonging to Italy. In the deep channel between them and Malta is the small but lofty island Limosa. It is entirely volcanic, with an extinct crater on its north-eastern side, and three smaller ones to the southward. It resembles the Lipari group off the north coast of Sicily, which rise abruptly out of deep water, being connected by no bank either with the African or the Sicilian coasts. Some of the Lipari group are still active, Stromboli and Vulcano being of the number. Off the south coast of Sicily, and between it and the island of Pantellaria, occurs the famous Graham's shoal, the remains of what was for a few weeks an island.[2]

The deepest water of the Mediterranean is found in its widest part between Malta and Crete, and the deep water comes close up to the Italian and Greek coasts, while on the African shore the water shoals more gradually. In the Strait of Messina, close to Reggio, there are depths of over 500 fathoms, and similar depths are found inside gulfs such as those of Taranto (nearly 1000 fathoms), of Corinth, Kalamata, and others. Also all through the Ægean in its many bights and channels very deep water is met with; in the Sea of Marmora we have 500 fathoms, and in the Black Sea over 1000 fathoms. All along the south coast of Asia Minor the water is very deep, and the large islands of Cyprus and Crete are both separated by very deep water from the mainland. If we take the eastern basin, and run along its western and southern coasts from the mouth of the Po along the shore of Italy, Sicily, and Africa to the mouth of the Nile, and even further along the Syrian shore, we do not find a single off-lying island of any importance except the Malta group, while all along the eastern and northern coasts from Trieste to Asia Minor the coast is deeply indented, and the water broken up by many large and important islands. These islands are grouped along the west coast of Turkey and Greece, and irregularly throughout the Ægean. The east coast of the Adriatic is studded with islands and inlets, and resembles in this respect the Ægean; the west coast, on the other hand, is low, and the water off it shallow, and there are few harbours. The Adriatic stretches in a north-westerly direction for about 460 miles from its entrance between

[1] Continental islands are those separated from the mainland by comparatively shallow seas, generally under 100 fathoms.

[2] With regard to its appearance and disappearance Admiral Smythe (*Mediterranean*, p. 111) says:—"It seems that, as early as the 28th of June 1831, Captain Swinburne, in passing nearly over the spot, felt several shocks of a sea-quake, proving that the cause was then in operation; but on the 19th of the following July the crater had accumulated to a few feet above the level of the sea, and was in great activity, emitting vast volumes of steam, ashes, and scoriæ. From that time it gradually increased in all its dimensions till towards the end of August its circumference was about 3240 feet and its height 107; then from October various changes took place, and it entirely disappeared in December." Since that time it has changed considerably. In 1863 the least water on it was 15 feet. It has two heads close together, and at the distance of about 20 yards all round there are from 7 to 9 fathoms of water.

Cape Sta Maria di Leuca and the island of Corfu to the Venetian shore in the Gulf of Trieste. Its average width is about 100 miles. A ridge with little over 400 fathoms appears to run across its entrance. Inside this the water reaches a depth of 765 fathoms, but shoals again rapidly towards Pelagosa Island, from which to the northward, including quite two-thirds of the sea, the depth is under 100 fathoms; indeed no part of the sea within 150 miles of its northern extremity is over 50 fathoms deep. There is authentic historical evidence of the encroachment of the Italian shores on the Adriatic, causing thereby a diminution of its area. As a consequence many towns which were once thriving seaports are now many miles inland; thus Adria, which was a station of the Roman fleet, is now 15 miles inland, and there are many similar examples. The large rivers Po and Adige, which bring the drainage of the southern slopes of the Alps to the sea, deliver large quantities of sediment in the course of the year. The distribution of this mud is affected, not only by its own weight tending to make it sink to the bottom, but also by the set of the currents, which, running up the eastern coast, turn to the westward and southward at the upper end of the sea, and so tend to distribute the river mud along the bottom in the neighbourhood of the Italian coasts. The fact that towns which were formerly seaports are now inland does not therefore necessitate the assumption of a general rise of the land, it is merely a reclamation by natural agencies of land from the sea at the expense of the inland mountainous country. Precisely similar phenomena are observed in the neighbourhood of the mouths of the Rhone and of the Nile.

Specific Gravity, Currents, &c.—On the specific gravity Dr Carpenter reports many and interesting observations. In round numbers, that of the surface-water of the Atlantic off the Straits of Gibraltar is 1·0260 to 1·0270, that of the western basin of the Mediterranean 1·0280 to 1·0290, and that of the eastern basin 1·0290 to 1·0300, while that of the Black Sea is 1·0120 to 1·0140. It will thus be seen that the water of the Mediterranean proper is very much salter than either the Atlantic on the west or the Black Sea on the east, and this great density of the water affords a useful means of recognizing it when investigating the interchange of waters which takes place at the two extremities of the sea. Both the temperature and the specific gravity of the water are evidences of the local climate. The great concentration of the water shows how dry the atmosphere at the surface must be, and how insignificant the contributions of fresh water. With regard to the balance existing between the two factors, evaporation and precipitation, it would be impossible to give figures with any claim to accuracy, but a rough estimate may be formed by taking such data as Fischer has given. He puts the rainfall over the whole Mediterranean drainage area at 759·4 millimetres, or almost exactly 30 inches. If we remember that the average rainfall of the eastern slopes of Great Britain is less than 30 inches, and that therefore this may be taken as the maximum yearly supply to the North Sea, we may be sure that the Mediterranean does not receive more than 30 inches of fresh water in the year. With regard to the rate of evaporation over the area of the Mediterranean there is but very meagre information, but wherever it has been observed it has been found to exceed the rainfall, even as much as three times. Thus at Madrid it is 65 inches, or more than four times the rainfall, at Rome 105 inches, and at Cairo 92 inches. It may therefore without exaggeration be assumed that the evaporation is at least twice as great as the precipitation. Putting the latter at 30 inches, we should have 60 inches for the yearly evaporation, and a balance of 30 inches evaporation over precipitation. Were there no provision for making good this deficiency, the level of the Mediterranean would sink until its surface was so far contracted as to lose no more by evaporation than would be supplied by rain. This condition would probably not be fulfilled before all the Ægean and Adriatic and the whole of the western basin west of the island of Sardinia were laid dry, and what is now the Mediterranean would be reduced to two "Dead Seas," one between Sardinia and Naples and the other between Africa and the mouth of the Adriatic. That the level and the salinity of the Mediterranean remain constant is due to the supply of water which enters at the Straits of Gibraltar. The currents in this passage have frequently engaged attention both from their scientific and their nautical interest. The most detailed investigation was that carried out by Captain Nares and Dr Carpenter in H.M.S. "Shearwater" in the year 1871.[1] From these investigations it appears that there are usually two currents in the Straits at the same time, one superposed on the other. Both are affected by tidal influence, but, after allowing for it, there is still a balance of inflow in the upper and of outflow in the under current. The waters of the two currents are sharply distinguished from each other by their salinity. Further, the upper current appears to affect by preference the middle of the channel and the African coast, while the under current appears to crop out at the surface on the Spanish coast. This distribution, however, is much modified by the state of the tide, and it must be remembered that in such places the surface separating the upper and under currents is rarely, if ever, a horizontal plane. That there is a balance of outflow over inflow at the bottom was well shown by the result of soundings as much as 200 miles north-west of the entrance of the Straits, where, in a depth of 1560 fathoms, water of decided Mediterranean origin was got from the bottom. There can be no doubt that this outflow of warm and dense Mediterranean water is largely instrumental in causing the comparatively very high bottom temperature in the eastern basin of the North Atlantic.

We have assumed that the balance of water removed by evaporation is 30 inches, or 2·5 feet. If we take the area of the Mediterranean to be 1,000,000 square miles, we have the volume of water removed—

$$v = 2{\cdot}5 \times 36 \times 10^{12} = 90 \times 10^{12} \text{ cubic feet.}$$

This quantity of water has to be supplied from the Atlantic without raising the total quantity of salt in the sea. We have seen that the only provision for the removal of the surplus salt is the outward under current in the Straits. Hence the inward upper current must be sufficient to replace the water lost both by evaporation and by the outflow of the under current. We may take the Atlantic water to contain 3·6 per cent. and the Mediterranean to contain 3·9 per cent. of salt. In order that the under current may remove exactly as much salt as is brought in by the upper one, their volumes must be in the inverse ratio of their saline contents, or the volume of the upper current must be to that of the under one in the ratio 39 : 36 or 1000 : 923; so that only 7·7 per cent. of the inflow goes to replace the water removed by evaporation, while the remaining 92·3 per cent. replaces the water of the under current. We have then for the total volume of the inward current per annum

$$V = \frac{100}{7{\cdot}7} v = 1170 \times 10^{12} \text{ cubic feet.}$$

The width of the Straits from Tarifa to Point Cires is 8 miles, or 48,000 feet, and the average depth of the stream may fairly be taken as 100 fathoms; hence the sectional area is in round numbers 29,000,000 square feet.

[1] *Proc. Roy. Soc.* (1872), xx. 97, 414.

Dividing the volume by the area we have for the mean annual flow

$$R = \frac{1170 \times 10^{12}}{29 \times 10^6} = 40 \times 10^6 \text{ feet.}$$

Reducing this to miles per day, we find that if the above data are correct the inflowing current at the Straits of Gibraltar ought to be equivalent to a current 8 miles wide, 100 fathoms deep, and running with the uniform velocity of 18·3 miles in twenty-four hours. As the currents are reversed with the tides this is the balance of inflow over outflow in the upper current. It is worthy of remark that the flood tide runs to the westward at the surface and the ebb to the eastward. The following table of tides at places inside and outside the Straits will show that the mere differences of level due to the different tidal ranges at adjacent localities are sufficient to cause strong local currents.

Places.	High Water. Full and Change.	Springs Rise.	Neaps Rise.	Neaps Range.
	H. M.	Ft. in.	Ft. in.	Ft. in.
Chipiona	1 30	12 5	8 0	3 6
Rota	1 24	12 6	8 0	3 6
Cadiz	1 23	12 9	8 2	...
Conil	1 18	12 0	7 5	3 3
Cape Plata	1 45	8 0	5 3	2 6
Tarifa	1 46	6 0	3 6	1 3
Algesiras	1 49	3 9	2 6	1 3
Gibraltar	1 47	4 1	2 7	1 3
Ceuta	2 6	3 7	2 5	1 3
Tetuan	2 23	2 6	1 6	0 6
Tangier	1 42	8 3	5 1	2 0
Rabat	1 46	11 0	7 1	3 3
Mogador	1 18	12 4	8 0	3 6

A similar phenomenon is witnessed at the other end of the sea. Here the fresher waters of the Black Sea rush in through the narrow channel of the Dardanelles, causing a surface inflow of comparatively fresh water, while there is an outflow below of denser Mediterranean water. The dimensions of the Straits are too small to make the phenomenon of any importance for the supply of the Mediterranean. The conditions both in the Dardanelles and in the Bosphorus were examined very carefully in the year 1872 by Captain Wharton, R.N., of H.M.S. "Shearwater," and his results are published in an interesting report to the admiralty, of that date. It is remarkable that the comparatively fresh water of the Black Sea persists without sensible mixture through the Sea of Marmora and into the Dardanelles, while there is constantly a current of Mediterranean water running underneath, and the depth in the two channels is only from 30 to 50 fathoms. There can be little doubt that the saltness of the Black Sea is due wholly to the return current of Mediterranean water entering through the Bosphorus. Were the exit of the Black Sea a channel with sufficient fall to bring the surface of the Sea of Marmora below the level of the highest part of its bottom, so that no return current could take place, the waters of the Black Sea would be fresh.

In the body of the sea the rise and fall are much less than at any of the places in the above table. At Algiers a self-recording tide gauge was set up by Aimé, and from its records he deduced a rise and fall of 88 millim. (say $3\frac{1}{2}$ in.) at springs and half that amount at neaps, a fluctuation which would escape ordinary observation, as it would be masked by the effects of atmospheric disturbances. At Venice and in the upper reaches of the Adriatic, the true lunisolar tide seems to be more accentuated than in other parts; but here also its effects are subordinate to those of the wind. In summer the Mediterranean is within the northern limit of the north-east trade wind; consequently, throughout a great part of the year, the winds are tolerably constant in direction; and, blowing as they do over large areas of water, they are instrumental in moving large masses of it from one point to another, and so producing streams and currents.

The effect of wind on a surface of water is twofold: it produces the rhythmic motion of waves and the motion of translation of currents. Besides the motion produced by the direct action of the wind on the surface-water, there are currents due in the first instance to the accumulation of water produced by a wind which has been blowing constantly in one direction. The phenomenon of an abnormally high tidal rise with a gale of wind blowing on shore is one with which inhabitants of the British Islands are familiar. It is also a matter of frequent observation that, for instance, a south-west gale which exaggerates the height of high water on the western coasts of Britain reduces it on the east coasts. It blows the water on the west coast and off the east coast, so that the difference in the high-water levels on the two coasts is very pronounced. Supposing free communication were quickly made between the two coasts, a current would be the result, and its violence would be much greater than would be due to the local action of the wind on its surface. In the Mediterranean the winds blow during a great portion of the year very constantly from one direction or another, and generally from north and east. The extent of the sea is so great that the slope produced by the transference of the surface water constantly in one direction might have a sine or arc capable of being measured in feet and inches when the radius is as much as 200 miles long. Thus at Port Mahon, in the island of Minorca, according to the *Admiralty Sailing Directions*, the water rises and falls according to the direction of the wind. With wind from south-east or south-west the water rises, but from north-west or north-east it falls. When northerly or north-westerly winds prevail, and this is the case for two-thirds of the year, a strong current sets to the south-west off Ayre Island, which is reversed in seasons when south-westerly winds prevail. This current is due to the water escaping round the end of Minorca having been driven southward so as to raise a head on the north coasts of the island. Similarly in the Faro or Strait of Messina the currents, of which the famous Scylla and Charybdis are swirls or eddies, are the evidence of a tendency towards equalizing the levels of the eastern extremity of the western basin and of the western extremity of the eastern basin. In addition to this peculiarity of position with reference to the two basins, it has been found that there is a very strong purely tidal influence at work which alone produces an alteration in the direction of the currents, and thus adds to the confusion of the waters. At Capo di Faro the rise is scarcely perceptible, at Messina it may attain a maximum of 10 to 13 inches. In the Straits of Bonifacio, between Corsica and Sardinia, the currents follow entirely the direction of the prevailing winds, and are at times very rapid. In the channel between Sicily and the African coast the currents also follow the winds. In long periods of calm weather a steady easterly set is observed, no doubt a prolongation or reproduction of the Gibraltar current.

Temperature.—Nothing whatever was known of the temperature of the deep water of the Mediterranean until Saussure extended to it his classical investigation into that of the Swiss lakes. In October 1780 he sank his thermometer to a depth of 160 fathoms off Genoa and of 320 fathoms off Nice, and at both depths he found the temperature of the water to be 55°·8 F. These observations have a special value, for, owing to Saussure's method of experimenting, his results were not affected by the pressure obtaining at great depths in the sea. Fifty years elapsed before any similar experiments were made, when D'Urville, in the "Astrolabe," made a few observations at the beginning and the end of his famous expedition. There is some uncertainty about his observations in 1826 and 1829, and also about the later ones of Bérard in 1831, as we are not informed whether the self-registering instruments used were protected from pressure or not. Mr Prestwich,[1] however, who has collected and critically discussed all the older deep-sea temperature observations, concludes, from a comparison of their results with those obtained by Aimé with protected instruments, that they were so protected, and admits their results into his tables without correction. In the deep water to the northward of the Balearic Islands D'Urville found in April 1826 54°·5 F. in 270 fathoms, and in March 1829 54°·7 at the same depth, and the same temperature (54°·7) in 530 fathoms. Bérard, experimenting in the sea between the Balearic Islands and Algeria, found the temperature of the deep water nearly a degree higher, namely 55°·4 F., in depths of 500 to 1000 fathoms. Aimé[2] relates his own careful experiments on the temperature of both surface and deeper water in the neighbourhood of Algiers, and discusses them in connexion with those of other observers with very great ability. He concludes from his own observations and those of Bérard that the uniform temperature at great depths is 54°·86 F. From a consideration of the general climate of the Mediterranean, he comes to the conclusion that the temperature in the deeper layers of the sea ought to be lower than the annual mean of the surface, and that it ought to be not very different from the mean surface temperature in the winter months. From observations at Toulon and Algiers, he finds that at neither place does the surface temperature fall below 50° F., and that the mean surface temperatures in the months December, January, February, March, and April is at Toulon 53°·06 F. and at Algiers 56°·84 F. The mean of these two temperatures is 54°·9 F., which is almost exactly what he finds to be the mean annual temperature of the deepest water of the western basin. During the forty years which have elapsed since Aimé made his experiments and speculations, further observations have only tended to confirm his theory. It is true that the temperatures observed in the many soundings which have been made of late years have not shown absolute identity of temperature, and it is probable that the greater the refinement in the instruments used the more decided will the local differences appear. Especially it will be apparent that the bottom temperature varies with the climate of the preceding winter, and the distribution of temperature varies much with the prevalence of the winds. At the few stations where the temperature of the sea-water and that of the air are regularly examined, it appears that the water is generally for the greater part of the year warmer than the air, and in winter considerably so. The existing observations, however, are too few to justify any very definite statement on the subject. At Palermo the sea is warmer than the air throughout the whole year with the exception of the months May and June. In Algiers Aimé found but little difference; in autumn and winter the water was slightly warmer, in spring and summer slightly colder, than the air. In the eastern basin we have first Admiral Spratt's observations in July 1845 in Ægina Gulf. In all his experiments made previous to the year 1860 he determined the temperature of the bottom water by taking that of the mud brought up in the dredge. This is a very excellent method; in fact it is probably the best of all methods if a sufficient quantity of mud be obtained. From 1860 he used self-registering unprotected thermometers, which gave results necessarily too high, and it is impossible to apply any reliable correction to them without experimentally determining it on each thermometer which was used. By the first method Admiral Spratt found 55°·5 F. at depths between 100 and 200 fathoms.

From these observations it seemed reasonable to conclude, as Aimé had done, that all over the Mediterranean a practically uniform temperature is found at all depths greater than 100 or 200 fathoms, and that this temperature is 54° to 56° F. In order thoroughly to investigate this matter, as well as the biological conditions of the deep water of the Mediterranean, H.M.S. "Porcupine," Captain Calver, with Messrs Carpenter and Gwyn Jeffreys, visited the western basin of the Mediterranean in the autumn of 1870. A large number of temperature observations were made in the western basin near its southern coasts, and one sounding with temperature observation in the eastern basin a short distance from the Sicilian coast, the result of which was to confirm the conclusion arrived at from earlier observations, that, however high the temperature of the surface may be (and it may reach 90° F.), the water becomes rapidly cooler as we go below the surface until we reach a depth of about 100 fathoms, where a temperature of 54° to 56° F. is found, and persists without sensible variation to the greatest depths. The average of all the bottom temperatures in the western basin was 54°·88 F. Three soundings were made in the intermediate basin to the eastward of Pantellaria in depths of 266, 390, and 445 fathoms, and in each case the bottom temperature was found to be 56°·5 F., or about a degree and a half warmer than in the deeper western basin. This is precisely what might have been expected from what we know of inland seas divided into several basins. In summer the shallower basin has usually a higher temperature at the bottom than is found at the same depth in the deeper one. Only one observation was made in the eastern basin, namely off Cape Passaro, in 1743 fathoms, with a bottom temperature of 56°·0 F. That the temperature in this basin should be lower than in the Pantellaria basin is due to its greater depth, and that it should be higher than is found in the western basin is due to its lower latitude. These researches were further prosecuted in the autumn of 1871 in the "Shearwater," Captain Nares, accompanied by Dr Carpenter. At two stations in the eastern basin "serial temperatures" were taken. At the first, 35° 54′ N. lat., 16° 23′ E. long., depth 1650 fathoms, the bottom temperature was 56°, or the same as had been observed the year before in 1743 fathoms; at the second, 32° 17½′ N. lat., 26° 44′ E. long., depth 1970 fathoms, the bottom temperature was 56°·7, and the temperature at all intermediate depths was much higher than at the first station. The mean temperature of the water from the surface to a depth of 200 fathoms was, at the first station, 63°·75 F., and at the second 66°·78 F., or three degrees higher. At the first station all the temperatures down to 100 fathoms are higher than were observed in 1870 in the western basin, but it must be remembered that temperature observations made in different years cannot with justice be closely compared, as the climates of the two years are sure to differ considerably, and in the present case the difference in climate between the summers of 1870 and 1871 appears to have been very considerable.

In the autumn of 1881 a very interesting series of observations were made by Captain Magnaghi, hydrographer of the Italian navy, and Professor Giglioli, on board the Italian surveying ship "Washington," in that part of the western basin which is enclosed between the islands Corsica and Sardinia on the one side and the Italian coasts on the other. It is here that the deepest water of the western basin was found; and, apart from the great interest attaching to the physical results obtained, the collections made with the dredge in the comparatively lifeless waters were of the very highest importance, showing, as they did, a practical identity in the abyssal fauna with that of the open ocean. This is the more remarkable as we have hitherto been accustomed to consider the similarity in the fauna of portions of the ocean remotely distant from each other as being due to the likeness of their temperatures. In the Mediterranean, however, the bottom temperature is quite 20° F. higher than is found in great depths anywhere in the open ocean.

For determining the temperature of the deep water Captain Magnaghi used the half-turn reversing thermometer of Negretti and Zambra, which in itself is a very beautiful instrument. The mechanical arrangement, however, for reversing, even as improved by Magnaghi, was not so satisfactory, and from certain irregularities in the temperature observations reported the writer is inclined to think that some of the remarkable results obtained, for instance on the 11th August, are due to this instrumental imperfection. On that day the water at 70 metres was found to have a temperature of 25°·1 C., while that at 50 metres was 20°·1 C., and that at 90 metres was 16°·7 C. The results obtained in the deep water are no doubt quite reliable, for the temperature is so uniform that a few fathoms more or less in the depth at which it turned would make no difference in the temperature registered. In the more northern parts of this portion of the western basin, off the coast of Corsica, we find a practically uniform temperature from 250 metres down to the bottom in 2800 metres, the mean bottom temperature being 55°·96 F. Further to the south the temperature of the abyssal water appears to be distinctly higher. Thus between the south end of Sardinia and the Bay of Naples, in the deepest water, the practical uniformity of temperature is not reached until a depth of 1000 metres has been passed, and it is there 56°·7 F. It is unfortunate that we do not know what the bottom temperature in other parts of the Mediterranean was. In this summer of 1881 it was quite one degree higher than that observed by Dr Carpenter in 1870.

The great value of such a volume of water as an equalizer of temperature on its shores must be apparent, though in this respect it is inferior to the Atlantic Ocean in its immediate neighbourhood. Places on the west coast of Spain and Portugal have a much higher winter temperature and lower summer temperature than places in the same latitude in Italy. The reason of this is simple: on the Atlantic coast the principal winds in winter are from the south-west, and have a warming effect, while in summer the source of the north-east trade wind is pushed back into the Bay of Biscay, causing in this season constant northerly winds along the coast of Portugal. The winds of the Mediterranean have no seas of remote latitudes to draw on either for heating or cooling purposes, though the sandy deserts of Africa which bound its southern coasts have at certain seasons a very decided influence on the climate. The tempering action of the sea does not extend very far inland, as is evident from the climate of inland towns in Italy. As the Mediterranean shores have so much importance as health-resorts, the data presented in the following table are of interest. They are taken chiefly from Theobald Fischer's *Studien über das Klima der Mittelmeerländer*.

[1] *Phil. Trans.*, 1875, part ii. p. 601.
[2] *Ann. Chem. et Phys.*, 1845, xv. p. 5.

Table of mean January temperature (J.), of mean temperature of three winter months, December, January, and February (W.), also Rainfall (R.) in the same three months, for places on the Mediterranean, with those for some others for comparison.

Place.	J.	W.	R.	Place.	J.	W.	R.
	° F.	° F.	In.		° F.	° F.	In.
Bilbao	46·4	48·1	14·2	Ajaccio	50·45	52·2	8·0
Oporto	49·5	50·54	23·1	Trieste	39·95	41·3	7·8
Lisbon	50·54	50·9	11·3	Corfu	50·45	51·28	22·5
Tarifa	52·88	53·6	9·6	Athens	47·57	49·2	5 7
Gibraltar	54·0	54·5	12·4	Constantinople	40·28	41·6	10·1
Malaga	54·0	57·38		Jerusalem	48·74	49·1	12·7
Valencia	50·72	52·52	4·3	Port Said	57·38	57·2	
Mahon	51·62	52·52		Cairo	56·84	58·1	
Barcelona	48·02	49·64	4·1	Alexandria	60·0	60·1	5 6
Montpellier	42·08	43·16	9·3	Suez	56·3	56·58	
Marseilles	43·52	46·04	5·0	Tunis	53·06	55·76	
Nice	46·94	48·92	8·5	Algiers	59·18	59·65	14·4
Mentone	48·2	48·2		Oran	51·8	52·76	9·0
San Remo	47·48	48·38	8·0				
Genoa	46·4	47·66	13·0	S. Cruz (Teneriffe)	63·84	64·65	
Turin	32·0	35·06	4·6	Funchal (Madeira)	60·40	61·60	
Milan	32·9	35·42	8·0				
Venice	36·86	39·4		Valentia (Ireland)	45·00	44·60	18·3
Florence	41·54	43·16	12·0	Scilly	44·90	45·76	12·1
Rome	45·7	46·6	9·9	Jersey	41·70	42·97	10·1
Naples	48·2	49·3	10·5	Ventnor	41·80	42·60	
Catania	51·62	52·7	7·5	Pembroke	41·10	41·97	12·2
Palermo	51·62	52·7	8·8	Monach (Hebrides)	42·90	43·27	15·9
Malta	54·5	56·0	17·5	St Kilda	44·70	44·50	

Nature of the Bottom.—In the western basin the bottom consists chiefly of clay of a grey to brownish colour. Without doubt, when freshly collected, the surface layer is reddish-brown and the lower ones dark grey. There is always some carbonate of lime, chiefly due to *Foraminifera*. The mud very much resembles that obtained from similar depths in those parts of the open ocean whose bottom waters are shut off from free communication by ridges which may not approach within 2000 or 1500 fathoms of the surface, and with the exception of the *Foraminifera* it much resembles the mud from enclosed and comparatively shallow basins off the west coast of Scotland. In the following table the analyses are given of a few samples on the line of the submarine cable connecting Marseilles with Algiers.

Locality.			Composition per Cent.					
			Insoluble in HCl.		Soluble in HCl.			
Latitude N.	Longitude E.	Depth in Fathoms	Residue.	SiO_2 in Residue.	$CaCO_3$	Fe_2O_3	FeO	Al_2O_3
37° 39′	3° 23′	1,343	66·13	63·98	19·79	3·09	0·39	3·46
38° 11′	4° 6′	1,469	39·16	79·98	38·25	2·44	0·25	10·93
39° 26′	4° 36′	782	28·13	78·98	47·50	2·21	0·20	2·54
42° 47′	5° 11′	780	48·63	70·16	31·52	2·09	0·33	4·26
43° 1′	5° 15′	265	48·04	78·60	30·80	2·40	0·36	4·58

To the student of the physical conditions of the sea the Mediterranean possesses a very high interest; its size is such as to entitle it to rank among oceans, while it is so completely cut off from the remaining world of water that it presents us with a type which is purely local, and one might almost say provincial. (J. Y. B.)

MEDLAR, *Mespilus Germanica*, L., of the tribe *Pomeæ* of the order *Rosaceæ*, regarded by Bentham and Hooker as a subgenus of *Pyrus* (*Gen. Pl.*, i. 626; see also DC., *Prod*, ii. 633; *Trans. Lin. Soc.*, xiii. 99), is a native of European woods, &c., from Holland southwards, and of western Asia (London, *Arb.*, ii. 877). It occurs in hedges, &c., in middle and south England, as a small much-branched spinous tree, but is not indigenous to Great Britain (Hooker's *Stud. Fl. of Br. Isles*, 132; Baxter's *Brit. Gen. of Pl.*, 493, and *Mag. Nat. Hist.*, vol. ix. 86). The medlar was well known to the ancients. Pickering (*Chron. Hist. of Pl.*, 201) identifies it with a tree mentioned in a Siao-ya ode (*She-King*, ii. 1, 2), 827 B.C. It is the *μεσπίλη* of Theophrastus and *Mespilus* of Pliny. Loudon (*l.c.*) gives three varieties, *diffusa*, *stricta*, and *sylvestris*,—the last being spiny, but losing its spines under cultivation,—as well as four varieties of fruit. He also mentions several instances of large specimens throughout England. The well-known fruit is globular, but depressed above, with leafy persistent sepals, and contains stones of a hemispherical shape. It is not fit to eat until it begins to decay. (For culture of the medlar see HORTICULTURE.) The Japanese medlar is *Eriobotrya japonica*, L, a genus of the same tribe of *Rosaceæ*.

MÉDOC is the name given to the district in France adjoining the left bank of the Gironde from Ambès, the point where the Garonne and Dordogne unite, to Lesparre, where the marshes and polders which border on the mouth of the river begin; its length varies from 35 to 40 miles, its breadth from 12 to 5, and the area is about 386 square miles. It is formed by a number of low hills, which separate the Landes from the Gironde, and is traversed only by small streams; the Gironde itself is muddy, and often enveloped in fog, and the region as a whole is very far from being picturesque; but a fifth part of its soil is occupied by vineyards, the products of which form the finest growths of Bordeaux. Of these the most esteemed are Château-Margaux, Château-Laffitte, and Château-Latour. Prior to the ravages of the *Phylloxera*, the annual product of the Médoc district was 40,000 tuns, of which 9000 were of fine quality.

MEDUSA. See GORGON, vol. x. p. 785. See also HYDROZOA, vol. xii. p. 547 *sq.*

MEDYN, a district town of Russia, situated in the government of Kaluga, 39 miles north-west of the capital of the province, on the highway from Moscow to Warsaw. It was formerly known under the name of Mezetsk, and in the 14th century formed part of the Smolensk principality. The soil of the surrounding country being rather infertile, the population is engaged to some extent in manufactures of linen, cotton, and paper, and the merchants of Medyn carry on a brisk trade in this produce, as well as in rye, oats, and hemp seed. The population is 8000.

MEER, JAN VAN DER (1632–1675), of Delft,—not to be confounded with the elder or younger Van der Meer of Haarlem or with Van der Meer of Utrecht,—is one of the excellent painters of Holland about whom the Dutch biographers give us little information.[1] Van der Meer, or Vermeer, by which name he is also known, was born in Delft in 1632. There is a tradition, handed down by the Dutch writers, that he was a pupil of Carel Fabritius, but, in the strict sense of the word, this is almost impossible, for Fabritius was but eight years older than Van der Meer, and entered the guild of St Luke only one year before our painter. From his early death the works by Fabritius are few, but his contemporaries speak of him as a man of remarkable power, and the paintings now ascertained to be from his hand, and till recently ascribed to Rembrandt, prove him to have been deeply imbued with the spirit and manner of that master. Whether Van der Meer had ever any closer relation to Rembrandt than through companionship with Fabritius remains as yet uncertain. In 1653 he married Catherine Bolenes, and in the same year he entered the guild of St Luke of Delft, becoming one of the heads of the guild in 1662, and again in 1670. He died at Delft in 1675, leaving a widow and eight children. His circumstances cannot have been flourishing, for at his death he left twenty-six pictures undisposed of, and his widow had to apply to the court of insolvency to be placed under a curator, who, it is interesting to know, was Leeuwenhoek, the naturalist.

It is his works, however, that claim our attention. For more than two centuries he has been almost completely forgotten, and his pictures have been sold under the names

[1] This undeserved neglect seems to have fallen on him at an early period, for Houbraken (*Groote Schouburgh*, 1718), writing little more than forty years after his death, does not even mention him. The only definite information we have from a contemporary is given by Bleyswijck (*Beschrijving der Stad Delft*. 1687), who tells us that he was born in 1632, and that he worked along with Carl Fabritius, an able disciple of Rembrandt, who lost his life by an explosion of a powder magazine in Delft in 1654. It is to the patient researches of W. Bürger (Th. Thoré), Havard, Obreen, Soutendam, and others that we owe our knowledge of the main facts of his life, discovered in the archives of his native town.

and forged signatures of the more popular De Hooch, Metzu, Terborch, and even of Rembrandt. The honour of first recalling the attention of the art-world to this most original painter belongs undoubtedly to Thoré, an exiled Frenchman, who described his then known works in his *Musées de la Hollande* (1858-60), published under the assumed name of W. Bürger. The result of his researches, continued in his *Galerie Suermondt* and *Galerie d'Arenberg*, was afterwards given by him in a charming, though incomplete, monograph (*Gazette des Beaux-Arts*, 1866, pp. 297, 458, 542). The task has since been prosecuted with success by Havard (*Les Artistes Hollandais*), and by Obreen (*Nederlandsche Kunstgeschiedenis*, Dl. iv.), and we are now in a position to refer to Van der Meer's works. His pictures are rarely dated, but, luckily for us, one of the most important bears the date 1656, and thus gives us a key to his styles. The picture referred to is the only one that has figures of life size. It is the Woman and Soldier, with other two figures, of the Dresden gallery, and is painted with remarkable power and boldness, great command over the resources of colour, and with wonderful expression of life. For strength and colour it more than holds its own beside the neighbouring Rembrandts. To this early period of his career belong, from internal evidence, the Reading Girl of the same gallery, the luminous and masterly view of Delft in the museum of the Hague, La Laitière and the small street view, both in the collection of M. Six van Hillegom at Amsterdam, Le Soldat et la Fillette qui Rit of M. Double, the Country House in the gallery at Berlin, and others. In all these we find the same brilliant style and vigorous work, a solid impasto and a crisp sparkling touch. His first manner seems to have been influenced by the pleiad of painters circling round Rembrandt, a school which we know lost favour in Holland in the last quarter of the century. During the last ten or twelve years of his life Van der Meer adopted a second manner. We now find his painting smooth and thin, and his colours paler and softer. Instead of masculine vigour we have refined delicacy and subtlety, but in both styles beauty of tone and perfect harmony are conspicuous. Through all his work may be traced his love of lemon-yellow and of blue of all shades. Of his second style typical examples are to be seen in La Coquette of the Brunswick gallery, in the Woman Reading in the Van der Hoop collection at the Hague, in the Lady at a Casement belonging to Lord Powerscourt (exhibited at Burlington House, 1878), and in the Music Master and Pupil belonging to the Queen (exhibited at Burlington House, 1876).

Van der Meer's works are extremely rare. There is but one in the Louvre, the Lace Maker; Dresden has the two above-mentioned, while Berlin has three, all acquired in the Suermondt collection, and the Czernin gallery of Vienna is fortunate in possessing a fine picture, believed to represent the artist in his studio. In the Arenberg gallery at Brussels there is a remarkable head of a girl, half the size of life, which seems to be intermediate between his two styles. Several of his paintings are to be found in private foreign collections. In all his work there is a singular completeness and charm. In rendering momentary expression he is a master, and his pictures attract by the perfect delineation of character as well as by the technical skill of the painter. His tone is usually silvery with pearly shadows, and the lighting of his interiors is equal and natural. In all cases his figures seem to move in light and air, and in this respect he resembles greatly his fellow-worker De Hooch, who entered the guild of St Luke only two years later than Van der Meer. It is curious to read that, at one of the auctions in Amsterdam about the middle of last century, a De Hooch is praised as being "nearly equal to the famous Van der Meer of Delft." So nearly are they allied that the best judges are divided in opinion whether the Dutch Family ("La Promenade") of the academy of Vienna should be attributed to our painter or to De Hooch. Doubtless many of Van der Meer's works have yet to be restored to their proper author; but, as he is now in vogue, much care will have to be used in judging. This is specially true in regard to the landscapes and "still life" subjects which are attributed to him. The task is made more difficult by the diversity of style of this "Protean painter," as he is called by Dr Waagen, or, as Bürger names him, "the Sphinx of Delft." (J. F. W.)

MEERANE, a rapidly increasing industrial town in south-eastern Saxony, lies in the district of Zwickau, about 37 miles to the south of Leipsic. It contains an old church, a "Realschule," and a technical school for weavers. The leading industry is the weaving of woollen and half-woollen cloth, employing 3000 power-looms and 15,000 hand-looms, and producing goods of the annual value of upwards of £200,000. A large proportion of the cloth is exported to America and Japan. Meerane also possesses several important dye-works, besides smaller industrial establishments of various kinds. The population in 1880 was 22,293.

MEERSCHAUM. This German name is applied to a certain mineral, in consequence of its lightness, softness, and white colour, which suggest a resemblance to "sea foam." In like manner it is called in French *écume de mer*. By the German mineralogist Glocker it was termed *sepiolite*, in allusion to its resemblance to the so-called bone of the sepia or cuttle-fish. Possibly the fact that pieces of meerschaum, washed out of their matrix, are occasionally found floating on the Black Sea, may have led to the association of the mineral with marine products. Meerschaum is an opaque earthy mineral, of white, greyish, or yellowish colour, compact in texture, and breaking with a conchoidal or fine earthy fracture; it adheres to the tongue, and is so soft as to be scratched by the nail, its degree of hardness being about 2 or 2·5. Its specific gravity varies from 0·988 to 1·279; hence it floats in sea-water until saturated. Meerschaum is a hydrated silicate of magnesium, represented by the formula $Mg_2Si_3O_8 + nH_2O$. The value of n, according to some analyses, is 2. Most of our meerschaum comes from Asia Minor, especially from the plains of Eski-shehr, where it occurs in nodular masses, of variable size and irregular shape, distributed through the alluvial deposits of the plain, which are systematically worked for its extraction by means of pits and galleries. The mineral is associated with magnesite, or carbonate of magnesium, and has probably been derived from the neighbouring mountains, where a similar carbonate is found in connexion with serpentine. Meerschaum is found also, though less abundantly, in Greece and in some of the Grecian islands; at Hrubschitz in Moravia, where it occurs in a serpentinous matrix; and in Morocco, where it is used, when soft and fresh, as a substitute for soap; while a coarse variety is found at Vallecas near Madrid, and is employed as a building stone. Meerschaum also occurs in South Carolina.

By far the greatest quantity of meerschaum is used in the manufacture of tobacco-pipes, a purpose for which it is well fitted by its porosity. The nodular masses are first roughly scraped in order to remove the red earthy matrix; they are then dried, scraped again, and finally polished with wax. In this state the rudely-shaped nodular pieces are sent from the East principally to Vienna and to various parts of Germany. The pipe-bowls, after having been turned and carved, are rubbed with glass-paper and Dutch rushes; they are next boiled in wax, spermaceti, or stearine, and afterwards subjected to careful polishing with bone-ash, chalk, &c.

An imitation of meerschaum for common pipes is made of hardened plaster of Paris, treated with paraffin, and coloured by gamboge and dragon's blood. A peculiar preparation, into which potato largely enters, is said to have been successfully employed in France as a substitute for meerschaum.

MEERUT, or MÍRATH, a district in the division[1] of

[1] The division lies between 27° 38′ and 30° 57′ N. lat., and between 77° 7′ and 78° 42′ E. long., and comprises the six districts of Dehra Dun, Sahâranpur, Muzaffarnagar, Meerut, Bulandshahr, and Alígarh. The area in 1878 was 11,138 square miles, and the population in 1872 4,977,173.

Meerut and the lieutenant-governorship of the North-Western Provinces, India, lying between 28° 28′ and 29° 18′ N. lat., and 77° 10′ and 78° 14′ E. long., is bounded on the N. by Muzaffarnagar district, on the E. by the Ganges, on the S. by Bulandshahr district, and on the W. by the Jumna. The area in 1881 was given as 2361 square miles. Meerut forms a portion of the long and narrow plain lying between the Ganges and the Jumna, with a very gentle slope from north to south. Though well wooded in places and abundantly supplied with mango groves, it has but few patches of jungle or waste land to break the general expanse of cultivated soil. Sandy ridges run along the low watersheds which separate the minor channels, but with this exception the whole district is one continuous expanse of careful and prosperous tillage. Its fertility is largely due to the system of irrigation canals, which intersect it in every direction. The eastern Jumna canal runs through the whole length of the district, and supplies the rich tract between the Jumna and the Hindan with a network of distributary streams. The main branch of the Ganges canal passes across the centre of the plateau in a sweeping curve, and waters the midland tract. The Anúpshahr branch supplies irrigation to the Ganges slope. Besides these natural and artificial channels, the country is everywhere cut up by small water-courses. The Burh Gangá, or ancient bed of the Ganges, lies at some distance from the modern stream; and on its bank stood the abandoned city of Hastinapur, the legendary capital of the Pandavas at the period of the *Mahâbhârata*, said to have been deserted many centuries before the Christian era, owing to the encroachments of the river.

The census of 1872 returned the population of the district at 1,276,104, the Hindus numbering 991,226. Among the higher castes Bráhmans muster strong (109,804). The Rájputs (both Hindus and Mohammedans) number 55,083, and enjoy great social distinction as landholders; the Baniás, or traders (66,942), also now hold considerable landed property. The great cultivating castes are the Chamárs (197,273) and Játs (145,514). The Gujars (60,350) are a pastoral tribe, with an ancient character for plunder and cattle-lifting, which is now passing away. The Mohammedans (281,857) are for the most part the descendants of converted Hindus. The Christian population consists of 2149 Europeans, 142 Eurasians, and 730 natives. Fifteen towns in the district contain a population exceeding 5000; namely, Meerut, 81,386; Hápur, 14,544; Sardhána, 12,466; Garhmukhtesar, 7962; Bágpat, 7367; Ghaziábád, 7365; Shahdara, 7257; Baro, 7056; Mawána, 6864; Pilkhuá, 6239; Khekara, 6045; Tikri, 5698; Kirthal, 5651; Dasna, 5605; Chaprauli, 5594.

Meerut is one of the most flourishing and best tilled districts of the Doáb. Out of a total area of 1,505,824 acres, as many as 1,048,221 were under cultivation in 1881, 281,095 acres being irrigated by Government works, and 303,526 by private individuals. The grazing lands comprehended 242,091 acres, and the waste 185,400. The condition both of agricultural labourers and of artisans and workmen in the towns has considerably improved of late years. About one-half the soil is cultivated by the proprietors themselves, the remainder being about equally divided between tenants with occupancy rights and tenants-at-will. Rents are paid in money, and range from 18s. 10d. per acre for the best canal-watered lands down to 2s. 5¼d. per acre for "dry" unirrigated soils. The chief exports of the district are grain, cotton, and indigo; and the principal imports are Manchester goods, English hardware, tobacco, drugs, and spices. The chief commercial centres are Meerut, Ghaziábád, and Bágpat. Besides the great waterways of the Jumna and Ganges, and the navigable canals, communication is afforded by the East Indian and the Punjab and Delhi Railways; also by 1505 miles of made roads. In 1876 the district was in the administrative charge of four covenanted civilians, and contained seventeen magisterial and fifteen civil courts. The gross revenue in 1881 was £248,754, of which £203,977 was derived from the land-tax; the cost of officials and police was £27,520. In 1881 there were 214 schools, attended by 6677 pupils. The comparatively high latitude and elevated position of Meerut make it one of the healthiest districts in the plains of India. The average temperature varies from 57° Fahr. in January to 87° in June. The rainfall is small, less than 30 inches annually. The only endemic disease in the district is malarial fever; but small-pox and cholera occasionally visit it as epidemics.

The authentic history of the district commences with the Moslem invasions. Until the 11th century it is probable that Meerut was mainly in the hands of predatory native tribes, such as the Játs and Dors. The first undoubted Mohammedan invasion was that of Kutab-ud-dín in 1191, when Meerut town was taken, and all the Hindu temples turned into mosques. In 1398 Timúr swooped down upon the district, captured the fort of Loni after a desperate resistance, and put all his Hindu prisoners to death. He then proceeded to Delhi, and after his memorable sack of that city, returned to Meerut, captured the town, razed all the fortifications and houses of the Hindus, and put the male inhabitants to the sword. The firm establishment of the great Mughal dynasty in the 16th century, under Bábar and his successors, gave Meerut a period of internal tranquillity and royal favour. After the death of Aurangzeb, however, it was exposed to alternate Síkh and Mahrattá invasions. From 1707 till 1775 the country was the scene of one perpetual strife, and was only rescued from anarchy by the exertions of the military adventurer Walter Reinhardt, afterwards the husband of the celebrated Begám Samru, who established himself at Sardhána in the north, and ruled a large estate. The southern tract, however, remained in its anarchic condition under Mahrattá exactions until the fall of Delhi in 1803, when the whole of the country between the Jumna and the Ganges was ceded by Sindhia to the British. It was formed into a separate district in 1818. In the British period it has become memorable as being the place where the first outbreak of the great mutiny of 1857 took place.

MEERUT, a city and cantonment in the above district, is situated about half way between the Ganges and the Jumna, in 29° 0′ 41″ N. lat. and 77° 45′ 3″ E. long. The city proper lies south of the cantonments, and although a very ancient town, dating as far back as the days of the Buddhist emperor Asoka (*circ.* 250 B.C.), Meerut owes its modern importance to its selection by the British Government as the site of a great military station. In 1805 it is mentioned as "a ruined depopulated town." The cantonment was established in 1806, and the population rose rapidly to 29,014 in 1847, and 82,035 in 1853. In 1872 the census returned the population (exclusive of the military) at 81,386, viz., Hindus, 47,606; Mohammedans, 33,532; Christians, 248. The slight decline of population between 1853 and 1872 may probably be attributed to the mutiny of 1857. Most of the streets have a poor appearance, owing to the hasty manner in which they were erected. The cantonment, a little to the north of the city, forms the headquarters of a military division. The principal building is the Meerut church with its handsome tall spire. There are also a Roman Catholic church, mission chapel, asylum for the relief of Europeans and Christians, and a club. The Mall is one of the finest drives in India.

MEGALOPOLIS, a city of southern Arcadia, situated in a plain about 20 miles south-west of Tegea, on both banks of the Helisson, about 2½ miles above its junction with the Alpheus. Like Messene, it owed its origin to Epaminondas, and was founded in 370 B.C., the year after the battle of Leuctra, as a bulwark for the southern Arcadians against Sparta, and as the seat of the Arcadian federal diet, which consisted of ten thousand men. The builders of the city were protected by a Theban force, and directed by ten native œcists, who likewise attended to the peopling of the new city, which apparently drew inhabitants from all parts of Arcadia, but more especially from the neighbouring districts of Mænalia and Parrhasia. Forty townships are mentioned by Pausanias (viii. 27, 3–5) as having been incorporated in it. It was fifty stadia in circumference, and was surrounded with strong walls. Its territory was the largest in Arcadia, extending northward 24 miles. The city was built on a magnificent scale, and adorned with many handsome buildings, both public and private. Its temples contained many ancient statues brought from the towns incorporated in it. On the north side of the Helisson, which divided it into two nearly equal parts, was the agora with four porticos, the gymnasium, a sacred grove, temples to the Lycæan Zeus, Pan Oinoeis, Rhea, Tyche, the great goddesses (Demeter and Core), Zeus Philios (with a statue by Polycletus), Aphrodite, Core, Athena Polias, and Hera Teleia. Among the numerous statues which stood in the open air the finest was that of Apollo Epicurius, 12 feet high, brought from the beautiful temple of Bassæ, which was built by Ictinus, and is still in great part standing. On the south side of the river were the theatre, the largest in Greece, the Thersilion or hall for the assembly of the Arcadian diet, a house built for Alexander the Great, with a statue of Zeus Ammon, the stadium, temples to the Muses, Apollo, and Hermes, to Aphrodite, to Ares, to Dionysus, to Hercules and Hermes, to Artemis Agrotera, to Asclepius and Hygiea, to the son of Asclepius, and to Apollo. Of all these buildings, with the exception of the theatre, hardly a trace remains above ground. The ruins of Megalopolis are near Sinanou.

The foundations of Megalopolis were hardly laid when Agesilaus undertook an expedition in the hope of breaking up the union of which it was the visible sign and capital. He accomplished nothing, and had hardly reached home when the Thebans and their allies under Epaminondas and Pelopidas entered the Peloponnesus and marched through Laconia almost unopposed. After the departure of Epaminondas, Lycomedes of Mantinea succeeded in drawing the Arcadian federation away from its alliance with Thebes, in consequence of which it had to make common cause with Athens. An attempt on the part of the federation to use the treasures of the temple of Zeus at Olympia led to internal dissensions, so that in the battle of Mantinea (362) one half of the Arcadians fought on the side of the Spartans, the other on that of the Thebans. After this battle many of the inhabitants of Megalopolis sought to return to their former homes, and it was only by the assistance of three thousand Thebans under Pammenes that the authorities were able to prevent them from doing so. In the year 352, when Thebes had her hands full with the so-called Sacred War, the Spartans made an attempt to reduce Megalopolis; but the Thebans promptly sent assistance, and the city was rescued. Not sure of this assistance, the Megalopolitans had appealed to Athens, an appeal which gave occasion to Demosthenes's oration Περὶ Μεγαλοπολιτῶν. The Spartans were now obliged to conclude peace with Megalopolis and acknowledge her autonomy. Nevertheless their feeling of hostility did not cease, and Megalopolis consequently entered into friendly relations with Philip of Macedon. Twenty years later, when the Spartans and their allies rebelled against the power of Macedon, Megalopolis remained firm in its allegiance, and was subjected to a siege of considerable duration. After the death of Alexander, Megalopolis was governed by native tyrants. In the war between Cassander and Polysperchon it took part with the former, and was, in consequence, besieged by the latter. On this occasion it was able to send into the field an army of fifteen thousand. In 234 B.C. Lydiades, the last tyrant of Megalopolis, voluntarily resigned his power, and the city joined the Achæan league. In consequence of this it was once more exposed to the bitter hatred of Sparta. In 222 Cleomenes took and plundered it, and killed or dispersed its inhabitants, but in the year following it was restored and its inhabitants reinstated by Philopœmen, a native of the city. At this time the circuit of its walls always too great, seems to have been contracted. At all events it never again attained political importance, and gradually sank into insignificance. The only great men whom it produced were Philopœmen and Polybius the historian. Lycortas, the father of the latter, may be accounted a third. In the time of Pausanias the city was mostly in ruins.

MEGALOSAURUS. See REPTILES.

MEGAPODE, the name given generally to a small but remarkable Family of birds, highly characteristic of some parts of the Australian Region, to which it is almost peculiar. The *Megapodiidæ* with the *Cracidæ* form that division of the Order *Gallinæ* named by Professor Huxley *Peristeropodes* (*Proc. Zool. Society*, 1868, p. 296), and morphologically seem to be the lowest of the Order, with which apparent fact may perhaps be correlated their singular habit of leaving their eggs to be hatched without incubation, burying them in the ground (as many Reptiles do) or heaping over them a mound of earth, leaves, and rotten wood. This habit attracted attention more than three hundred years ago,[1] but the accounts given of it by various travellers were generally discredited by naturalists,[2] and as examples of the birds, probably from their unattractive plumage, appear not to have been brought to Europe, no one of them was seen by any ornithologist or scientifically described until near the end of the first quarter of the present century. The first member of the Family to receive authoritative recognition was one of the largest, inhabiting the continent of Australia, where it is known as the Brush-Turkey, and was originally described by Latham in 1821 under the name of the New-Holland Vulture, a misleading designation which he subsequently tried to correct on perceiving its Galline character. It is the *Talegallus lathami* of modern ornithologists, and is nearly the size of a hen Turkey. Six smaller species of the same genus have since been described, all from New Guinea or the neighbouring islands, but two of them, *T. pyrrhopygius* and *T. bruyni*, have been separated to form a group *Æpypodius*. The Australian bird is of a sooty-brown colour, relieved beneath by the lighter edging of some of the feathers, but the head and neck are nearly bare, beset with fine bristles, the skin being of a deep pinkish-red, passing above the breast into a large wattle of bright yellow. The tail is commonly carried upright and partly folded, something like that of a domestic Fowl.

The next form of which we may speak is another inhabitant of Australia, commonly known in England as the Mallee-bird, but to the colonists as the "Native Pheasant"—the *Lipoa ocellata*, described by Gould in the zoological *Proceedings* for 1840 (p. 126), which has much shorter tarsi and toes, the head entirely clothed, and the tail expanded. Its plumage presents a pleasing combination of greys and browns of various tints, interspersed with black, white, and buff, the wing-coverts and feathers

[1] Antonio Pigafetta, one of the survivors of Magellan's glorious but disastrous voyage, records in his journal, under date of April 1521, among the peculiarities of the Philippine Islands, then first discovered by Europeans, the existence of a bird there, about the size of a Fowl, which laid its eggs, as big as a Duck's, in the sand, and left them to be hatched by the heat of the sun (*Premier Voyage autour du Monde*, ed. Amoretti, Paris, A.R. ix. p. 88). More than a hundred years later the Jesuit Nieremberg, in his *Historia Naturæ*, published at Antwerp in 1635, described (p. 207) a bird called "Daie," and by the natives named "Tapun," not larger than a Dove, which, with its tail (!) and feet, excavated a nest in sandy places and laid therein eggs bigger than those of a Goose. The publication at Rome in 1651 of Hernandez's *Hist. Avium Novæ Hispaniæ* shews that his papers must have been accessible to Nieremberg, who took from them the passage just mentioned, but, as not unusual with him, misprinted the names which stand in Hernandez's work (p. 56, cap. 220) "Daic" and "Tapum" respectively, and omitted his predecessor's important addition "Viuit in Philippicis." Not long after, the Dominican Navarrete, a missionary to China, made a considerable stay in the Philippines, and returning to Europe in 1673 wrote an account of the Chinese empire, of which Churchill (*Collection of Voyages and Travels*, vol. i.) gave an English translation in 1704. It is therein stated (p. 45) that in many of the islands of the Malay Archipelago "there is a very singular bird call'd *Tabon*," and that "What I and many more admire is, that it being no bigger in Body than an ordinary Chicken, tho' long legg'd, yet it lays an Egg larger than a Gooses, so that the Egg is bigger than the bird itself. . . . In order to lay its Eggs, it digs in the Sand above a yard in depth; after laying, it fills up the hole and makes it even with the rest; there the Eggs hatch with the heat of the Sun and Sand." He adds further information which need not be quoted here. Gemelli Careri, who travelled from 1663 to 1699, and in the latter year published an account of his voyage round the world, gives similar evidence respecting this remarkable bird, which he calls "Tavon," in the Philippine Islands (*Voy. du tour du Monde*, ed. Paris, 1727, v. pp. 157, 158). The Megapode of Luzon is fairly described by Camel or Camelli in his observations on the Birds of the Philippines communicated by Petiver to the Royal Society in 1703 (*Phil. Trans.*, xxiii. p. 1398). In 1726 Valentyn published his elaborate work on the East Indies, wherein (deel iii. bk. v. p. 320) he very correctly describes the Megapode of Amboina under the name of "Malleloe," and also a larger kind found in Celebes, so as to shew he had in the course of his long residence in the Dutch settlements become personally acquainted with both.

[2] Thus Willughby (*Ornithologia*, p. 297), or Ray for him, who had, however, only Nieremberg's evidence to cite, and they can scarcely be blamed for their hesitation, considering the number of other marvels narrated by the same worthy father. Buffon also (*Oiseaux*, ix. p. 436) was just as sceptical in regard to the relation of Careri.

of the back bearing each near the tip an oval or subcircular patch, whence the trivial scientific name of the bird is given, while a stripe of black feathers with a median line of white extends down the front of the throat, from the chin to the breast. There is but one species of this genus known, as is also the case with the next to be mentioned, which is a singular bird long known to inhabit Celebes, but not fully described until 1846,[1] when it received from Salomon Müller (*Arch. f. Naturgeschichte*, xii. pt. 1, p. 116) the name of *Macrocephalon maleo*, but, being shortly afterwards figured by Gray and Mitchell (*Gen. Birds*, iii. pl. 123) under the generic term of *Megacephalon*, has since commonly borne the latter appellation. This is a very remarkable form, bearing a helmet-like protuberance on the back of its head, all of which as well as the neck is bare and of a bright red colour; the plumage of the body is glossy black above, and beneath roseate-white.

Of the Megapodes proper, constituting the genus *Megapodius*, many species have been described, but authorities are greatly at variance as to the validity of several, and here it would be impossible to name all that have been supposed to exist. Some are only known from very young examples—mere chickens; and some have even been described from their eggs alone. In 1870 Mr G. R. Gray enumerated twenty species, of which sixteen were represented in the British Museum, and several have been described since; but ten years later Professor Schlegel recognized only seventeen species, of which examples of twelve were contained in the Leyden Museum (*Mus. des Pays-Bas*, viii., Monogr. 41, pp. 56–86), while M. Oustalet, in his elaborate monograph of the Family (*Ann. Sc. Nat., Zoologie*, ser. 6, vols. x. and xi.), admits nineteen species. The birds of this genus range from the Samoa Islands in the east, through the Tonga group, to the New Hebrides, the northern part of Australia, New Guinea and its neighbouring islands, Celebes, the Pelew Islands, and the Ladrones, and have also outliers in detached portions of the Indian Region, as the Philippines (where indeed they were first discovered by Europeans), Labuan, and even the Nicobars—though none are known from the intervening islands of Borneo, Java, or Sumatra. Within what may be deemed their proper area they are found, says Mr Wallace (*Geogr. Distr. Animals*, ii. p. 341) "on the smallest islands and sand-banks, and can evidently pass over a few miles of sea with ease." Indeed proof of their roaming disposition is afforded by the fact that the bird described by Lesson (*Voy. Coquille: Zoologie*, p. 703) as *Alecthelia urvillii*, but now considered to be the young of *Megapodius freycineti*, flew on board his ship when more than 2 miles from the nearest land (Guebé), in an exhausted state, it is true, but that may be attributed to its extreme youth. The species of *Megapodius* are about the size of small Fowls, the head generally crested, the tail very short, the feet enormously large, and, with the exception of *M. wallacii* (*Proc. Zool. Society*, 1860, *Aves*, pl. 171), from the Moluccas, all have a sombre plumage.

The extraordinary habit possessed by the Megapodes generally of relieving themselves of the duty of incubation, as before mentioned,—a habit which originally attracted the attention of travellers, whose stories were on that very account discredited,—as well as the highly developed condition of the young at birth, has been so fully described by Gould (*Handb. B. Australia*, ii. pp. 152–175), G. R. Gray (*Proc. Zool. Society*, 1861, pp. 292–296), and Mr Wallace (*Malay Archipelago*, i. pp. 415–419; ii. pp. 147–149), and so often repeated by other writers, as to be very commonly known, and here there seems no necessity to enter into further details concerning it. (A. N.)

[1] As we have seen, it was mentioned in 1726 by Valentyn, and a young example was in 1830 described and figured by Quoy and Gaimard (*Voy. de l'Astrolabe: Oiseaux*, p. 239, pl. 25) as the *Megapodius rubripes* of Temminck, a wholly different bird.

MEGARA was the name of two Greek towns, one in Sicily, which has been already described under HYBLA, the other on the road from Attica to Corinth. The country which belonged to the city was called Μεγαρίς or ἡ Μεγαρική; it occupied the broader part of the isthmus between Attica, Bœotia, Corinth, and the two gulfs, and its whole area is estimated by Clinton at 143 square miles. The range of Mount Geraneia extends across the country from east to west, forming a barrier between continental Greece and the Peloponnesus. The shortest road across this range passes along the eastern side of the mountains, and the most difficult part is the celebrated Scironian rocks, the mythic home of the robber Sciron. The only plain in the rugged little country was the White Plain, in which was situated the only important town, Megara. The town was one of the most important commercial and colonizing centres of Greece in early times, and there is no doubt that its trade, like that of Corinth, owed its origin to the Phœnicians, who found its situation on the isthmus convenient. It became a Dorian city when that tribe conquered the Peloponnesus. Like many other cities of Greece, Megara was formed out of five villages, which were united on one political foundation; and this event must have taken place not later than the middle of the 8th century. From this time for two centuries Megara was among the most powerful cities of Greece. Though it had a harbour called Pegæ on the Corinthian Gulf, and founded a Sicilian colony, Megara Hyblæa, in 728 B.C., yet it did not long compete with Corinth and Corcyra for the western trade. Nisæa on the Saronic Gulf was a better harbour, and gave the Megarians a stronger footing on the eastern seas. In order to keep their hold on the Black Sea traffic, they founded numerous trading stations alongside of their chief rivals, the people of Miletus: Chalcedon and Byzantium on the Bosphorus, and Astacus and Heraclea in Bithynia were colonies of Megara. Wealth and culture increased in the city; the country festivals were celebrated in a more elaborate and orderly manner, and Susarion of Tripodiscus first gave literary form to Grecian comedy, which was soon transferred to Attica.

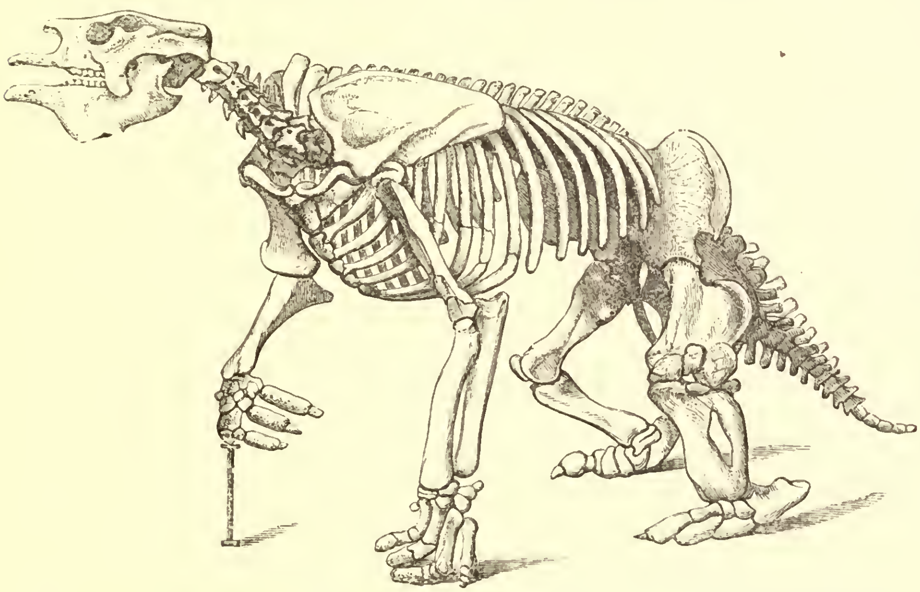
The situation of Megaris on the isthmus gave it great political power, inasmuch as it commanded all the roads from the Peloponnesus into continental Greece; and so long as the people continued united under an orderly government they maintained their high position. But the development of education prompted the lower classes to demand from the nobles an equal share in the government, and Megara did not, like Athens and Sparta, produce a constitution which could reconcile the contending parties. A tyrant Theagenes raised himself to supreme power as the leader of the popular party; he made an aqueduct for the city, and appears to have maintained its power and splendour. But he was expelled by the nobles about 600 B.C., and for many years Megara was the scene of continual struggles. The poor, who were indebted to the rich, refused to pay what they counted exorbitant interest, and plundered the houses of the nobles. A vivid picture of the state of the city in the 6th century B.C. is preserved in the writings of the poet Theognis, who belonged to the aristocratic party. Meanwhile Athens was rising to power, and maintained a long war with Megara for the island of Salamis. The Megarians gradually lost strength, and finally Solon wrested the island from them for ever. They sent three thousand troops to fight at Platæa. In the wars between Athens and Sparta they were impelled by jealousy of their neighbours of Corinth to join the Athenian alliance, 455–45; but they soon found that they were only the subjects of Athens, and finally enrolled themselves among the allies of Sparta. They suffered terribly during the Peloponnesian War: Athenian ships blockaded their harbours and Athenian armies ravaged their land once or twice every year. The long famine in the city is referred to by Aristophanes in the *Acharnians*. The city maintained a flourishing existence throughout the Greek and Roman periods, but played a very subordinate part in history. In the unsettled time when the Roman empire had decayed, it was often plundered by pirates.

As regards literature, Megara's chief distinction, besides the poems of Theognis and the comedy of Susarion, was the school of philosophy founded there by Euclid, a disciple of Socrates. The coinage of the city is a very confused and difficult subject; no very early coins can be with certainty attributed to it. The usual types are Apolline. The topography is described by Pausanias, bk. i. Megara is about four hours' carriage-drive from Athens.

MEGATHERIUM is the name given by Cuvier to a large extinct animal belonging to the order *Edentata* (see MAMMALIA, p. 384). A nearly complete skeleton, found on the banks of the river Luxan, near Buenos Ayres, and sent in 1789 to the Royal Museum at Madrid, long remained the principal if not the only source of information with regard to the species to which it belonged, and furnished the materials for many descriptions, notably that of Cuvier, who determined its affinities with the Sloths.[1] In 1832 an important collection of bones of the Megatherium were discovered near the Rio Salado, and were secured for the museum of the College of Surgeons of England, and these, with another collection found at Luxan in 1837, and now in the British Museum, supplied the materials for the complete description of the skeleton published by Professor Owen in 1861. Other skeletons have subsequently been received by several of the Continental museums, as Milan and Paris, and, consequently, our knowledge of the organization of the Megatherium, so far as it can be deduced from the bones and teeth, is as complete as that of any other animal, recent or extinct.

The remains hitherto spoken of are all referred to one species, *Megatherium americanum* of Blumenbach, *M. cuvieri* of Desmarest, and are all from the newest or post-Tertiary geological formations of the Argentine Republic and Paraguay, or the lands forming the basin of the Rio de la Plata. Dr Leidy has described, from similar formations in Georgia and South Carolina, bones of a closely allied species, about one-fourth smaller, which he has named *M. mirabile*. A third species, *M. laurillardi* of Lund, is founded upon remains found in Brazil.

The following description will apply especially to the best-known South American form, *Megatherium americanum*. In size it exceeded any existing land animal except the elephant, to which it was inferior only in consequence of the comparative shortness of its limbs, for in length and bulk of body it was its equal, if not superior. The full length of a mounted skeleton from the fore part of the head to the end of the tail is 18 feet, of which the tail occupies 5 feet. The head, which is small for the size of the animal, presents a general resemblance to that of the Sloth; the anterior part of the mouth is, however, more elongated, and the malar bone, though branched posteriorly in the same way as that of the Sloth, meets the zygomatic process of the squamosal, completing the arch. The lower jaw has the middle part of its horizontal ramus curiously deepened, so as to admit of implantation of the very long-rooted teeth. In number the teeth exactly resemble those of the Sloths, being five above and four below on each side, and they are limited to the lateral parts of the mouth, front teeth being entirely wanting. They resemble those of the Sloths also in their persistent growth, and in their composition of three tissues — vaso-dentine, true dentine, and cement; but they are of prismatic or quadrate form, and the constituent materials of different densities are so arranged that, as they wear, two transverse ridges of hard dentine remain at a greater elevation than the rest of the tooth, producing a very efficient triturating apparatus (see figs. 35 and 36, article MAMMALIA, p. 385). The vertebral column consists of seven cervical, sixteen dorsal, three lumbar, five sacral, and eighteen caudal vertebræ. The spinous processes are much better developed than in the Sloths, and are all directed backwards, there being no reversing of the inclination near the posterior end of the dorsal series, as in most active-bodied mammals. In the lumbar region, the accessory zygapophyses, rudimentary in Sloths, are fully developed, as in the Anteaters.



Skeleton of the Megatherium, from the specimen in the Museum of the Royal College of Surgeons of England. × $\frac{1}{25}$.

The tail is large, and its basal vertebræ have strong lateral and spinous processes and chevron bones, indicating great muscular development. The scapula resembles that of the Sloths in the union of the acromion with the coracoid, and in the bridging over of the supra-scapular notch. The clavicle is complete and very large much resembling that of man on a large scale. The fore limbs are longer than the hind limbs. The radius and ulna are both well-developed, and have a considerable amount of freedom of movement. The hand is singularly modified. The first digit is represented only by a rudimentary metacarpal, but the next three are large, and terminate in phalanges

[1] An excellent figure of this skeleton, which unfortunately was incorrectly articulated, and wanted the greater part of the tail, was published by Pander and D'Alton in 1821, and has been frequently reproduced in subsequent works.

adapted for the support of immense claws, the middle one being especially large. The outer or fifth digit has no claw, and it may be considered as certain that the weight of the foot was, in standing and walking, chiefly thrown upon this, and that it was protected by a callous pad below as in the existing great Anteater, while the other toes were curved inwards towards the palm, only coming in contact with the ground by their outer surfaces. The mechanical arrangements by which the weight of the body was thrown entirely upon the outer side of the foot are very curious, and are fully described in Professor Owen's memoir. The pelvis is remarkably wide, even more so than that of the Elephant, but it is formed on the same principle as in the Sloths. The femur is extremely broad and flattened; the tibia and fibula are short and strong, and united together at each end. The hind foot, contrary to the usual rule in the *Edentata*, is even more singularly modified than the hand. The ankle-joint is formed upon a peculiar plan, quite unlike that of the Sloths, or of any other mammal, except the Megatherium's nearest allies. The calcaneum projects nearly as far backwards as the fore part of the foot does forwards. There is no trace of great toe or hallux, or of its corresponding cuneiform bone. The second toe is rudimentary. The third has an enormous ungual phalanx, which, like those of the hand, is remarkable for the immense development of the bony sheath which is reflected from its proximal end around the base of the claw. The two outer toes have large and very peculiarly-shaped metatarsals, but only small phalanges, and no claws. The creature probably walked upon the outer edge of the sole, so that the great falcate claw of the third toe did not come into contact with the ground, and so was kept in a state of sharpness ready for use. The foot was therefore formed upon quite a different principle from that of the Anteaters or Sloths, though somewhat like the latter in having two of the toes aborted.

Taking all the various points of its structure together, they clearly indicate affinities both with the existing Sloths and with the Anteaters, the skull and teeth more resembling those of the former, and the vertebral column and limbs the latter It is also not difficult to infer the food and habits of this enormous creature. That it was a leaf-eater there can be little doubt, but the greater size and more complex structure of its teeth might have enabled it to crush the smaller branches as well as the leaves and succulent shoots which form the food of the existing Sloths. It is, however, very improbable that it climbed into the branches of the trees like its diminutive congeners, but it is far more likely that it obtained its subsistence by tearing them down with the great hook-like claws of its powerful prehensile fore limbs, being easily enabled to reach them by raising itself up upon the massive tripod formed by the two hind feet, firmly fixed to the ground by the one huge falcate claw, and the stout, muscular tail. The whole conformation of the hinder part of the animal is strongly suggestive of such an action. There can also be little doubt but that all its movements were as slow and deliberate as those of its modern representatives.

An idea at one time prevailed that the Megatherium was covered externally with a coat of bony armour like that of the Armadillos, but this originated in dermal plates belonging to the Glyptodon, a totally distinct animal, having been accidentally associated with bones of the Megatherium. Similar plates, on a smaller scale, have indeed been found in connexion with the skeleton of both Mylodon and Scelidotherium, animals of the same family, but never yet with the Megatherium, which we may therefore imagine with a covering of coarse hair like that of its nearest living allies, the Sloths and Anteaters.

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MEGHNÁ, a river of India, forming, in the lower part of its course, the great estuary of the Bengal delta, which conveys to the sea the main body of the waters of the Ganges and the Brahmaputra, which unite at Goalánda in Farídpur district. The united waters thence roll south—a mighty river of great depth and turbidness, sometimes split up into half a dozen channels by sand-banks of its own formation, sometimes spreading out into a widespread sheet of water which the eye cannot see across. The river enters the sea by four principal mouths, enclosing the three large islands of Dakshin Sháhbazpur, Hatia, and Sandwíp. It is navigable by native boats of the largest burden, and also by river steamers, all the year through; but the navigation is difficult, and sometimes dangerous, on account of shifting sand-banks and "snags," and boisterous weather when the monsoon is blowing. The most favourable season for navigation is between November and February. Alluvion and diluvion are constantly taking place, especially along the seaboard, and in Noákhálí district the land is said to have advanced seawards 4 miles in twenty-three years; while the islands fringing the mouth are annually being cut away and redeposited in fresh shapes.

The tidal phenomena of the Meghná surpass those of any other Indian river. The regular rise of the tide is from 10 to 18 feet, and at springs the sea rushes up in a single wave, known as the "bore,"—on the Meghná a justly dreaded danger to boatmen. It is greatest at the time of the biennial equinoxes, when navigation is sometimes impeded for days together. The tidal wave is suddenly beheld advancing like a wall topped with foam of the height of nearly 20 feet, and at the rate of 15 miles an hour; in a few minutes all is over, and the river has changed from ebb to flood tide. A still greater danger is the "storm wave," which occasionally sweeps up the Meghná in the shape of cyclones. The latest and most destructive of these disasters were those of May 1867 and October 1876, when the whole islands and sea-face of the mainland were entirely submerged. In the latter calamity it has been officially estimated that about 19 per cent. of the population in the mainland portion of Noákhálí, and in the islands of Sandwíp and Hatia, were drowned, and that a like proportion subsequently died of cholera and other diseases caused by the results of the storm.

MEHÁDIA, a market-town in the county of Szörény, Hungary, is situated on the Bella-Reka, or Bereka, 13½ miles north of Orsova, in 44° 55′ N. lat., 22° 22′ E. long. The town is small but thriving, and contains Greek Orthodox and Roman Catholic churches, the ruins of a castle, and some interesting Roman antiquities. Mehádia is, however, chiefly of importance as the station for the Hercules Baths, distant about 3 miles east from the town, and situated in a narrow pass in the romantic valley of the Cserna. Of the twenty-two hot springs of Mehádia, nine are now in use, the most powerful one being the Hercules, which yields about 5000 cubic feet of water per hour. The springs are all strongly impregnated with salts of sulphur, iodine, bromine, and chlorine, and their average temperature is 70° to 145° Fahr. They are much used for chronic rheumatism, gout, and cutaneous eruptions, and, during the season, which usually lasts from the middle of

May to the end of September, are resorted to by over a thousand visitors. The town of Mehádia has about 2200 inhabitants, principally Roumanians and Germans.

Already in the times of the Romans famous for their healing efficacy, the *Thermæ Herculis* (*Fontes Herculis, Aquæ Herculis*) were the resort of emperors, generals, and senators, whose sojourn there is attested by various inscriptions and relics. The town is the site of the ancient Roman colony of *Ad Mediam*, near which the Roman road from the Danube to Dacia passed in its course through the valley of the Cserna. Subsequent to the destruction of the Roman empire the baths fell into disuse until 1735; great improvements have been effected in them during the present century, and recently a spacious kursaal has been built at the expense of the Hungarian Government. The fortress of Mehádia was often stormed during the wars with the Turks, and notably in 1716, 1738, and 1789.

MEHEMET ALI, or MOHAMMED 'ALÍ. See EGYPT, vol. vii. p. 760 *sq.*

MÉHUL, ÉTIENNE HENRI (1763–1817), one of the most remarkable composers of France, was born at Givet, in Ardennes, on the 24th of June 1763. His father being too poor to give him a regular musical education, his first ideas of art were derived from a poor blind organist of Givet; yet such was his aptitude that, when ten years old, he was appointed organist of the convent of the Récollets. In 1775 an able German musician and organist, Wilhelm Hauser, was engaged for the monastery of Lavaldieu, a few miles from Givet, and Méhul became his occasional pupil. In his sixteenth year he was taken to Paris by a military officer, and placed himself under Edelmann, a good musician and harpsichord player. His first attempts at instrumental composition in 1781 did not succeed, and he therefore turned his attention to sacred and dramatic music. The great composer Gluck received him kindly, and gave him advice in his studies. After various delays and disappointments during his efforts for six years to obtain, at the Grand Opera, a representation of his *Cora et Alonzo*, he offered to the Opéra Comique his *Euphrosine et Coradin*, which, being accepted and performed in 1790, at once fixed his reputation. The critics acknowledged in it great energy of dramatic expression, and much brilliant instrumentation, but objected to a general want of graceful melody,—a strange complaint, since his style is far more refined than that of either Hérold or Auber. His opera of *Stratonice* had great success. After several other operas which did not succeed, his *Adrien* appeared, and added much to his fame, which was still further increased by his three best works, *Le jeune Henri*, *Uthal*, and *Joseph*, the finest of the series. He had been appointed one of the four inspectors of the Paris Conservatory, but that office made him feel continually the insufficiency of his early studies, a want which he endeavoured to remedy by incessant application. *Timoléon*, *Ariodant*, and *Bion* followed *Stratonice*, with various success. *Uthal* can scarcely be expected to live, since, by desire of Napoleon Bonaparte, it was written for an orchestra without violins. *Épicure* was composed by Méhul and Cherubini jointly; but the superiority of the latter was evident. Méhul's next opera, *L'Irato*, failed. After writing forty-two operas, besides a number of songs for the festivals of the republic, cantatas, and orchestral pieces of various kinds, his health gave way, from an affection of the chest, which terminated his life on the 18th of October 1817.

MEIBOM, HEINRICH (1555–1625), was born at Lemgo on December 4, 1555, and died on September 20, 1625, at Helmstädt, where he had held the chair of history and poetry from 1583. He was a writer of Latin verses (*Parodiarum Horatianarum Libri III. et Sylvarum Libri II.*, 1588), and his talents in this direction were recognized by the emperor Rudolph II., who ennobled him and made him poet laureate in 1590, but his claim to be remembered rests entirely on his services in elucidating the mediæval history of Germany. His *Opuscula Historica ad res Germanicas spectantia* were edited and published in 1660 by his grandson, Heinrich Meibom (1638–1700), who also was professor of history and poetry at Helmstädt, and incorporated the grandfather's work with his own *Rerum Germanicarum Scriptores* (1688).

MEININGEN, the capital of the little duchy of Saxe-Meiningen, in central Germany, and the seat of the provincial courts for Saxe-Meiningen, Saxe-Coburg, and the Prussian districts of Schmalkalden and Schleusingen, is situated on the right bank of the Werra, about 40 miles to the south of Eisenach. It consists of an old town and several handsome suburbs, but much of the former has been rebuilt in a modern style since a destructive fire in 1874. The chief buildings are the Elisabethenburg, or old ducal palace, dating chiefly from 1682, and containing several collections; the new palace; the new town-house; the post-office; the barracks; and the old town church, with its two towers, erected in 1003. The theatre has lately attained a European reputation for its admirably drilled actors and unexcelled scenic effects. The English Garden, a beautiful public park, contains the ducal mortuary chapel and several monuments. The industries, consisting of brewing and the weaving of woollen and cotton cloth, are insignificant. The population in 1880 was 11,227.

Meiningen, which was subject to the bishops of Würzburg for upwards of 500 years (1000–1542), came into the possession of the dukes of Saxony in 1583. At the partition of 1660 it fell to the share of Saxe-Altenburg, and in 1680 it became the capital of Saxe-Meiningen.

MEISSEN, an ancient and important industrial town of Saxony is situated on the left bank of the Elbe, between the streams Meisse and Triebisch, in the district and about 9 miles to the north-west of the town of Dresden. Its irregular hilly site and numerous fine old buildings give it a quaint and picturesque appearance, and most of the streets are narrow and uneven. The cathedral, one of the finest Early Gothic edifices in Germany, is conspicuously situated on the Schlossberg, 160 feet above the town. It is said to have been originally founded by the emperor Otho I., but the present building was begun in the 13th century, and completed soon after 1400. The lofty tower dates from the 15th century. Within the cathedral are the tombs of several Saxon princes of the 15th and 16th centuries, including those of Albert and Ernest, the founders of the present reigning lines. Adjoining the cathedral stands the castle, dating originally from 1473–81, but restored and named Albrechtsburg in 1676. Another thorough restoration was undertaken in 1863, when a series of historical frescos by celebrated modern artists was begun upon its walls. An old stone bridge of the 13th century connects the Schlossberg with the Afraberg, which owes its name to the old convent of St Afra. The convent was suppressed by Duke Maurice in 1543, and converted into the "Fürstenschule," one of the most renowned schools in Germany, counting Lessing and Gellert among its former pupils. The other chief buildings are the town-house, built in 1479, and restored in 1875; the fine old town church, also called the Frauenkirche or Marienkirche; and the churches of St Francis, St Nicholas (coeval with the town), and St Afra. Since 1710, immediately after Böttcher's great discovery, Meissen has been the seat of the manufacture of the so-called Dresden china. Till 1863 the porcelain factory was in the Albrechtsburg, but in that year it was transferred to a large new building in the Triebischthal, close to the town, where about six hundred and seventy hands are now employed. Meissen also contains iron foundries, manufactories of earthenware stoves and pottery, a jute-mill, sugar refineries, breweries, tanneries, &c. A considerable trade is carried on in the wine produced in the surrounding vineyards. The population in 1880 was 14,166.

Meissen, one of the oldest and most interesting towns in Saxony, was founded by the emperor Henry I. in 928 as an outpost against the Wends, and became the capital of a margraviate, which was afterwards merged in the duchy of Saxony. Its margraves were among the most powerful mediæval princes in Germany, and were the direct ancestors of the present royal house of Saxony. From 965 till 1581 Meissen was also the seat of an important line of bishops, who ranked as princes of the empire. The town suffered greatly from the Hussites in the 15th century, and it was captured by the imperial troops in the war of the Smalkaldian League, and again in the Thirty Years' War. In 1637 it was severely handled by the Swedes, and in 1745 it fell into the hands of the Prussians.

See *Die Stadt Meissen und ihre Umgegend*, 1855; and H. Herbst's *Praktischer Wegweiser durch die Stadt Meissen*, 1878.

MEKONG, Mekhong, or Makong, less frequently Nam-Kong, the Da-Kio of the Tibetans, the Lantsang-Kiang or Lankiang of the Chinese, and the Son-Kong of the Anamese, sometimes also called the Cambodia or Camboja, is one of the largest and most remarkable rivers of southern Asia. As it rises in Tibet, probably about 34° N. lat. and 94° E. long., and reaches the China Sea about 10° N. lat., after a somewhat devious course through Yunnan, Burmah, Siam, Cambodia, and Cochin-China, its total course may be safely stated at 2000 miles. In spite, however, of this great length, the Mekong must be regarded as little more than a mountain torrent on an unusually large scale. It certainly forms a very extensive delta (see Cochin-China, vol. vi. pp. 93, 94), and is navigable for steamboats as far up as Cratieh (about 280 miles from the river mouth), but navigation soon becomes difficult, not through want of water, but from the great irregularity of the bed. At Stung-Streng the river measures about 2 leagues from bank to bank, and its current is strong even to violence; it "twists into the sharpest eddies, and drives against the banks with fury." A little higher up are the great cataracts of Kong. Beyond these the channel again becomes navigable as far as Bassac, when it is still about 6500 feet in width; but before long the banks close in and the river, narrowed to about 900 feet, pours along a current of extraordinary depth. Above Khemarat the rapids again begin. At Paklay, Mouhot describes the Mekong as larger than the Menam at Bangkok, forcing its way between the lofty mountains with a noise like the roaring of the sea. About 130 miles farther up, at Luang-Prabang, it has again an unobstructed channel about 3000 feet wide; above Sien-kong the river winds through a magnificent plain; but soon afterwards, in spite of its volume of water, it becomes less navigable than before. The great French expedition of 1866–67 touched its course only at one place higher up, Sien-hong; but other travellers have crossed it at various points in Yunnan. Mr Grosvenor found it, near Yung-feng-chang, at a height of 4700 feet above the sea, a stream of from 60 to 80 yards wide, flowing smoothly and steadily in the floor of a deep gorge (see Coleborne Baker, "Trav. and Res. in Western China," *Roy. Geog. Soc. Suppl. Papers*, 1882). It is there crossed by an iron suspension bridge, of Chinese workmanship, consisting of twelve chains with links about 1 foot long (see Gill, *River of Golden Sand*, vol. ii. p. 330). Higher up, near Tse-ku mission-station, lies the terrific defile to which Cooper (*Trav. of a Pioneer of Commerce*, 1871) gave the name of Hogg's Gorge. The head waters of the Mekong have never been traced to their source; but Huc and Gabet saw the confluence of the two main branches at Tsiamdo (32° N. lat.), and the abbé Desgodins has followed the stream from that point down to Ye-tche in 27° 20′ N. lat. (see *La Mission du Thibet*, Paris, 1872, and the abbé's papers in *Bull. Soc. Géog.*, 1871, 1875, 1876, and 1877). At Yerkalo he observed a curious phenomenon: a number of wells from 12 to 24 feet deep were sunk down among the granite pebbles which form the bed of the river, just above mean-water mark; and they all yielded water with a greater or less degree of saltness and warmth. They are covered when the river is in full flood. The river basin in all the upper section is extremely narrow, being separated by long lines of high mountains from the valley of the Salwin on the west and from that of the Chin-sha-kiang or River of Golden Sands on the east. Not till the comparatively low country of Siam is reached are there any affluents of considerable size. The most important are the Se-mún and the Udong on the right, and the Attopeu or Se-Kong on the left. The Se-mún or Ubon river was explored as far as Korat by the Lagrée expedition, and its tributary the Se-dóm has been followed by Dr Harmand (*Bull. Soc. Géog.*, 1877). Both streams have a rapid and interrupted course. Like the Nile, the Mekong is subject to a great annual inundation, described as early as the 16th century by Camoens, who calls the river Mecom. At some places the difference between flood-mark and ordinary level is from 35 to 40 feet (see Cochin-China). The first Europeans to make true acquaintance with the river course were the Dutchman Wusthoff and his fellow ambassadors, who in 1641 ascended as far as Winkyan, *i.e.*, Vienchang; their narrative is given by Valentijn, and might have been enough to suggest that the Mekong could not form a trade route to the interior. For the French exploration which finally settled the question, see Garnier's *Expédition*, &c., 1873, and the notice of Garnier in vol. x. p. 82.

MELA, Pomponius, a Roman writer on geography. His little work, though a mere compendium, is the only systematic treatise on the subject preserved to us in the Latin language, with the exception of that which forms part of the encyclopædic work of the elder Pliny, and from this circumstance it derives a value to which it would be little entitled from its intrinsic merits. Nothing is known of the author except his name, and that he was born, as he himself informs us, at a small town called Tingentera in the south of Spain. But the date of his work may be fixed with little doubt from an allusion in the preface to a proposed expedition of the reigning emperor to Britain, which can hardly be referred to any other event than the visit to that island of the emperor Claudius in 43 A.D. This conclusion is accepted by all the recent editors; the view of some earlier scholars, who understood this passage as referring to the expedition of Julius Cæsar, is clearly disproved by the mention of several facts which were not anterior to the reign of Augustus. The little treatise is not only a mere abridgment, occupying less than one hundred pages of ordinary print, but is so deficient in method and systematic character that we should have supposed it to be little more than a mere schoolbook, were it not that we find the name of the author figuring in a prominent manner among the authorities cited by Pliny for the geographical books of his vast compilation.

His general views of the geography of the earth do not differ materially from those which were current among Greek writers from the time of Eratosthenes to that of Strabo, and are well known to us from the great work of the latter author, which was, however, in all probability unknown to Mela, as it certainly was to Pliny. But in one of his views he stands alone among ancient writers on geography, that after describing the division of the earth into five zones, of which two only were inhabitable, he states as an undoubted fact the existence of *antichthones*, who inhabited the southern temperate zone, but were inaccessible and consequently unknown to the inhabitants of the corresponding zone in the north, on account of the excessive heat of the intervening torrid zone. His views of the division and boundaries of the three continents of Europe, Asia, and Africa coincide with those of Eratosthenes; and, in common with all ancient geographers from the time of Alexander to that of Ptolemy, he regarded the Caspian Sea as an inlet from the Northern Ocean, corresponding to the Persian Gulf on the south. His ideas concerning India are extremely confused and imperfect,—altogether inferior to those possessed by Greek writers long before; he follows Eratosthenes in supposing that country to occupy the south-eastern angle of Asia, whence the coast trended northwards to Scythia, and then swept round to the westward to the opening of the Caspian Sea. As usual he places the Rhipæan Mountains and the Hyperboreans near the Scythian Ocean, which he of course connects with that supposed to exist to the north of Europe.

With regard to the west of Europe, on the other hand, his knowledge was somewhat in advance of the Greek geographers, as might be expected from the extension of the Roman dominion and civilization in that quarter, and from a writer who was himself a native of Spain. Accordingly we find him possessing a more accurate idea than either Eratosthenes or Strabo of the western coast-line of Spain and Gaul, and its deep indentation by a gulf (the Bay of Biscay) between the projecting headlands of the two countries. Of Britain, on the contrary, he has little to tell us, beyond what we find in Cæsar or Strabo, though he appears to have had a clearer idea of the position of the British Islands than the Greek geographer. He is also the first ancient writer who mentions the name of the Orcades or Orkneys, which he correctly describes as a large group of islands to the north of Britain. Of the north of Europe his knowledge was still utterly imperfect; but he had a vague notion of the existence to the north of Germany of a large bay, which he calls Codanus Sinus, containing many islands, large and small, among which was one much larger than the rest, which he calls Codanovia,—evidently the same name that reappears in Pliny under the form Scandinavia, which has been attached by modern writers to the great northern peninsula of Europe.

The method followed by Mela in describing the three continents is peculiar and inconvenient. Instead of treating each continent separately, and describing the countries included in it, he begins at the Strait of the Columns (the Straits of Gibraltar), which was close to his own birthplace, and describes the countries adjoining the south coast of the Mediterranean from Mauretania to Egypt, and afterwards those around the east coast of the same sea with its tributary the Euxine, and then back along the north of the Mediterranean from Scythia to Gaul and Spain. He then begins again with the countries bordering the western and northern ocean from Spain and Gaul round to India, and from thence by Persia and Arabia to the Ethiopians, and thence again round Africa to the straits from which he began. In common with most ancient geographers, he considered Africa as surrounded by the sea, but had a very inadequate idea of its extent towards the south.

The first edition of Pomponius Mela was published in 1471, and it was very often reprinted in the 15th and 16th centuries. The edition of Voss in 1658, with a valuable commentary, became the foundation of all the subsequent editions, of which those by Gronovius (in 1685 and 1742) are among the best-known and most useful. The edition by Tzschucke, in 6 vols. 8vo (1806), contains an overwhelming mass of notes and commentaries, but by far the best text is that of the recent edition by G. Parthey (Berlin, 1867), who has in many instances restored the original readings, which had been displaced by the conjectures of Voss and others. (E. H. B.)

MELANCHTHON, PHILIP (1497–1560), was born at Bretten, a town of the lower Palatinate, on February 16, 1497. His father, George Schwartzerd, was a kinsman of the famous Reuchlin, and by profession an armourer or commissary of artillery under the Palatinate princes. His mother, Barbara Reuter, was a thrifty housewife and affectionate parent, whose pious character is evidenced by a well-known German rhyme, of which she is the reputed author, beginning *Almosen geben armet nicht*. His mother's father, John Reuter, who was for many years mayor of Bretten, charged himself with the education of Philip. Taught first by John Hungarus, then by George Simler at the academy of Pfortzheim, where he lived in the house of Reuchlin's sister, young Schwartzerd exhibited remarkable precocity, and speedily won the regard of Reuchlin, who dubbed him Melanchthon (the Greek form of Schwartzerd), according to the fashion of that age. He lived two years at Heidelberg, and the next three at Reuchlin's university of Tübingen, where he studied law, medicine, and theology, taking his doctor's degree in 1514. He began soon after to give public lectures on rhetoric, and to comment on Virgil and Terence, and ere long it became known among European scholars that a new brilliant star of learning had risen on the horizon, Erasmus prophesying that he would himself be speedily eclipsed. In 1518, on Reuchlin's recommendation, Melanchthon was appointed by the elector of Saxony professor of Greek in the university of Wittenberg. This appointment marked an epoch in German university education; Wittenberg became the school of the nation; the scholastic methods of instruction were summarily set aside, and in a *Discourse on Reforming the Studies of Youth* Melanchthon gave proof, not only that he had thoroughly caught the Renaissance spirit, but that he was fitted to become one of its foremost leaders. He began to lecture on Homer and the Epistle to Titus, and in connexion with the former he announced that, like Solomon, he sought Tyrian brass and gems for the adornment of God's temple. Luther himself received a fresh impulse towards the study of Greek, and his translation of the Scriptures, begun as early as 1517, now made rapid progress, Melanchthon helping to collate the Greek versions and revising Luther's translation. Melanchthon on his part felt the spell of Luther's large personality and spiritual depth, and he seems to have been prepared on his first arrival at Wittenberg to accept the new theology, which indeed as yet existed mainly in subjective form, and as a living spiritual force, in the person of Luther. To reduce it to an objective system, to exhibit it dialectically, the calmer mind of Melanchthon, with its architectural faculty and delicate moral tact, was requisite. Theologically it is impossible to separate Melanchthon from Luther; "the miner's son drew forth the metal, the armourer's son fashioned it." Luther, in whom courage and energy were too much akin to violence and zealous decision to narrow intolerance, and Melanchthon, whose calm deliberation was apt to degenerate into vacillation and whose conciliatory temperament was too much allied to timidity, were each the fit complement of the other.

Melanchthon was first drawn into the arena of the Reformation controversy through the Leipsic discussion, of which he was an eager spectator. He had been sharply reproved by Dr Eck for giving aid to Carlstadt ("Tace tu, Philippe, ac tua studia cura nec me perturba"), and he was shortly afterwards himself attacked by the blustering Ingolstadt doctor. Melanchthon replied in a brief treatise—a model of Christian moderation—setting forth Luther's first principle of the supreme authority of Scripture in opposition to the patristic writings on which Eck so boastfully relied. His marriage in 1520 to Catherine Krapp of Wittenberg increased his own happiness, and gave a domestic centre to the Reformation. In 1521, during Luther's confinement in the Wartburg, Melanchthon occupied the important position of leader of the Reformation cause at the university. He defended the action of the Augustinian monks when they substituted for the celebration of the mass the sacrament of the supper partaken of by the people under both kinds; but, on the advent of the Anabaptist enthusiasts of Zwickau, he had a still more difficult part to play. Melanchthon was irresolute. In their attacks upon infant baptism they seemed to him to have hit upon a "weak point"; and in regard to their claim to personal inspiration his position was summed up in his own words, "Luther alone can decide; on the one hand let us beware of quenching the Spirit of God, and on the other of being led astray by the spirit of Satan." In the same year he published his *Loci Communes Rerum Theologicarum.*

After the first diet of Spires (1526), where a precarious peace was patched up for the Reformed faith, Melanchthon was deputed as one of twenty-eight commissioners to visit the Reformed states and regulate the constitution of churches, he having just published a famous treatise called the *Libellus Visitatorius*, a directory for the use of the commissioners. At the Marburg conference (1529) between the German and Swiss Reformers, Luther was pitted against Œcolampadius and Melanchthon against Zwingli in the discussion regarding the real presence in the sacrament. How far the candid conciliatory spirit of Melanchthon was biassed by Luther's intolerance is evident from the exaggerated and inaccurate accounts of the conference written by the former to the elector of Saxony. At the diet of Augsburg (1530) Melanchthon was the leading representative of the Reformation. With anxiety and tears he drew up for that diet the seventeen articles of the evangelical faith, which are known as the "Augsburg Confession." He held conferences with Romish divines appointed to adjust differences, and afterwards wrote an *Apology for the Augsburg Confession.* After the Augsburg conference further attempts were made to settle the Reformation controversy by a compromise, and Melanchthon, from his conciliatory spirit and facility of access, appeared to the Romanists the fittest of the Reformers to deal with. His historical instinct led him ever to revert to the original unity of the church, and to regard subsequent Romish errors as excrescences rather than proofs of an essentially anti-Christian system. He was weary of the *rabies theologorum*, and fondly dreamed that the evangelical leaven, if simply tolerated, would at length purify the church's life and doctrine. In 1537, when the Protestant divines signed the Lutheran Articles of Smalkald, Melanchthon appended to his signature the reservation that he would admit of a pope provided he allowed the gospel and did not claim to rule by divine right.

The year after Luther's death, when the battle of Mühlberg (1547) had given a seemingly crushing blow to the Protestant cause, an attempt was made to weld together the iron and clay of the evangelical and the papal doctrines, which resulted in the compilation by Pflug, Sidonius, and Agricola of the Augsburg "Interim." This was proposed to the two parties in Germany as a provisional ground of agreement till the decision of the council of Trent. Melanchthon, on being referred to, declared equivocally that, though the Interim was inadmissible, yet so far as matters of indifference (*adiaphora*) were concerned it might be received. Hence arose that "adiaphoristic" controversy in connexion with which he has been misrepresented as holding among matters of indifference such cardinal doctrines as justification by faith, the number of the sacraments, as well as the dominion of the pope, feast-days, and so on. The fact is that, in these tentative negotiations, Melanchthon sought, not really to minimize differences, but to veil them under an intentional obscurity of expression. Thus he allowed the necessity of good works to salvation, but not in the Romish sense, proposed to allow the seven sacraments, but only as rites which had no inherent efficacy to salvation, and so on. He afterwards retracted his compliance with the adiaphora, and never really swerved from the views set forth in the *Loci Communes*; but he regarded the surrender of more perfect for less perfect forms of truth or of expression as a painful sacrifice rendered to the weakness of erring brethren. Luther, though he had uttered certain expressions of dissatisfaction with Melanchthon, and had more keenly defended in his last years what was distinctively his own, yet maintained hearty and unbroken friendship with him; but after Luther's death certain smaller men arose in name of Luther who formed a party emphasizing the extremest points of the doctrine of the latter. Hence the later years of Melanchthon were much occupied with acrid controversies within the evangelical church; an account of these, however, would be out of place here. His last years were spent in fruitless conferences with his Romanist adversaries, and amid various controversies among the Reformed, but the flame of his piety burnt brightly till the close. He died in his sixty-third year, on the 19th April 1560, and his body was laid beside that of Martin Luther.

Melanchthon's ever ready pen, clear thought, and elegant style made him the scribe of the Reformation, most public documents on that side being drawn up by him. He never attained entire independence of Luther, though he gradually modified some of his positions from those of the pure Lutherism with which he set out. His development is chiefly noteworthy in regard to these two leading points—the relation of the *evangelium* or doctrine of free grace (1) to free will and moral ability, and (2) to the law and *pœnitentia* or the good works connected with repentance. At first Luther's cardinal doctrine of grace appeared to Melanchthon inconsistent with any view of free will; and, following Luther, he renounced Aristotle and philosophy in general, since "philosophers attribute everything to human power, while the sacred writings represent all moral power as lost by the fall." In the first edition of the *Loci* (1521) he held, to the length of fatalism, the Augustinian doctrine of irresistible grace, working according to God's immutable decrees, and denied freedom of will in matters civil and religious alike. In the Augsburg Confession (1530), which was largely due to him, freedom is claimed for the will in non-religious matters, and in the *Loci* of 1533 he calls the denial of freedom Stoicism, and holds that in justification there is a certain causality, though not worthiness, in the recipient subordinate to the Divine causality. In 1535, combating Laurentius Valla, he did not deny the spiritual incapacity of the will *per se*, but held that this is strengthened by the word of God, to which it can cleave. The will co-operates with the word and the Holy Spirit. Finally, in 1543, he says that the cause of the difference of final destiny among men lies in the different method of treating grace which is possible to believers as to others. Man may pray for help and reject grace. This he calls free will, as the power of laying hold of grace. Melanchthon's doctrine of the three concurrent causes in conversion, viz., the Holy Spirit, the word, and the human will, suggested the semi-Pelagian position called Synergism, which was held by some of his immediate followers.

In regard to the relation of grace to repentance and good works, Luther was disposed to make faith itself the principle of sanctification. Melanchthon, however, for whom ethics possessed a special interest, laid more stress on the law. He began to do this in 1527 in the *Libellus Visitatorius*, which urged pastors to instruct their people in the necessity of repentance, and to bring the threatenings of the law to bear upon men in order to faith. This brought down upon him the opposition of the Antinomian John Agricola. In the *Loci* of 1535 Melanchthon sought to put the fact of the co-existence of justification and good works in the believer on a secure basis by declaring the latter necessary to eternal life, though the believer's destiny thereto is already fully guaranteed in his justification. In the *Loci* of 1543 he did not retain the doctrine of the necessity of good works in order to salvation, and to this he added, in the Leipsic Interim, "that this in no way countenances the error that eternal life is merited by the worthiness of our own works." Melanchthon was led gradually to lay more and more stress upon the law and moral ideas; but the basis of the relation of faith and good works was never clearly brought out by him, and he at length fell back on his original position that we have justification and inheritance of bliss in and by Christ alone, and that good works are necessary by reason of immutable Divine command.

Melanchthon's life has been written by Camerarius. See also Matthes, *Ph. Melanchthon, sein Leben und Wirken*, 1841; Galle, *Charakteristik Melanchthons als Theologen*, Halle, 1845; Rothe's *Gedächtnissrede auf Melanchthon*, 1860; Nitzsch, *Melanchthon*, 1860; Schmidt, *Melanchthons Leben*, 1864. There is a biography in English by F. A. Cox, 2d ed., London, 1817. The works of Melanchthon, including his correspondence, are contained in the voluminous *Corpus Reformatorum*, edited by Bretschneider and Bindseil. (J. Wl.)

MELANESIA. This term comprises that long belt of island groups which, beginning in the Indian archipelago at the east limits of the region there occupied by the Malay race, and, as it were, a prolongation of that great island region, runs south-east for a distance of some 3500 English miles, *i.e.*, from New Guinea at the equator, in 130° E. long., to New Caledonia just within the Tropic, 167° E. long., and eastwards to Fiji, in 180°. This chain of groups has a certain geographical as well as ethnical unity. Its curve follows roughly the outline of the Australian coast, and large islands occur, with a number of small ones, along the whole length, with mountains of considerable height, coinciding pretty closely with a line of volcanic action. Melanesia is usually held to begin with New Guinea, this great island being then viewed as the headquarters of that dark Papuan race which, widely and variously modified in all the other groups, occupies the whole region, as the name Melanesia implies; but the race really extends farther west, for the large islands Flores and Timor, with several smaller ones, are also essentially Papuan.

New Guinea, 1490 miles long, and containing about 303,000 square miles, the largest island in the world after Australia, is clothed with almost impenetrable forests, through which mountain ranges rise to a height of 13,000 feet. Parallel to its longer axis, 150 miles to the north, are the Admiralty Islands, all small, with one exception, in which the hills rise to 1600 feet, and which is probably of volcanic origin, as the natives use spearheads and implements of obsidian. A Polynesian element seems to be present, and customs peculiar to both races have been observed. Mr H. N. Moseley, of the "Challenger," found them shrewd but honest traders, with much artistic skill in their carvings and designs. They have numerals up to 10, with an idiom for 8 and 9, viz., 10–2 and 10–1, which is found also at Yap in the Carolines, and in the Marshall Islands.

Next follow, east, the two large islands of New Britain, about 340 by 23 English miles, with active volcanoes up to 4000 feet, and New Ireland, about 240 by 22 miles. Next comes the Solomon group, 600 English miles in length, with seven large islands from 135 to 90 miles long, all running north-west and south-east, with volcanic peaks up to 8000 feet. The forms more characteristic of the New Guinea fauna do not extend beyond this group. Its forest vegetation is especially luxuriant. Then comes Santa Cruz, a small group partly volcanic, but with numerous coral reef islands. Then the Banks and New Hebrides group, over 500 English miles in length, all volcanic except the Torres reef islands in the north. Several spots in this group are occupied by people of purely Polynesian race, immigrants apparently from the eastward. Two hundred miles south-west from the New Hebrides lies the island of New Caledonia, about 240 by 25 English miles. It is in parts very mountainous, rising to 5380 feet, the rocks being sedimentary and plutonic, but there are no volcanoes. It lies half way between Australia and Fiji, 700 miles from each. Being outside the equatorial belt, it is much drier and more barren than the other groups, and its fauna and flora have many Australian and Polynesian affinities. The small Loyalty chain lies 70 miles east of New Caledonia, and parallel to it. Fiji is detached from the other Melanesian groups, and differs from them in various particulars. It consists of two large and about 300 small islands, the total area being about 7400 square miles.

Of the two great Pacific races—the brown Polynesian, and the dark Melanesian—the former, considering the vast region it occupies, is singularly homogeneous both in appearance and language, whereas in Melanesia even neighbouring tribes differ widely from each other in both respects. Still, all the Melanesians have certain common characteristics which distinguish them sharply from the other race. They stand at a lower level of civilization, as is well seen at certain spots in Melanesia where isolated Polynesian settlements exist, due probably to involuntary migration, and where the two races, though they have some peculiar customs in common, live in bitter mutual hostility. The Melanesians are mostly "negroid" in appearance, nearly black, with crisp curly hair elaborately dressed; the women hold a much lower position than among the Polynesians; their institutions, social, political, and religious, are simpler, their manners ruder and often indecent; they have few or no traditions; cannibalism, in different degrees, is almost universal; but their artistic skill and taste, as with some of the lower African negroes, are remarkable, and they are amenable to discipline and fair treatment. Their languages, amid considerable differences, which, as between the Melanesian proper and the Papuan, are very wide, have features which mark them off clearly from the Polynesian, notwithstanding certain fundamental relations with the latter.

The various Melanesian groups will be found described in detail under separate headings.

MELBOURNE, the capital of the colony of Victoria, and the most populous city in Australia, is situated at the head of the large bay of Port Phillip, on its northern bend known as Hobson's Bay, about 500 miles S.W. of Sydney by land and 770 by sea, the position of the observatory being 37° 49′ 53″ S. lat. and 144° 58′ 42″ E. long. Along the shores of the bay the suburbs

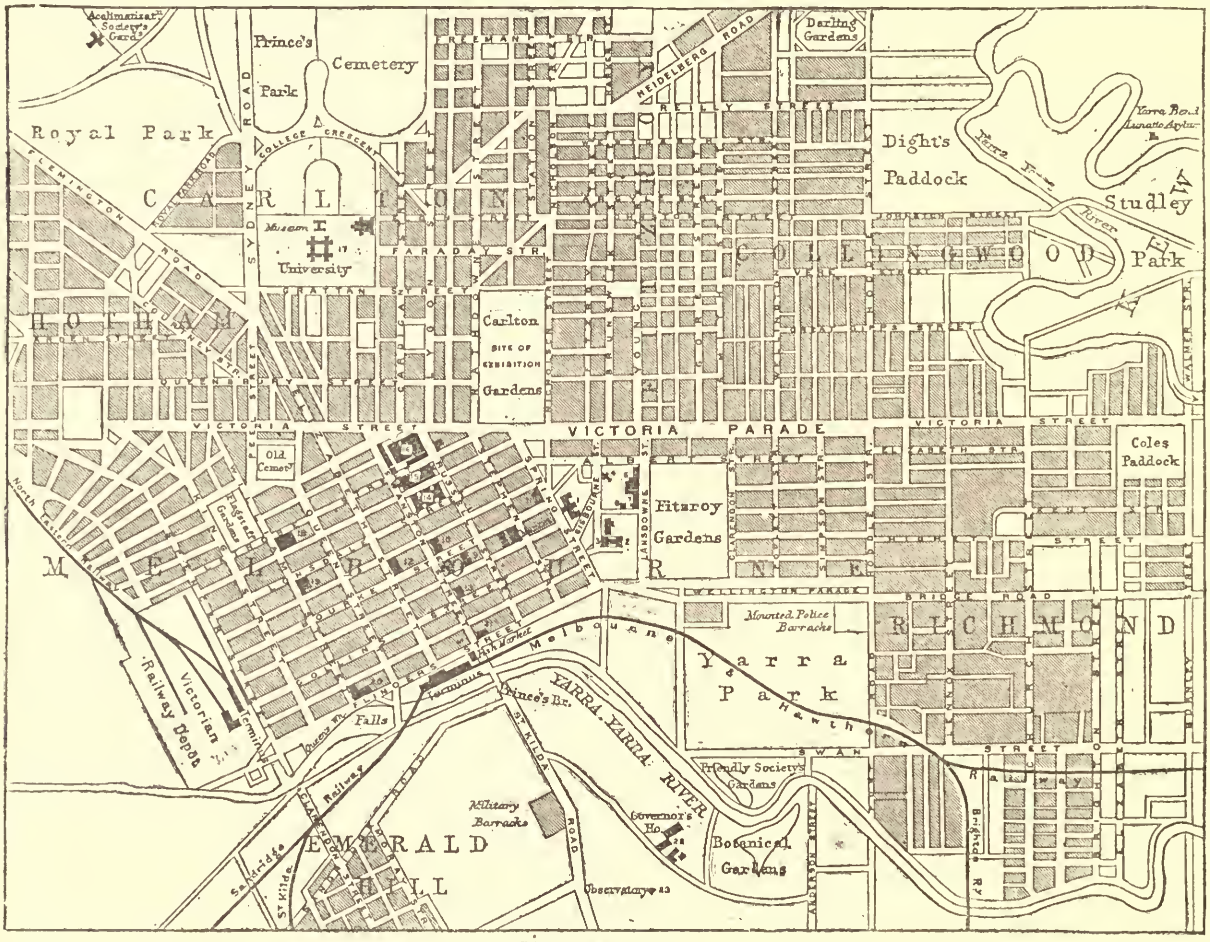
Port Phillip and Environs of Melbourne.

extend for a distance of over 10 miles, but the part distinctively known as the "city" occupies a site about 3 miles inland on the north bank of the Yarra river.

The appearance of Melbourne from the sea is by no means picturesque. The shipping suburbs of Sandridge and Williamstown occupy the alluvial land at the mouth of the Yarra, and, as the district is low and flat, and covered with factories, the prospect is not inviting. But the city itself has a very different aspect: its situation is relieved by numerous gentle hills, which show off to great advantage its fine public buildings; its streets are wide and well kept; and the universal appearance of prosperity, activity, and comfort under its usually clear blue sky impresses the visitor favourably.

That part specially known as the "city" had a population in 1881 of 65,800. It occupies the two hills of East Melbourne and West Melbourne; the valley that separates them, once occupied by a densely wooded little stream, is now partly filled in, and forms the busy thoroughfare of Elizabeth Street; parallel to this runs Swanston Street, and at right angles to these, and parallel to the river, are Bourke Street, Collins Street, and Flinders Street,—the first being the busiest in Melbourne, the second containing the most fashionable shops, and the third, which faces the river, being given over to maritime pursuits. These streets are the eighth of a mile apart; between them are narrower streets occupied by warehouses and business premises.

Round the "city" lies a circle of populous suburbs. North-east is Fitzroy with 23,000 inhabitants; farther east, Collingwood, 24,000; east of Melbourne, Richmond, 23,400; south-east, Prahran, 21,000; south, Emerald Hill, 25,300; south-west, Sandridge, 8700; north-west, Hotham, 17,800. These all lie within three miles of the general



Plan of Melbourne.

1. Houses of Parliament.
2. Treasury.
3. Government Offices.
4. St Patrick's Cathedral.
5. St Patrick's College.
6. Scotch Church.
7. Scotch College.
8. Opera House.
9. Academy of Music.
10. Theatre Royal.
11. Princes Theatre.
12. Post-Office.
13. Town-Hall.
14. Hospital.
15. Public Library, &c.
16. Jail.
17. University.
18. Mint.
19. Law Courts.
20. Custom House.
21. Anglican Cathedral.
22. Governor's House.
23. Observatory.

post-office in Elizabeth Street; but outside of them, and within a radius of 5 miles, there is a circle of less populous suburbs: to the north, Brunswick, 6200; east, Kew, 4200, and Hawthorn, 6000; south-east, St Kilda, 11,600, and Brighton, 4700; south-west, Williamstown, 9000, and Footscray, 6000; north-west, Essenden and Flemington, 5000. Numerous smaller suburbs fill up the spaces between these,—the principal being Northcote, Preston, Camberwell, Toorak, Caulfield, Elsternwick, and Coburg, with a united population of 19,000.

Fifteen of these suburbs rank as independent municipalities, and many of them have streets which for importance rival the main streets of the city.

The following table shows the growth of the population since 1851:—

	1881.			Total.		
	Male.	Female.	Total.	1871.	1861.	1851.
Melbourne	34,526	31,333	65,859	54,993		
Suburbs	113,785	103,263	217,048	151,787		
Total	148,311	134,596	282,907	206,780	191,254	25,000

The land on which the city now stands was sold in allotments of half an acre, the prices realized being in June 1837 about £34 each, in November 1837 about £42, and in September 1838 about £120 each. These allotments are now (1882) sold at prices ranging from £20,000 to £40,000. But, though land has thus increased in value, Melbourne is by no means a crowded city; the streets are all 99 feet wide, and the parks, squares, and gardens are so numerous that with only one-thirteenth of the population of London it occupies very nearly half as great an area.

The public buildings are generally situated on positions from which they are seen to advantage. The Parliament Houses form a great pile of brickwork with four fronts in freestone, of which the main front is not yet completed; the interior decorations are highly elaborate. The Treasury is a well-proportioned building in freestone; behind it stands a vast building known as the Government offices. On the hill of West Melbourne there is a large structure, newly erected, for the law courts; it has four very handsome fronts, each about 300 feet in length, and the whole is surmounted by a lofty cupola, in the manner of the Capitol at Washington. The public library in Swanston Street forms one of four fronts of a building which was projected on a grand scale, but has never been completed. Much of the interior has been erected, but of the fronts only the main one is yet in existence, its cost having been £111,000. The lower story is devoted to sculpture; on one side there are casts of all the most famous statues; on the other there is a small collection of original works by modern sculptors, together with a gallery containing 8000 engravings and photographs; to the rear is the picture gallery, a very handsome hall, with oil paintings, chosen from the works of living artists. Another of the interior portions of the building is occupied by the technological museum, in which are arranged about 30,000 specimens illustrative of the industrial arts. The upper story of the front is devoted to the library, which occupies a chamber 240 feet long; 22 recesses contain each its own special branch of literature, the total number of volumes being 112,000. The book shelves rise to a height of 20 feet, but they are divided by a narrow gallery which runs all round the room, and gives access to the upper tiers. The library is open to the public; and every visitor ranges at will, being bound by the two conditions only that he is to replace each book where he found it, and that he is to preserve strict silence. During 1881 there were 261,886 visits made to the room.

The Melbourne University is a picturesque, but by no means imposing mass of buildings, buried among the trees of extensive and well-kept grounds about a mile from the heart of the city. In front of it stands the "Wilson Hall," erected at a cost of £40,000. Behind is the National Museum, containing collections of specimens of natural history. The museum, like all public places in Melbourne, is freely open to the people. About 98,000 visitors entered it in 1881. The university has a staff of 10 professors and 12 lecturers, with about 400 students. There are four courses open to students: arts, law, medicine, and civil engineering. Affiliated to the Melbourne University are the two denominational colleges, Trinity and Ormond, in which about 80 students reside, and where provision is made for instruction in theology.

The Exhibition building consists of a nave 500 feet long and 160 feet broad, surmounted by a dome, with two annexes each 460 feet long. These are built in brick with cement facings. The mint is a very handsome quadrangle, erected in 1872. In the year 1881 there were three millions of sovereigns coined in it, making a total of sixteen millions since its erection. The governor's residence is a large building on a hill overlooking the Yarra. The general post-office forms only half of a magnificent pile of buildings which will, when completed, include the central telegraph office.

The town-hall, at the corner of Swanston Street and Collins Street, contains, besides the usual apartments for municipal offices, a hall seated for nearly 3000 persons, and fitted with a colossal organ, on which the city organist performs two afternoons a week, the public being admitted at a nominal charge. Hotham, Richmond, Emerald Hill, Prahran, and Fitzroy have their own town-halls, all costly and somewhat pretentious buildings.

The markets, erected at a cost of £80,000, stand in Bourke Street. They are handsome in external appearance, and ingeniously contrived for convenience within. The observatory is a humble-looking building on the St Kilda Road; it contains an equatorial telescope, which had for some years the distinction of being the largest in the world.

There are two railway stations, one being the terminus of all the country lines, and the other devoted to suburban traffic. The suburbs of Williamstown, Sandridge, Footscray, St Kilda, Emerald Hill, Brighton, Elsternwick, Hawthorn, Richmond, and Essendon are connected by rail with the city.

The Melbourne Hospital is in the form of an extensive series of brick buildings, situated close to the public library. There are beds for about 300 patients. The Alfred Hospital, on the St Kilda Road, was built in commemoration of the visit of Prince Alfred; it has beds for nearly 100 patients. The lying-in hospital can accommodate 62 persons. The blind asylum has over 100 inmates; and there are a deaf and dumb asylum, an immigrants' home, and other charitable institutions.

Melbourne contains many churches, but few of them will compare with the public buildings in appearance. The Roman Catholic cathedral of St Patrick, when completed, will, however, be a conspicuous ornament to the city. The Anglican cathedral, now (1882) in the course of erection, is to cost about £100,000. The most striking ecclesiastical building is the Scotch church in Collins Street, which divides with Ormond College and the Wilson Hall the honour of being the finest specimen of architecture in the city.

There are in Melbourne, among its numerous state schools, about thirty whose size and proportions entitle them to rank with the architectural ornaments of the city. They have each accommodation for from 600 to 2000 scholars. Abundant provision has been made for secondary instruction by the denominations and by private enterprise. The Scotch College and the Presbyterian Ladies' College, the Wesley College and the Wesleyan Ladies' College, the Church of England Grammar School, St Patrick's College and St Francis Xavier's College, are all connected with the churches; and there are besides between twenty and thirty good private grammar schools.

Melbourne contains the offices of numerous banks, savings banks, and building societies.

The parks and public gardens of Melbourne are extensive and handsome. Within the city proper there are four gardens, which have been decorated with a lavish expenditure. The Fitzroy Gardens are one dense network of avenues of oak, elm, and plane, with a "fern-tree gully" in the middle. Casts of famous statues abound; and ponds, fountains, rustic houses, and small buildings after the design of Greek temples give a variety to the scene. The Treasury, Flagstaff, and Carlton Gardens are of the same class, but less costly in their decorations. Around the central city there lie five great parks. The Royal Park, of about 600 acres, is lightly timbered with the original gum trees; some portions of open land are used for recreation. About 30 acres in the centre are beautifully laid out to accommodate a very superior zoological collection. The Yarra Park, of about 300 acres, contains the leading cricket grounds; of these the "Melbourne" is the chief, distinguished by its very large stand and the excellence of its pitch. The Botanic Gardens occupy about 200 acres of land, sloping down to the banks of the river, and laid out with great taste and skill. Albert Park, about 500 acres in extent, is not so elaborately laid out, but contains a small lake, which is much used for boating purposes, as the bay is stormy and exposed. Studley Park, a favourite place for picnics, is a romantic corner on a bend of the upper Yarra, of about 200 acres extent, left entirely in a state of nature.

Besides these parks each suburb has its own "gardens" of moderate extent. At Flemington a large reserve is devoted to racing purposes, where in November the race for the Melbourne Cup is held, the great racing carnival of Australia, attended by about 100,000 persons.

The shipping of Melbourne is very considerable. In 1880 about 1500 vessels entered and cleared again, their tonnage being 960,000. Nearly all the intercolonial and a small proportion of the foreign vessels ascend the Yarra and unload in the heart of the city. The river was originally navigable for vessels of only 9 feet draught; but of late years the channel has been deepened so much that vessels drawing 16 feet can ascend with safety. Great works are now in operation by which the course is to be straightened and further deepened; and the quays which line the river banks will be made accessible to the large vessels which now have to lie in the bay off the Sandridge and Williamstown piers.

Shipbuilding is a comparatively unimportant industry, but a great deal of repairing is done; the graving dock at Williamstown is able to hold the largest vessels which enter the port.

The total values of the imports of Melbourne for 1879 and 1880 were respectively £15,035,000 and £14,557,000, and of the exports £12,454,000 and £15,954,000.

In 1881 Melbourne contained 2469 factories, employing 38,141 hands, and converting £8,012,745 worth of raw material into £13,384,836 worth of finished articles. The leading products are leather, flour, clothing, furniture, boots, carriages, preserved meats, ales, soap, candles, cigars, ironwork, jewellery, jams, confectionery, biscuits, and woollens.

The city is abundantly supplied with newspapers, including three morning and three evening dailies. Two reviews are published.

The climate of Melbourne is exceptionally fine, the only drawback being the occasional hot winds which blow from the north for two or three days at a time, and raise the temperature to an uncomfortable extent. But the proportion of days when the sky is clear and the air dry and mild is large. The mean annual temperature is 57°, which would make the climate of Melbourne analogous to that of Madrid, Marseilles, or Verona, but without the extremes experienced in those places. Snow falls every year in Italy, while it is unknown in Melbourne; and the highest temperature reached there in summer is below that of the cities mentioned.

As a field for emigration from European countries, Melbourne offers many advantages to the industrious mechanic or labourer.

The cost of living is about the same as in London. Rents are higher, and furniture and utensils dearer; but butcher meat, bread, and clothes are cheaper.

There is no city where more has been done for the working-classes or where they have made so good a use of their advantages. Many of their efforts at government (for they have all the power in their hands) have been ill-advised, but individually they have exhibited a prudence of which the community reaps the fruits. It is one of the peculiar features of Melbourne that about three out of every four mechanics who have reached middle life own the neat cottages they occupy.

History.—The city of Melbourne is without exception the most striking instance of the aptitude of the Anglo-Saxon race for colonization. It was not till the opening years of the present century that the first European sailed through the narrow entrance to Port Phillip, and it was only in 1835 that the white man made his habitation there. In that year John Fawkner sailed up the Yarra in his little vessel the "Enterprise," laden with materials for a settlement; he was stopped by a slight waterfall in a valley where dense groves of wattle trees all in bloom loaded the air with perfume, and where flocks of white cockatoos whirled aloft when the first stroke of the axe resounded in the forest. This spot is now the centre of a great city 10 miles in length, 6 in breadth, covering an area of 45,000 acres, and peopled by 283,000 persons. So rapid and solid a growth, at a distance from the mother country of the whole extent of the earth, is an example of colonizing enterprise altogether without parallel.

The settlement was at first called by the native name "Dootigala," but a desire for distinguished patronage caused the portion on the sea-shore, which was then esteemed the more important, to be called "Williamstown," after King William IV., while the little collection of huts some 3 or 4 miles inland was named "Melbourne," in honour of the prime minister Lord Melbourne.

For two years a constant stream of squatters with their sheep flowed in from Tasmania; then numerous "overlanders" drove their flocks from the Sydney side across the Murray and settled near Port Phillip. Captain Lonsdale was sent by the Sydney Government to act as police magistrate, but in 1838 Mr Latrobe was placed in charge with the title of superintendent. As the squatters prospered Melbourne increased in size, so that in 1841 it contained 11,000 inhabitants. A period of depression occurred in 1843, followed by several years of the greatest prosperity, till, in 1851, gold was discovered in New South Wales. The district of Port Phillip became infected by the excitement; many parties scoured that part of the country in search of the precious metal, and six weeks after the first discovery of it there the great riches of Ballarat were made known. Within a year from that time a hundred thousand men had landed in the colony in order to proceed to the diggings; for several years after the same number landed every twelve months; and Melbourne increased in population from 30,000 to 100,000 in the course of two or three years.

During the year of the gold discoveries, the Port Phillip district was separated from New South Wales, and formed into a separate colony with the name Victoria. In 1855 the British Government granted to it a complete autonomy; Melbourne became the capital of the new colony. (A. SU.)

MELBOURNE, William Lamb, second Viscount (1779–1848), second son of the first Viscount Melbourne, was born 15th March 1779. After completing his course at Trinity College, Cambridge, he studied law at the university of Glasgow, entered Lincoln's Inn in 1797, and was called to the bar in 1804. In 1805 he married Lady Caroline Ponsonby, daughter of the earl of Bessborough, who after her separation from him acquired some fame as a novelist, and was also a friend of Lord Byron. On entering parliament the same year Lamb joined the opposition under Fox, of whom he was an ardent admirer; but his Liberal tendencies were never of a very decided character, and he not unfrequently gave his support to Lord Liverpool during that statesman's long tenure of office. During the short ministry of Canning in 1827 he was chief secretary for Ireland, but he afterwards for a time adhered to the small remnant of the party who supported the duke of Wellington. The influence of Melbourne as a politician dates from his elevation to the peerage in 1828. Disagreeing with the duke of Wellington on the question of parliamentary reform, he in 1830 entered the ministry of Grey as home secretary. For the discharge of the difficult and multifarious duties of this office at such a critical time he was decidedly deficient both in insight and in energy, but his political success was totally independent of his official capacity; and, when the ministry of Grey was wrecked on the Irish question, Melbourne was chosen to succeed him. Almost immediately he had to give place to a Conservative ministry under Peel, but, the verdict of the country being in his favour, he resumed office in 1835. The period of his ministry was wholly uneventful, and for a considerable time before he resigned in 1841 he had lost the confidence of the country. From the time of his retirement from office he took little interest in politics. He died at Melbourne House, Derbyshire, 24th November 1848.

Lord Melbourne was without even the elementary qualification of diligent attention to details, which in the absence of higher endowments sometimes confers on a statesman the greater part of his success. Nor can it be said that in public he ever displayed any of those specious and brilliant talents which are often found an acceptable substitute for more solid acquirements. Though he possessed a fine and flexible voice, his manner as a speaker was ineffective, and his speeches were generally ill-arranged and destitute of oratorical point, notwithstanding his occasional indulgence in inelegant flights of rhetoric. Indeed his political advancement was wholly due to his personal popularity. He had a thorough knowledge of the private and indirect motives which influence politicians, and his genial attractive manner, easy temper, and vivacious, if occasionally coarse, wit helped to confer on him a social distinction which for a time led many to take for granted his eminence as a statesman. The most notable and estimable feature of his political conduct is his relation to Queen Victoria, whom he initiated into the duties of sovereign with the most delicate tact and the most friendly and conscientious care.

MELCHIADES, or MILTIADES (other forms of the name being Meltiades, Melciades, Milciades, and Miltides), was pope from July 2, 310, to January 10 or 11, 314. He appears to have been an African by birth, but of his personal history nothing is known. The toleration edicts of Galerius and of Constantine and Licinius were published during his pontificate, which was also marked by the holding of the Lateran synod in Rome (313), at which Cæcilianus was acquitted of the charges brought against him, and Donatus condemned. Melchiades was preceded and followed by Eusebius and Sylvester I. respectively.

MELCHITES. The name of Melchites (Syriac, *Malkâyê*; Arabic, *Malakîya*, or in the vulgar pronunciation *Milkîya*) means etymologically the royal party, and so is currently applied in the East to Syrian and Egyptian Christians of the Orthodox Greek Church, adherents of the creed supported by the authority of the king, that is, of the Byzantine emperor. The Melchites therefore are those who accept the decrees of Ephesus and Chalcedon as distinguished from the Nestorians and Jacobites, and the name reflects in an interesting manner the way in which the doctrinal controversies that agitated the Eastern empire associated themselves with national feelings of antagonism to the imperial rule.

MELCHIZEDEK (מַלְכִּי־צֶדֶק, "king of righteousness"), king of Salem and priest of "supreme El" (*El 'elyôn*), brought forth bread and wine to Abram, on his return from the expedition against Chedorlaomer, and blessed him in the name of the supreme God, possessor (or maker) of heaven and earth. And Abram gave him tithes of all his booty (Gen. xiv. 18–20). The Bible history tells us nothing more about Melchizedek (comp. Hebrews vii. 3); but the majestic figure of the king-priest, prior to the priesthood of the law, to whom even the father of all Israel paid tithes, suggested a figurative or typical application, first in Psalm cx. to the vicegerent of Jehovah, seated on the throne of Zion, the king of Israel who is also priest after the order of Melchizedek, and then, after the gospel had confirmed the Messianic interpretation of the Psalm (Matt. xxii. 42 *sq.*), to the kingly priesthood of Jesus, as that idea is worked out at length in the Epistle to the Hebrews.

The theological interest which attaches to the idea of the pre-Aaronic king-priest in these typical applications is practically independent of the historical questions suggested by the narrative of Gen. xiv. It is generally recognized that this chapter holds quite an isolated place in the Pentateuchal history; it is the only passage which presents Abraham in the character of a warrior, and connects him with historical names and political movements, and there are no clear marks by which it can be assigned to any one of the documents of which Genesis is made up. Thus, while one school of interpreters finds in the chapter the earliest fragment of the political history of western Asia, some even holding with Ewald that the narrative is probably based on old Canaanite records, other critics, as Nöldeke, regard the whole as unhistorical and comparatively late in origin. On the latter view, which finds its main support in the intrinsic difficulties of the narrative, it is scarcely possible to avoid the conclusion that the chapter is one of the latest additions to the Pentateuch (Wellhausen). The historical arguments *pro* and *con* may be seen at length in recent commentaries, but especially in Tuch's essay (*Z. D. M. G.*, i. 161 *sq.*, reprinted in the second edition of his *Genesis*), which was long viewed as decisive in favour of the narrative, and in Nöldeke's *Untersuchungen*, 1869, p. 156 *sq.*, with which compare Wellhausen in *Jahrb. f. D. Th.*, 1876, p. 414 *sq* The Assyrian monuments offer no decisive evidence, but are held to confirm the historical possibility of the proper names (Schrader, *KI. und AT.*, p. 46 *sq.*; Delitzsch, *Paradies*, p. 224). Here we can only speak of the episode of Melchizedek, which, though connected with the main narrative by the epithets given to Jehovah in verse 22, seems to break the natural connexion of verses 17 and 21, and may perhaps have come originally from a separate source. As the narrative now stands Salem must be sought in the vicinity of "the king's dale," which from 1 Sam. xviii. 18 probably but not necessarily lay near Jerusalem. That Salem is Jerusalem, as in Psalm lxxvi. 2, is the ancient and common view, and is necessarily followed by those who view Melchizedek as a late creation. Those who hold the opposite view now lean to the identification with the Σαλείμ of John iii. 23, 8 miles south of Bethshean, which Jerome (*Ep.* lxxiii. *ad Evangelium*) confirms by a worthless tradition. In a genuine record of extreme antiquity the union of king and priest in one person, the worship of El as the supreme deity by a Canaanite,[1] and the widespread practice of the consecration of a tithe of booty can present no difficulty; but, if the historical character of the narrative is denied, the origin of the conception must be placed as late as the rise of the temporal authority of the high priests after the exile. An ancient legend identifies Melchizedek with Shem (Palestinian Targum, Jerome on Isa. xli., Ephraem Syrus *in loco*).

MELCOMBE REGIS. See WEYMOUTH.

MELENDEZ VALDES, JUAN (1754–1817), minor poet of Spain, was born at Ribera del Fresno, Badajoz, on March 11, 1754. He was destined by his parents, who were in good circumstances, for an official career; and accordingly, after having completed his preliminary education at Madrid and Segovia, he went to Salamanca, and duly graduated in laws. At an early age he had begun to write verses in imitation of the then much admired though now justly forgotten Eugenio Lobo; but at Salamanca he came under the influence of the purer literary taste of the elder Moratin, while to the friendship of the cultivated and well-read Cadahalso he owed his introduction to the writings of recent English poets. At the age of twenty-six Melendez obtained the prize of the Spanish Academy for the best eclogue, one of the unsuccessful competitors being the well-known Iriarte; the poem (*Batilo: egloga en alabanza de la vida del campo*, 1780) continues to be highly spoken of by native critics, who echo in various forms the remark of one of the adjudicators, that it was "redolent of the wild thyme." In 1781 Melendez went to Madrid, where Jovellanos became his friend, and obtained for him in 1783 the appointment of professor of the humanities at Salamanca. In 1784, in competition for a prize offered by the city of Madrid, he produced his longest poem, a "dramatic eclogue" entitled *Las Bodas de Camacho* ("Camacho's Wedding"), which secured the vote of the judges, but did not add to his reputation, and soon fell into neglect. His genius does not seem to have been at all dramatic; at any rate he was unfortunate in his choice of a subject so little capable of dramatic treatment as the well-known episode in *Don Quixote*. In the following year, at the age of thirty-one, he published a little volume of lyrics and pastorals which gave him the first place he still holds among Spanish poets of the 18th century. Several editions were exhausted in a single year. With poetical fame came professional advancement, and in 1789 the "Restorer of Parnassus" (Restaurador del Parnaso), as Melendez is sometimes pedantically called by his countrymen, received a judicial appointment at Saragossa, which in 1791 he exchanged for a chancery

[1] On the other hand it is not correct to appeal to the *Pœnulus* of Plautus for the epithet 'elyôn.

auditorship at Valladolid. In 1797 the publication of a new and greatly enlarged edition of his works, dedicated to the prince of the peace, was followed by his removal to Madrid to a high post in connexion with the treasury. The new poems included somewhat heavy philosophical epistles written after the manner of Young, and an unmistakably dull epic canto entitled *Caida de Luzbel* ("The Fall of Lucifer"), suggested by Milton, as well as an *Ode to Winter*, which showed how well the author had made himself acquainted with Thomson. On the fall of his friend Jovellanos in 1798 Melendez was ordered away from Madrid, first to Medina del Campo and afterwards to Zamora, and it was not till 1802 that he was permitted to settle in Salamanca. For the next six years his literary activity was but slight, being limited to the production of a short poem on "Creation" and the preparation of an unfinished translation of the *Æneid*. After the revolution of Aranjuez (1808) Melendez accepted from King Joseph the post of councillor of state and afterwards that of minister of public instruction, a failure of patriotism which involved him in many indignities and even dangers; in 1813 he was of course compelled to quit his country, and, after sojourning successively at Alais, Nîmes, and Toulouse, he died in considerable poverty and neglect at Montpellier, on May 24, 1817. During his exile he employed himself in the preparation of a complete edition of his works, with numerous additions and corrections; this was afterwards published, along with a life of the author by Quintana, at the expense of the Government (4 vols. 8vo, Madrid, 1820; reprinted at Paris, 1832, and at Barcelona, 1838).

MELFI, a city of Italy, in the province of Potenza, 30 miles N. of Potenza, on the road and railway between that city and Foggia, is built on a small hill on the lower slopes of Monte Volture. The castle was originally erected by Robert Guiscard, but as it now stands it is mainly the work of the Doria family, who have possessed it since the time of Charles V.; and the noble cathedral which was founded in 1155 by Robert's son and successor, Roger, has had to be subjected to a modern restoration in consequence of the earthquake of 1851. In 1871 the city had 10,945 inhabitants; the commune had 9863 in 1861 and 12,657 in 1881.

Melfi is of doubtful origin, but appears to have existed at least as early as the 4th century. By the Normans it was made the capital of Apulia in 1041, and provided with fortifications. The council held by Nicholas I. in 1059, that of Urban II. in 1090, the rebellion against Roger in 1133 and the subsequent punishment, the plunder of the town by Barbarossa in 1167, the attack by Richard, count of Acerra in 1190, and the parliament of 1223, in which Frederick II. established the constitution of the kingdom of Naples, form the principal points of interest in the annals of Melfi during the more eventful period of its history. In 1348 Joanna I. of Naples bestowed the city on Niccolo Acciajuoli; but it was shortly afterwards captured, after a six months' siege, by the king of Hungary, who transferred it to Conrad the Wolf. In 1392 Goffredo Marzano was made count of Melfi; but Joanna II. granted the lordship to the Caracciolo family, and they retained it for one hundred and seven years till the time of Charles V. An obstinate resistance was offered by the city to Lautrec de Foix in 1528; and his entrance within its walls was followed by the massacre, it is said, of 18,000 of its citizens. As a bishopric Melfi is directly dependent on the Holy See.

MELITA (Μελίτη), the classical name for MALTA (*q.v.*), was also the name borne by the modern *Meleda*, one of the Dalmatian islands, situated immediately to the south of Sabbioncello and to the north of Ragusa. It is about 24 miles in length, averaging about $1\frac{1}{2}$ in breadth, and has a good harbour. At one time it was supposed by some authors to have been the scene of the shipwreck of St Paul, but this point has now for some time been conclusively settled in favour of Malta. See Smith, *Voyage and Shipwreck of St Paul*, 1848.

MELITO, bishop of Sardes, a Christian writer of the 2d century, is mentioned by Eusebius (*H. E.*, iv. 21) along with Hegesippus, Dionysius of Corinth, Apollinaris of Hierapolis, Irenæus, and others, his contemporaries, as a champion of orthodoxy and upholder of apostolic tradition. Of his personal history nothing is known, and of his numerous works (which are enumerated by Eusebius) only a few fragments are now extant. They included an *Apologia* addressed to Aurelius some time between 169 and 180 A.D., two books relating to the paschal controversy, and a work entitled Ἐκλογαί (selections from the Old Testament), which contained the well-known catalogue of "the books of the Old Covenant." The fragments have been edited with valuable notes by Routh (*Reliquiæ Sacræ*, vol. i., 1814). It seems more than doubtful whether the *Apologia* of Melito "the Philosopher," discovered in a Syriac translation by Tattam, and subsequently edited by Cureton and Renan, ought to be attributed to this writer and not rather to another of the same name.

MELLONI, MACEDONIO (1798–1854), a distinguished physicist, was born at Parma on April 11, 1798. From 1824 to 1831 he was professor at Parma, but in the latter year he was compelled to escape to France, having taken part in the revolution. In 1839 he went to Naples as director of the conservatory of arts and handicrafts. He was likewise director of the Vesuvius observatory, a post which he held until 1848. Melloni received the Rumford medal of the Royal Society in 1834. In 1835 he was elected correspondent of the Paris Academy, and in 1839 a foreign member of the Royal Society. He died from an attack of cholera on August 11, 1854.

From the Royal Society catalogue of papers we find that Melloni produced eighty-six memoirs by himself, as well as three in connexion with other physicists. These embrace a wide range of subjects, but the reputation of Melloni as a physicist rests more especially upon his discoveries in radiant heat. Men of science were, in the early part of this century, very much in the dark with regard to the nature of the invisible heat rays. Leslie and others had indeed advanced the subject by means of the differential thermometer, but such an instrument was at the best a very poor substitute for the human eye. It was necessary to invent an instrument more nearly capable of doing for the dark rays what the eye does for those of light before any great increase in our knowledge of this subject could be expected to take place. This step was taken (shortly after Seebeck's discovery of thermo-electricity) in the construction of the thermo-multiplier or combination of thermopile and galvanometer which formed the subject of a joint memoir by Nobili and Melloni in 1831. In this memoir, after describing their instrument, these physicists confirmed the experiments of Leslie and others. They tried screens of glass, sulphate of lime, mica, and ice, also of water, oil, alcohol, and nitric acid enclosed in glass, and found an instantaneous effect produced in the index of their instrument except for ice and water, the source of heat being an iron ball below redness. After finding that most substances when used as screens stopped a much larger proportion of dark heat than they did of light, Melloni set himself to discover some body that might be transparent for dark heat. In this search he was rewarded with complete success. Rock-salt was found to possess this property; and he immediately proceeded to construct prisms and lenses of rock-salt with which he proved the refraction of dark heat, that is to say, of the heat proceeding from bodies below incandescence.

Melloni was likewise very successful in studying the action upon dark heat of screens of various substances. His experiments in this and other directions are described by Baden Powell in his report to the British Association on *Radiant Heat* (1840). The rays of the lamp were thrown upon screens of various materials in such a manner that the effect transmitted from all the screens was of a certain uniform amount. This constant radiation was then intercepted by a plate of alum, and it was found that very different quantities of heat were transmitted through the alum in the different cases. Melloni concludes that the calorific rays issuing from the various diaphanous screens are, therefore, of different qualities, and possess what may be termed the diathermancy peculiar to each of the substances through which they have passed. One of his screens was made of green glass, and he found that a piece of alum transmitted only 1 per cent. of the heat which had passed through this screen. Green glass and alum form, therefore, an antagonistic combination.

These experiments suggest naturally a new analogy between dark heat and light which could not fail to strike Melloni, and accordingly we soon find him describing an experiment with the solar rays transmitted through green glass and then intercepted by other media. They pass copiously through rock-salt, he tells us, but feebly through alum, and hence Melloni concludes that there are amongst the solar rays some which resemble those of terrestrial heat, and in general that the differences observed between solar and terrestrial heat in the transmission of rays are to be attributed merely to the mixture in different proportions of these several species of rays. An instrument like the thermo-multiplier could not of course remain a monopoly, and shortly after its completion we find Professor James Forbes making use of it to prove the polarization of heat as well as to extend our knowledge of refraction. The brilliant researches of this experimentalist were, like those of Melloni, crowned with the Rumford medal of the Royal Society. On September 2, 1839, Arago communicated to the academy of sciences a letter by Melloni, who had found that rock-salt acquires by being smoked the power of transmitting most easily heat of low temperature, or dark heat. Forbes had discovered a similar property in mica split by heat, and he now showed that rock-salt roughened and mica scratched possess similar properties to blackened rock-salt. Melloni on his part took up the subject of polarization, and decided in favour of the equal polarizability of heat from different sources, a conclusion that did not then appear to Forbes to be in conformity with his experiments. It is very instructive to notice the loyalty which held both these experimentalists to the results of their observations. While Melloni differs from Forbes with regard to polarization, he will not allow the truth of a generalization proposed by Ampère, who had endeavoured to explain on the theory of undulations the identity of light and heat,—the difference of effect being dependent solely on the different wave-lengths, those producing heat being larger than those giving rise to light. Melloni admits that many phenomena may be explained by this hypothesis, but he mentions some experiments in which he thinks that this theory will not hold. The brilliant generalizer from without has of course a different point of view from the laborious experimentalist within. They are all worthy of scientific honour—for it is by the seeming conflict, but in reality the united efforts of workers such as these that the essential element of stability in the structure of scientific knowledge is finally secured.

MELON (*Cucumis Melo*, L.), a most polymorphic species of the order *Cucurbitaceæ*, the varieties of which are grouped by Naudin under ten tribes, while several other plants of less known characters probably belong to it.[1] The melon is an annual herb with palmately-lobed leaves, and bears tendrils. It is monœcious, having male and female flowers on the same plant. The flowers have deeply five-lobed campanulate corollas and three stamens. Naudin observed that in some varieties (*e.g.*, of Cantaloups) fertile stamens sometimes occur in the female flowers. It is a native of south Asia "from the foot of the Himalayas to Cape Comorin,"[2] where it grows spontaneously, but is cultivated in the temperate and warm regions of the whole world. It is excessively variable both in diversity of foliage and habit, but much more so in the fruit, which in some varieties is no larger than an olive, while in others it rivals the ponderous fruits of the gourd (*Cucurbita maxima*, L.). The fruit may be globular, ovoid, spindle-shaped, or serpent-like, netted or smooth-skinned, ribbed or furrowed, variously coloured externally, with white, green, or orange flesh when ripe, scented or scentless, sweet or insipid, bitter or even nauseous, &c. Like the gourd, the melon undergoes strange metamorphoses by crossing its varieties, though the latter preserve their characters when alone. The offspring, however, of all crossings are fertile. As remarkable cases of sudden changes produced by artificially crossing races, M. Naudin records that in 1859 the offspring of the wild melons m. sauvage de l'Inde (*C. melo agrestis*) and m. s. d'Afrique, le petit m. de Figari (*C. maculatus?*) bore quite different fruits from their parents, the former being ten to twelve times their size, ovoid, white-skinned, more or less scented, and with reddish flesh; though another individual bore fruits no larger than a nut. The offspring of m. de Figari after being crossed bore fruits of the serpent-melon. On the other hand, the serpent-melon was made to bear ovoid and reticulated fruit.[3]

With reference to the early cultivation of the melon, Naudin thinks it is probable that the culture in Asia is as ancient as that of all other alimentary vegetables. The Egyptians grew it, or at least inferior races of melon, which were either indigenous or introduced from Asia. The Romans and doubtless the Greeks were familiar with it, though some forms may have been described as cucumbers. Columella seems to refer to the serpent-melon in the phrase *ut coluber . . . ventre cubat flexo.* Pliny describes them as *pepones* (xix. 23 to xx. 6) and Columella as *melones* (xi. 2. 53); see Pickering, *Chron. Hist., of Pl.*, 229. The melon began to be extensively cultivated in France in 1629, according to Olivier de Serres. Gerard (*Herball*, 771) figured and described in 1597 several kinds of melons or pompions, but he has apparently included gourds under the same name. Pickering observes that the melon was carried by Columbus to America, and by the Portuguese to the Malayan Archipelago.

The origin of some of the chief modern races, such as "Cantaloups," "Dudaim," and probably the netted sorts, is due to Persia and the neighbouring Caucasian regions. The first of these was brought to Rome from Armenia in the 16th century, and supplies the chief sorts grown for the French markets; but many others are doubtless artificial productions of West Europe.

For cultivation of the melon, see art. HORTICULTURE, and also *Gard. Chron.*, May 6, 1882, p. 596; and for references to French literature on the same see Naudin, *ut supra*, p. 82.

MELOS (Att. Gr., Μῆλος), the modern Milo, one of the Sporades of the Ægean Sea, situated at the south-west corner of the archipelago, in 36° 45′ N. lat. and 24° 26′ E. long., 75 miles due east from the coast of Laconia. From east to west it measures about 14 miles, from north to south 8 miles, and its area is estimated at 52 square miles. The greater portion is rugged and hilly, and the culminating point, Mount Elias in the west, reaches a height of 2538 feet. Like the rest of the cluster to which it belongs, the island as a whole is of volcanic origin, with tuff, trachyte, and obsidian among its ordinary rocks. The great natural harbour, which, with a depth diminishing from 70 to 30 fathoms, strikes in from the north-west so as to cut the island into two fairly equal portions, with an isthmus not more than 1¼ miles broad, is evidently the hollow of the principal crater. In one of the caves on the south coast the heat is still so great that one cannot remain within more than a few minutes, and on the eastern shore of the harbour there is a remarkable cluster of hot sulphurous springs. Sulphur is found in abundance on the top of Mount Kalamo and elsewhere. In ancient times the alum of Milo was reckoned next to that of Egypt (Pliny, xxxv. 15 [52]), and millstones, salt (from a marsh at the east end of the harbour), and gypsum are still exported. The Melian earth (γῆ Μηλιάς), employed as a pigment by ancient artists, was probably native white-lead. Orange, olive, cypress, and arbutus trees grow throughout the island, which, however, is too dry to have any profusion of vegetation. The vine, the cotton plant, and barley are the main objects of cultivation. Including the neighbouring islands of Antimilos (4 square miles), Cimolos (16 square miles), and Polinos (5½ square miles), the total population of Melos was only 5538 in 1879.

Antimilo, 5½ miles north-west of Milo, is a mere uninhabited mass of trachyte, and is often called Eriomilo or Desert Melos. *Cimolos*, or *Argentiera*, less than 1 mile to the north-east, was famous in antiquity for its

[1] For generic characters see Benth. et Hook., *Gen. Pl.*, i. 826; and for a full account of the species of *Cucumis* and of the tribes of melon, by M. Naudin, see *Ann. des Sci. Nat.*, 4 sér., tom. xi. p. 34.

[2] Naudin, *l.c.*, pp. 39, 76; see also *Gard. Chron.*, 1857, p. 153, and 1858, p. 130.

[3] See also Naudin, in *Nouv. rech. sur l. hyb. dans les veg.*, p. 118, 1861.

figs and fuller's earth (Κιμωλία γῆ), and contained a considerable city, the remains of which still cover the cliff of St Andrews. *Polinos*, *Polybos* or *Polivo*, and *Kaimeni*, or "Burned Island," the *Île Brulée* or *Isola Bruciata* of the French and Italians, lies rather more than a mile south-east of Cimolos. It was in antiquity the subject of dispute between the Melians and Cimolians. It has long been almost uninhabited.

In ancient times the city of Melos, built terrace-fashion round a hill in the north-east of the main island, was a place of considerable size; "the western wall, of Cyclopean masonry, is traceable all the way down from the summit to the sea," and among the ruins are a temple in the Corinthian style and a beautiful little theatre cleared in 1836 by order of the king of Bavaria. Painted vases (the ancient Melians were great makers of this kind of ware), bronzes, gold ornaments, and similar specimens of art workmanship have been recovered from the debris; and in 1820 the "Venus of Milo," now in the Louvre, the noblest extant representation of Aphrodite, was found in the neighbourhood of the theatre. The top of the hill is now occupied by Castro, the principal village in the island. At some distance to the south-east, at the place called Tripiti (*i.e.*, τρυπητή, "the perforated"), lies a remarkable cluster of catacombs containing frescos, &c., of evidently Christian origin. Palæa Chora, about 5 miles farther south-east, is now an almost deserted village, but down to the beginning of the last century it had about 5000 inhabitants, and it continued for a time to be considered the capital of the island.

The first occupants of Melos were probably Phœnicians, but the island was Hellenized at an early date by Minyans and Dorians from Laconia. Though its inhabitants sent a contingent to the Greek fleet at Salamis, they held aloof from the Attic league, and sought to remain neutral during the Peloponnesian War. But in 416 B.C. the Athenians, having attacked the island and compelled the Melians to surrender at discretion, slew all the men capable of bearing arms, made slaves of the women and children, and introduced a body of five hundred Athenian colonists. Lysander restored the island to its old Dorian possessors, but it never recovered its former prosperity. There were many Jewish settlers in Melos in the beginning of the Christian era, and Christianity was early introduced. During the "Frankish" period the island formed part of the duchy of Naxos, except for the few years (1341–83) when it was a separate lordship under Marco Sanudo and his daughter.

See Leycester, "The Volcanic Group of Milo, Anti-Milo, &c.," in *Jour. Roy. Geog. Soc.*, 1852; Tournefort, *Voyage*; Leake, *Northern Greece*, vol. iii.; Prokesch von Osten, *Denkwürdigkeiten, &c.*; and Burslan, *Geog. von Griechenland*, vol. ii.

MELROSE, a village of Roxburghshire, Scotland, on the south bank of the Tweed, 37 miles by rail south-south-east of Edinburgh. Its population has steadily advanced from 966 in 1851 to 1550 in 1881. Though a burgh of barony since 1609, it is a purely agricultural village, and would be of little interest but for the ruins of its abbey, now the property of the duke of Buccleuch. It was formerly called Little Fordell, and its present name even dates from the foundation of the monastery by David II. in 1136.

There had been a Columbite monastery of Melrose at the place now known as Old Melrose, about a mile and a half to the east of the village, but this establishment, probably never of much architectural magnificence, had, according to the *Chronicle of the Picts and Scots*, been destroyed by Kenneth M'Alpin in 839, and may never have recovered from the disaster. King David's abbey, which he entrusted to a body of Cistercian monks from Rievaulx (Riuall) in Yorkshire, was dedicated on Sunday 28th July 1146; it was laid in ruins by Edward II. of England in 1322; Bruce caused the work of restoration to be vigorously prosecuted, but the edifice was again burned by Richard II. in 1385. The abbey church as it now stands consequently belongs in the main to the latter half of the 14th century and the first half of the 15th, with a good many portions of a considerably later date.

Architecturally the abbey may be described as a splendid example of the Middle Pointed style, strongly affected on the one hand by Flamboyant and Perpendicular tendencies, and on the other by the individuality of some of the builders. Cruciform in plan, it measured 214½ feet from east to west, the width of the nave being 69 feet, and across the transepts 115¼. The noble edifice was damaged by the English in 1545; and since the Reformation it has been altered to suit the necessities of Presbyterian worship (1618–1810), and plundered by builders to supply ornaments for houses. The whole building is now in ruins. The west end and a good part of the north side have disappeared; but the elevation of the south side is nearly entire, both the transepts and the east end are externally in very fair preservation, part of the central tower is standing, and the sculptured roof still covers the east end of the chancel. Of the individual features of the building, the great eastern window has been generally most admired since Sir Walter Scott celebrated the moonlit aspect of its "slender shafts of shapely stone." It has five lights; the height is 37 feet and the width 16; and the upper portion is filled in with delicate tracery of a geometrical design. Very beautiful too is the whole gable of the south transept. In the interior, on the north side of the nave, there still stand four of the original square piers, and one of them shows a Norman "cap." The choir, the west end of which is shut off by a massive rood-screen, has been largely "spoiled by rough 17th century work"; but enough remains of the decorative detail to provoke the admiration and despair of the modern artist in stone. The facile and at the same time elaborate rendering of vegetable forms, such as the Scotch "kail," is particularly striking. It was in the abbey-church of Melrose, where Alexander II. had long before been buried near the high altar, that the heart of Bruce found its final resting-place; and among the many tombs which afterwards gathered under the same roof were those of his faithful knight James Lord Douglas, Sir William the dark knight of Liddesdale, and the hero of Chevy Chase.

The ancient muniments of the abbacy have been preserved in the archives of the earl of Morton; they were published by the Bannatyne Club (2 vols., 1837, *Liber Sancte Marie de Melros*), under the editorship of Cosmo Innes. Among the many interesting documents is one of the very earliest specimens of the Scotch tongue. The *Chronica de Mailros*, preserved among the Cotton MSS., has been twice printed,—at Oxford (1684) by Fulman, and by the Bannatyne Club (1835), edited by John Stevenson. From about 1140 till its close in 1265 the chronicle may be considered original; it was put largely under contribution by later compilers.

See Walcott, *The Ancient Church of Scotland*; W. Hutchinson, *A View of Northumberland, &c.*, Newcastle, 1778; Adam Milne, *Description of the Parish of Melrose*, Kelso, 1782; J. Bower, *Description of the Abbeys of Melrose and Old Melrose*, Kelso, 1813; J. A. Wade, *History of St Mary's Abbey, Melrose*, Edinburgh, 1861; Fred. Pinches, *The Abbey Church of Melrose* (a series of architectural drawings), London, 1879.

MELTON MOWBRAY, a market-town of England, county of Leicester, is pleasantly situated in a fertile vale, at the confluence of the Wreake and Eye, 15 miles north-east of Leicester and 104 north of London by rail. The Eye is spanned by a bridge of four arches. The town consists principally of two main streets, and is substantially built of brick. The church of St Mary, a handsome cruciform structure partly in the Early English style, and adorned by a lofty and richly ornamented tower, was heightened and otherwise enlarged in the reign of Elizabeth, and has also undergone modern improvements. There are largely endowed almshouses and several other charities. Melton is the seat of a celebrated hunting district, in connexion with which there are stables in the town capable of accommodating about eight hundred horses. It is also well known for its pork pies, and has a very large trade in Stilton cheese. There are breweries and tanneries, as well as an important cattle market. Ironworks have lately been erected. The town possesses great railway facilities. The population of the urban sanitary district in 1871 was 5033, and in 1881 it was 5766.

The old name of Melton was Medeltone, and the place is of considerable antiquity. During the Civil War it was in February 1644 the scene of the defeat, with great slaughter, of the parliamentary forces by the royalists. It is the birthplace of John Henley the orator.

MELUN, capital of the department of Seine-et-Marne, France, 28 miles south-east of Paris by railway, occupies a hill on the right bank of the Seine and the level ground at its foot. It owes its rank as "chef-lieu" to its central position merely; for there are two other towns in the department, Meaux and Fontainebleau, which have a larger population. Melun is near one of the most beautiful parts of the forest of Fontainebleau. Among the rich estates in its neighbourhood the most remarkable is the magnificent chateau of Vaux-Praslin, which belonged to Fouquet, superintendant of finances under Louis XIV. The church of Notre Dame formerly belonged to a nunnery, now occupied by a central house of detention for twelve hundred prisoners. On the apse of the church of St Aspais may be seen a modern medallion in bronze, the work of the sculptor Chapu, representing Joan of Arc as the liberator of Melun. The population in 1881 was 12,145.

Melun is a very ancient town, and has played an important part in history. As early as the time of Cæsar's Gallic wars it was taken possession of by his lieutenant Labienus, in order to attack Lutetia with greater ease by the right bank of the Seine. It was pillaged by the Normans, and afterwards became the favourite residence of the first kings of the race of Capet; Robert and Philip I. both died there. During the Hundred Years' War Melun was given up by Jeanne of Navarre to her brother, Charles the Bad, but was retaken by the dauphin Charles and Duguesclin. In 1420 it made an heroic defence against Henry V. of England and his ally the duke of Burgundy. Ten years later the people of Melun, with the help of Joan of Arc, drove out the English. It was occupied by the League in 1589, and retaken by Henry IV. in the following year. Jacques Amyot was born there in 1504.

MELVILLE, Henry Dundas, Viscount (1741–1811), younger son of the Right Honourable Robert Dundas, lord president of the Scottish court of session, was born at Edinburgh in 1741, and was educated at the high school and university there. Becoming member of the faculty of advocates in 1763, he soon acquired a leading position at the bar. After his appointment as lord advocate in 1775, he gradually relinquished his legal practice to devote his attention more exclusively to public business. On entering parliament in 1774, he had joined the party of Lord North, and, notwithstanding his provincial dialect and ungraceful manner, he soon distinguished himself in the debates by his clear and argumentative speeches. After holding subordinate offices under the marquis of Lansdowne and Pitt, he in 1791 entered the cabinet as home secretary. From 1794 to 1801 he was secretary at war under Pitt, who conceived for him a special friendship. In 1802 he was elevated to the peerage as Viscount Melville and Baron Dunira. Under Pitt in 1804 he again entered office as first lord of the admiralty, when he introduced numerous improvements in the details of the department. His impeachment in 1806, for the appropriation of balances of public money remaining in his hands, resulted in his acquittal, but he never again held office. He died May 27, 1811.

MELVILLE, Andrew (1545–1622), a distinguished Scottish scholar, theologian, and religious reformer, was the youngest son of Richard Melville, proprietor of Baldovy, near Montrose, at which place Andrew was born in 1545. His father fell at the battle of Pinkie, fighting in the van of the Scottish army, two years after the birth of his son; and, his wife having soon after followed him to the grave, the young orphan, then a gentle and delicate child, was tenderly cared for by his eldest brother Richard and his amiable and pious wife, whose memory the great scholar ever afterwards cherished with the warmest gratitude and affection. At a very early age Melville began to show a strong taste for learning, and his brother did every thing in his power to give him the best education the country could then afford. The rudiments of Latin he obtained at the grammar school of Montrose, after leaving which he prosecuted the study of Greek for two years under Pierre de Marsilliers, a Frenchman whom John Erskine of Dun had induced to settle at Montrose; and such was the proficiency Melville made that on going to the university of St Andrews he excited the astonishment of both students and professors by using the Greek text of Aristotle, which no one else there understood, the Latin translation being that which was alone employed in the teaching of logic. On completing his course of study, Melville left St Andrews with the character of "the best poet, philosopher, and Grecian of any young master in the land." He then, in 1564, being nineteen years of age, set out for France to perfect his education at the university of Paris. He there applied himself especially to the study of the Oriental languages, but he had also the advantage of attending the last course of lectures delivered by Turnebus in the Greek chair, as well as those of the celebrated Ramus, whose mode of philosophizing and plan of teaching he afterwards introduced into the universities of Scotland. From Paris he proceeded to Poitiers for the purpose of studying civil law, and though only twenty-one years of age he was apparently at once made a regent in the college of St Marceon. After a residence of three years, however, the political troubles of the country compelled him to leave France, and he then went on to Geneva, where he was warmly welcomed by Theodore Beza, at whose instigation he was appointed to fill the chair of humanity in the academy of Geneva, which then happened to be vacant. In addition to his teaching, however, he also applied himself to the further prosecution of his studies in Oriental literature, and in particular acquired from Cornelius Bertram, one of his brother professors, a knowledge of Syriac. While he resided at Geneva the massacre of St Bartholomew in 1572 drove an immense number of Protestant refugees to that city, including several of the most distinguished French men of letters of the time, with whom Melville had now the opportunity of intimate intercourse. Among these were several men deeply learned in civil law and political science, and their society no doubt tended greatly both to increase Melville's knowledge of the world and to enlarge his ideas of civil and ecclesiastical liberty—acquisitions which he must have found of essential service when at a later period as a leader of the General Assembly he had to struggle against the attempts of James VI. to crush the liberties of the church of the Scottish Reformation. In 1574 Melville returned to Scotland, and almost immediately afterwards received the appointment of principal of Glasgow University, which at the time had fallen into an almost ruinous state, the college having in fact been shut up and the students dispersed. Melville, however, with the knowledge of academic methods of training which he had obtained abroad, immediately set himself with immense energy to establish a good educational system, and in a short time his fame spread through the kingdom, and students flocked in from all quarters, till the class-rooms lately empty could not contain those who came for admission. After labouring for six years in Glasgow, and having brought the seminary into a state of the most thorough efficiency, it was thought desirable that he should undertake the same duties at St Andrews. He accordingly proceeded there in 1580, and was installed as principal of the new theological college. His duties there comprehended the teaching, not only of theology, but of the Hebrew, Chaldee, Syriac, and Rabbinical languages, and the great ability of his lectures was universally acknowledged, and excited quite a new interest in the university. The sweeping reforms, however, which his new modes of teaching necessarily involved, and even some of the new doctrines which he began to introduce, such as the non-infallibility of Aristotle, soon brought him into collision with some of the other teachers in the university; and this, along with the troubles which arose from the attempts of the court to force a bastard system of Episcopacy upon the Church of Scotland, forced him to flee into England in order to escape the consequences of an absurd charge of treason which was made against him, and which seemed to threaten a prolonged imprisonment and not improbably even his life. After an absence of twenty months he returned to Scotland in November 1585, and in March 1586 resumed his lectures in St Andrews, where he continued to fulfil the duties of his office for twenty more years. During the whole of that time, however, his more prominent work was that of contending with unwearied energy and indomitable courage against the encroachments of an unscrupulous and tyrannical Government upon the liberties of the Scottish Church. Into the details of these it is of course impossible to enter here. But that in the main he and his coadjutors were fighting for the constitutionally guaranteed rights of the church is now admitted by all candid inquirers. (See in particular *The History of England from* 1603 *to* 1616, by Samuel Rawson Gardiner, vol. i. chap. ix.). The chief charge against Melville is that his fervour often led him to forget the reverence due to an "anointed monarch." Of this, however, it is not very easy now to judge. Manners at that time were rougher than at present. Any thing more rude, insolent, and brutal than James's own occasional explosions it would be difficult to match, and a king so undignified could scarcely expect to be treated with dignity. Besides, what title had one who was acting in a purely arbitrary and illegal manner to receive other than the plainest dealing,—such as being reminded that though he was king over men he was only "God's silly vassal?" Melville's rudeness (if it is to be called so) was simply the outburst of just indignation from a brave, true, and upright man, zealous only for the purity of religion and regardless of consequences to himself, and it contrasts nobly with the grovelling sycophancy of most of the English bishops towards James. The close of Melville's career in Scotland was at length brought about by James in characteristic fashion. In 1606 he and seven other clergymen of the Church of Scotland were summoned to London in order "that his majesty might treat with them of such things as would tend to settle the peace of the church." The contention of the whole of these faithful men was that the only way to accomplish that purpose was a free Assembly. Melville delivered his opinion to that effect with his accustomed freedom and boldness, and, having shortly afterwards written a sarcastic Latin epigram on some of the superstitious practices he had observed in the chapel of Hampton Court, and some eavesdropper having conveyed the lines to the king, he was committed to the Tower, and detained there for the space of four years. On regaining his liberty, and being refused permission to return to his own country, he was invited to fill a professor's chair in the university of Sedan, and there he spent the last eleven years of his brave, active, noble, and useful life. He died at Sedan in 1622, at the age of seventy-seven.

MELVILLE, George John Whyte (1821–1878), has a right to be regarded as the founder of a school of fashionable novels,—the fashionable sporting novel. He was lamented on his death as the Tyrtæus of the hunting field, the laureate of fox-hunting; all his most popular and distinctive heroes and heroines, Digby Grand, Tilbury Nogo, the Honourable Crasher, Mr Sawyer, Kate Coventry, Mrs Lascelles, are or would be mighty hunters. The eldest son of Major Whyte Melville, of Mount Melville, Fifeshire, he received his school education, like so many of his heroes, at Eton, entered the army in 1839, became captain in the Coldstream Guards in 1846, and retired in 1849. His first appearance in literature was made soon after, with a translation of Horace into fluent and graceful verse, published in 1850. His first novel was *Digby Grand*, published in 1853. Although this first effort has a good deal more in it of Lytton's early high-flying style than Whyte Melville's later works, the unflagging verve and intimate knowledge with which he described sporting scenes and sporting characters at once drew attention to him as a novelist with a new vein. His power of sustaining interest in hunting and the things connected with hunting appeared more markedly in his next novel, *Tilbury Nogo*, contributed to the *Sporting Magazine* in 1853. He showed in the adventures of Mr Nogo, what became more apparent in his later works, that he had a surer hand in humorous narrative than in pathetic description; there are many pathetic scenes in his novels, but the pathos is sometimes rather forced, intended to point a moral—rather the pathos of the preacher than the poet. The hero of *General Bounce*, his next novel in order of publication (*Fraser's Magazine*, 1854), little as one would expect it from the title, ends in a painful manner, somewhat out of keeping with the lively middle and beginning. When the Crimean War broke out, Whyte Melville took part in it as a volunteer in the Turkish contingent; but this was the only break in his literary career from the time that he began to write novels till his death in 1878. By a strange accident, he lost his life in the hunting-field, the hero of many a stiff ride meeting his fate in galloping quietly over an ordinary ploughed field.

Twenty-one novels appeared from his pen after his return from the Crimea:—*Kate Coventry*, 1856; *The Interpreter*, 1858; *Holmby House*, 1860; *Good for Nothing*, 1861; *Market Harborough*, 1861; *The Gladiators*, 1863; *Brookes of Bridlemere*, 1864; *The Queen's Maries*, 1864; *Cerise*, 1865; *Bones and I*, 1868; *The White Rose*, 1868; *M or N*, 1869; *Contraband*, 1870; *Sarchedon*, 1871; *Satanella*, 1872; *Uncle John*, 1874; *Sister Louise*, 1875; *Katerfelto*, 1875; *Rosine*, 1876; *Roy's Wife*, 1878; *Black but Comely*, 1878. Several of these novels are historical, the *Gladiators* being perhaps the most famous of them. As an historical novelist Whyte Melville cannot be put on a level with Harrison Ainsworth for painstaking accuracy and minuteness of detail; he makes his characters live and move with great vividness, but he obviously did not know at first hand the history of the periods chosen by him. It is on his portraiture of contemporary sporting society that his reputation as a novelist must rest; and, though now and then a character reappears, such as the supercilious stud-groom, the dark and wary steeple-chaser, or the fascinating sporting widow, his variety in the invention of incidents is amazing. Whyte Melville was not merely the annalist of sporting society for his generation, but may also be fairly described as the principal moralist of that society; he exerted a considerable and a wholesome influence on the manners and morals of the gilded youth of his time. His *Songs and Verses* and his metrical *Legend of the True Cross*, though respectable in point of versification, are hardly worth mentioning on their own merits.

MELVILL VAN CARNBEE, Pieter, Baron, an eminent Dutch geographer, was born at the Hague 20th May 1816, and died October 24, 1856. He traced his descent from an old Scotch family, originally it is said of Hungarian extraction. Destined for the navy, in which his grandfather had won distinction, Melvill imbibed a taste for hydrography and cartography as a student under Pilaar in the college of Medemblik, and he showed his capacity as a surveyor on his very first voyage to the Dutch Indies (1835). In 1839 he was again in the East, and was now attached to the hydrographical bureau at Batavia. With the assistance of the long-neglected documents collected by the old company, he completed in wonderfully short time his first great hydrographical work—a map of Java in five sheets, accompanied by sailing directions (Amsterdam, 1842; 2d revised edition, 1849),—which was received with great applause. Melvill remained in India till 1845 collecting materials for his second great hydrographical work, the chart of the waters between Sumatra and Borneo (two sheets, 1845 and 1846, revised edition of first sheet 1847; compare the descriptive memoir in Tindal and

Swart's *Journal*, 1846). On his return to Holland Melvill was attached to the naval department with the special charge of studying the history of the hydrography of the Dutch Indies. He also undertook, in connexion with Von Siebold, the publication of the *Moniteur des Indes*, a valuable series of scientific papers, mainly from his own pen, on the foreign possessions of Holland, which was continued for three years. In 1850 Melvill returned to India as lieutenant of the first class and adjutant to Vice-Admiral Van den Bosch; and after the premature death of this commander he was again appointed keeper of the charts at Batavia. He was one of the founders and for a time the president of the new society for natural science (1850). In 1853 he obtained exemption from active naval service that he might devote himself to a general atlas of the Dutch Indies; and under the most unfavourable circumstances he prosecuted the task with incredible energy. But he was not to see its completion. Just after he had lost his young wife and new-born son he was called in 1856 to be director of the marine establishment of Onrust; and there he soon fell a victim to climate, dying after much suffering in the hospital of Weltevreden, only forty years of age. In spite of delays caused by the engraving of the maps in Holland, no fewer than twenty-five sheets were already finished, but it was not till 1862 that the whole plan, embracing sixty sheets, was ably brought to a close by Lieutenant-Colonel W. F. Versteeg. The premature loss of Melvill was severely felt not only in Holland but in foreign countries, where, as shown by his connexion with the geographical societies of Paris, London, Berlin, and Bergen, his labours were highly esteemed. His industry and energy were equalled only by the benevolence and warmth of his heart. In 1843 he received the decoration of the Netherlands Lion, in 1849 that of the Legion of Honour.

MEMEL, the most northerly town in Germany, and the principal seat of the Baltic timber trade, is situated in the district of Königsberg, Prussia, at the mouth of the Dange, and on the bank of a sound connecting the Kurische Haff with the Baltic Sea. On the side next the sea the town is defended by a citadel and other fortifications, and the entrance to the large and fine harbour is protected by a lighthouse. Largely rebuilt since a destructive fire in 1854, Memel contains several churches, a gymnasium, a school of navigation, an exchange, and various judicial and official establishments. It also possesses large iron-foundries, shipbuilding yards, breweries, distilleries, and manufactories of chemicals, soap, and amber wares. By far the most important interest of the town, however, is its trade, the chief items in which are timber and the grain and other agricultural products of Lithuania. The timber is brought by river from the forests of Russia, and is prepared for exportation by about thirty saw-mills. The annual value of timber exported is about £600,000. In 1880 the port of Memel was entered by 898 ships with an aggregate burden of 164,374 tons, and cleared by 932 vessels with a burden of 164,441 tons. The population of Memel in 1880 was 19,660.

Memel was founded in 1252 by Poppo von Osterna, grand master of the Teutonic order, and was at first called New Dortmund and afterwards Memmelburg. It soon acquired a considerable trade, and joined the Hanseatic League. During the 13th, 14th, and 15th centuries it was repeatedly burned down by its hostile neighbours, the Lithuanians and Poles, and in the 17th century it remained for some time in the possession of Sweden. In 1757, and again in 1813, it was occupied by Russian troops. After the battle of Jena, King Frederick William III. retired to Memel; and there, in 1807, a treaty was concluded between England and Prussia. The poet Simon Dach and the astronomer Argelander were natives of Memel.

MEMLING, Hans, a painter of the 15th century, whose art gave a passing lustre to Bruges in the period of its political and commercial decline. Though much has been written respecting the rise and fall of the school which made this city famous, it still remains a moot question whether that school ever truly existed. Like Rome or Naples, Bruges absorbed the talents which were formed and developed in humbler centres. John Van Eyck first gained repute at Ghent and the Hague before he acquired a domicile elsewhere, and Memling, we have reason to think, was a skilled artist before he settled at Bruges. Yet if the question should be asked where the manner of Memling was shaped, and where he acquired the skill which he displayed at Bruges, we shall be greatly at a loss to reply. The annals of the city are silent as to the birth and education of a painter whose name was inaccurately spelt by different authors, and whose identity was lost under the various appellations of Hans and Hausse, or Hemling and Memling. But no other city of the Netherlands has vindicated the right which Bruges had no means of proving. Travellers who came to Bruges were only told that Memling's masterpieces were preserved in the hospital of St John. In one of these pictures it was said a portrait of the artist might be discovered; on the sculptured ornaments of a porch enframing one of its subjects an incident of the master's life might be traced,—his danger as he lay senseless in the street, his rescue as charitable people carried his body to the hospital. The legend grew too. It came to be told how the great artist began life as a soldier who went to the wars under Charles the Bold, and came back riddled with wounds from the field of Nancy. Wandering homeward in a disabled state in 1477, he fainted in the streets of Bruges, and was cured by the Hospitallers. Unknown to them, and a stranger to Bruges, he gave tangible proofs of his skill to the brethren of St John, and showed his gratitude by refusing payment for a picture he had painted. Unhappily the legend refutes itself. The portrait of Memling is a myth; the carvings of the capitals of the porch represent the ordinary incidents attending the reception of patients at an hospital. Memling did indeed paint for the Hospitallers, but he painted not one but many pictures, and he did so in 1479 and 1480, being probably known to his patrons of St John by many masterpieces even before the battle of Nancy.

Memling is only connected with military operations in a mediate and distant sense. His name appears on a list of subscribers to the loan which was raised by Maximilian of Austria to push hostilities against France in the year 1480. When he signed this list his position was that of a resident at Bruges who had probably lived there long enough to acquire a large practice and its advantages in the form of lands and tenements. In 1477, when he is said to have fallen, and when Charles the Bold was killed, he was under contract to furnish an altarpiece for the guild chapel of the booksellers of Bruges; and this altarpiece, now preserved, under the name of the Seven Griefs of Mary, in the gallery of Turin, is one of the fine creations of his riper age, and not inferior in any way to those of 1479 in the hospital of St John, which for their part are hardly less interesting as illustrative of the master's power than the Last Judgment in the cathedral of Dantzic. Critical opinion has been unanimous in assigning the altarpiece of Dantzic to Memling, and by this it affirms that Memling was a resident and a skilled artist at Bruges in 1473; for there is no doubt that the Last Judgment was painted and sold to a merchant at Bruges, who shipped it there on board of a vessel bound to the Mediterranean, which was captured by a Dantzic privateer in that very year. But, in order that Memling's repute should be so fair as to make his pictures purchasable, as this had been, by an agent of the Medici at Bruges, it is incumbent on us to acknowledge that he had furnished sufficient proofs before that time of the skill which excited the wonder of such highly cultivated patrons; and thus we come to admit without much difficulty the possible truth of a report made by a chronicler of the 16th century that Memling had sittings from Isabella, consort of Philip the Good of Burgundy, in the year 1450.

It is characteristic that the very oldest allusions to pictures connected with Memling's name are those which point to relations with the Burgundian court. The inventories of Margaret of Austria, drawn up in 1524, allude to a triptych of the God of Pity by Roger van der Weyden, of which the wings containing angels were by "Master Hans." But this entry is less important as affording testimony in favour of the preservation of Memling's work than as showing his connexion with an older Flemish craftsman. For ages Roger van der Weyden was acknowledged as an artist of the school of Bruges, until records of undisputed authenticity demonstrated that he was bred at Tournai and settled at Brussels. Nothing seems more natural than the conjunction of his name with that of Memling as the author of an altarpiece, since, though Memling's youth remains obscure, it is clear from the style of his manhood that he was taught in the painting-room of Van der Weyden. Nor is it beyond the limits of probability that it was Van der Weyden who received commissions at a distance from Brussels, and first took his pupil to Bruges, where he afterwards dwelt. The clearest evidence of the connexion of the two masters is that afforded by pictures, and particularly an altarpiece, which has alternately been assigned to each of them, and which may possibly be due to the joint labours of both. In this altarpiece, which is a triptych ordered for a patron of the house of Sforza, we find the style of Van der Weyden in the central panel of the Crucifixion, and that of Memling in the episodes on the wings. Yet the whole piece was assigned to the former in the Zambeccari collection at Bologna, whilst it was attributed to the latter at the Middleton sale in London in 1872. At first, we may think, a closer resemblance might be traced between the two artists than that disclosed in later works of Memling, but the delicate organization of the younger painter, perhaps also a milder appreciation of the duties of a Christian artist, may have led Memling to realize a sweet and perfect ideal, without losing, on that account, the feeling of his master. He certainly exchanged the asceticism of Van der Weyden for a sentiment of less energetic concentration. He softened his teacher's asperities and bitter hardness of expression.

In the very oldest form in which Memling's style is displayed, or rather in that example which represents the Baptist in the gallery of Munich, we are supposed to contemplate an effort of the year 1470. The finish of this piece is scarcely surpassed, though the subject is more important, by that of the Last Judgment of Dantzic. But the latter is more interesting than the former because it tells how Memling, long after Roger's death and his own settlement at Bruges, preserved the traditions of sacred art which had been applied in the first part of the century by Roger van der Weyden to the Last Judgment of Beaune. All that Memling did was to purge his master's manner of excessive stringency, and add to his other qualities a velvet softness of pigment, a delicate transparence of colours and yielding grace of slender forms. That such a beautiful work as the Last Judgment of Dantzic should have been bought for the Italian market is not surprising when we recollect that picture-fanciers in that country were familiar with the beauties of Memling's compositions as shown in the preference given to them by such purchasers as Cardinal Grimari and Cardinal Bembo at Venice, and the heads of the house of Medici at Florence. But Memling's reputation was not confined to Italy or Flanders. The Madonna and Saints which so lately passed out of the Duchatel collection into the gallery of the Louvre, the Virgin and Child of Sir John Donne at Chiswick, and other noble specimens in English and Continental private houses show that his work was as widely known and appreciated as it could be in the state of civilization of the 16th century. It was perhaps not their sole attraction that they gave the most tender and delicate possible impersonations of the "Mother of Christ" that could suit the taste of that age in any European country. But the portraits of the donors with which they were mostly combined were more characteristic, and probably more remarkable as likenesses than any that Memling's contemporaries could produce. Nor is it unreasonable to think that his success as a portrait painter, which is manifested in isolated busts as well as in altarpieces, was of a kind to react with effect on the Venetian school, which undoubtedly was affected by the partiality of Antonello da Messina for trans-Alpine types studied in Flanders in Memling's time. The portraits of Sir John Donne and his wife and children in the Chiswick altarpiece are not less remarkable as models of drawing and finish than as refined presentations of persons of distinction; nor is any difference in this respect to be found in the splendid groups of father, mother, and children which fill the noble altarpiece of the Louvre. As single portraits, the busts of Burgomaster Morcel and his wife in the museum of Brussels, and their daughter the Sibyl Zambetha in the hospital of Bruges, are the finest and most interesting of specimens. The Seven Griefs of Mary in the gallery of Turin, to which we may add the Seven Joys of Mary in the Pinakothek of Munich, are illustrations of the habit which clung to the art of Flanders, of representing a cycle of subjects on the different planes of a single picture, where a wide expanse of ground is covered with incidents from the Passion in the form common to the action of sacred plays. The time came, no doubt, when the players took their cue from the painters, as in the Ghent procession, which was formed on the model of Van Eyck's Adoration of the Lamb. But in Memling's days there were still some original "players," and the public was not averse to seeing illustrations of their work. In the first period of the development of Belgian art too, when the Flemings assigned more importance to carved work than to painting, and yet refused to accept sculpture without colour, it was natural that the sculptor should multiply incidents on bas-reliefs which were coated with tinting in the semblance of nature. Memling's pictures imitate reliefs so far as they abound in variety of episodes, and are marked by absence of contrast in light and shade or want of toning by gradations of atmosphere. Yet with all these peculiarities his works are very pleasant to the eye, because they are always graceful and quiet.

The masterpiece of Memling's later years, a shrine containing relics of St Ursula in the hospital of Bruges, is fairly supposed to have been ordered and finished in 1480 after the painter had become acquainted with the scenery of the Rhine. This shrine is one of the most interesting monuments of mediæval art in Flanders, not only because it is beautifully executed, but because it reveals some part of the life of the painter who produced it, and illustrates the picturesque legend of Ursula and her comrades. The delicacy of finish in its miniature figures, the variety of its landscapes and costume, the marvellous patience with which its details are given, are all matters of enjoyment to the spectator. There is later work of the master in the St Christopher and Saints of 1484 in the academy, or the Newenhoven Madonna in the hospital of Bruges, or a large Crucifixion with scenes from the Passion, of 1491, in the cathedral of Lübeck. But as we near the close of Memling's career we observe that his practice has become larger than he can compass alone; and, as usual in such cases, the labour of disciples is substituted for his own. The registers of the painters' corporation at Bruges give the names of two apprentices who served their time with Memling and paid dues on admission to the guild in 1480 and 1486. These subordinates remained obscure.

It would be easy to form a long list of pictures by Memling in the galleries of Berlin, Florence, London, Madrid, Paris, Rome, and Vienna, and pieces equally remarkable in many private collections of England and the Continent. These have all been described, and are widely known. The present notice must be closed with the admission that pictures tell more of Memling's life than records. The date of the master's death is not better certified than that of his birth. This much, however, is certain. The trustees of Memling's will appeared before the court of wards at Bruges on the 10th of December 1495, and we gather from records of that date and place that Memling died a short time before, leaving behind several children and a considerable property. (J. A. C.)

MEMMI. See MARTINI, SIMONE.

MEMMINGEN, a town of Bavaria, in the district of Schwaben and Neuburg, is situated about 35 miles to the south-west of Augsburg, near the river Iller. It is a well-built town, still partly surrounded with walls, and contains a Roman Catholic and three Protestant churches, a town-house of 1580, and several schools and charitable institutions. Its industrial products are yarn, calico, woollen goods, and thread. A considerable trade is carried on in hops, which are extensively cultivated in the neighbourhood, and in wool, leather, and grain. The population in 1880 was 8050.

Memmingen, first mentioned in a document of 1010, belonged originally to the Guelph family. In 1286 it became a free city of the empire, a position which it maintained down to 1802, when it was allotted to Bavaria. In 1529 Memmingen was one of the "protesting" towns represented at the diet of Spires. During the Thirty Years' War it was alternately occupied by Swedes and Imperialists. In 1800 the French under Moreau gained a victory over the Austrians near Memmingen. Compare Dobel, *Memmingen im Reformationszeitalter*, 1877–78.

MEMNON. In the Homeric mythology (or rather the mythology of the *Troica* in the much fuller form in which it existed in the times of Pindar and the tragic poets) this hero was called the son of Tithonus (the half-brother of Priam) and Eos (Aurora). Tradition represented him as an Ethiopian prince who came to assist the Trojans against the Greeks, and performed prodigies of valour, but was at length killed by Achilles, after having himself slain Antilochus, the son of Nestor, an event alluded to in Pindar, *Pyth.*, vi. 32–39. His story must have been very famous, for more than one Greek play was composed bearing the title.

The chief source from which our knowledge about Memnon as a chief is derived is the second book of the *Post-Homerica*, by Quintus Smyrnæus, where his exploits and death are described at length. That Memnon was slain by Achilles is more than once affirmed by Pindar (*Nem.*, vi. 52; *Isthm.*, iv. 41, vii. 54). He is mentioned also in the *Odyssey* (xi. 522), with especial praise for personal beauty; but the allusion to him is quite casual, and is one of many proofs that the compilation of that and the sister epic presupposes in the reader or hearer a full knowledge of the whole tale of Troy. Modern philology associates Memnon—like Achilles, whom he so closely resembles in many particulars, and like Sarpedon, who seems the representative of Memnon in the Iliad—with solar phenomena. He was the son of the dawn, and, though he might vanish from sight for a time, he could not be destroyed, and therefore it was said that Zeus, moved by the tears of his mother, granted him immortality. In this respect, as also in wearing bright armour made by Hephæstus, he is the counterpart of Achilles, who symbolizes the mid-day sun in his glory; and that Memnon is said to have come from the far east, *i.e.*, from the region of sunrise, is in itself significant. Ovid, in a beautiful elegy on the death of Tibullus, *Amor.*, lib. iii. 9, 3, thus associates the fates of Memnon and Achilles:—

Memnona si mater, mater ploravit Achillem,
Et tangunt magnas tristia fata deas,
Flebilis indignos, Elegeia, solve capillos;
Ah nimis ex vero nunc tibi nomen erit.

Like the body of the dead hero Sarpedon (*Il.*, xvi. 681), so that of Memnon was borne through the air, a legend represented on Greek vases of a rather early date. This appears to mean that the sun, the offspring of the dawn, careers through the sky to the place of his departure in the west. Another account represents Zeus as having sent forth birds from the funeral-pile of Memnon, which straightway fought with each other, and many fell back as victims to the soul of the hero.

The mere fact that a *Memnonium*, or temple in honour of the hero, was erected both at Susa and at Egyptian Thebes, both of which places were centres of sun-worship, is a strong confirmation of the probability, derived from his mythical pedigree, that he was really a sun-god. Sir G. W. Cox remarks,[1] "of Memnon's head the story was told that it retained the prophetic power of the living Helios or of Surya. The story is found in the myth of the Teutonic Wismir, and it might have been related of Kephalos, the head of the sun;" and again (p. 267), "Eos, the mother of Memnon, is so transparently the morning that her child must rise again as surely as the sun reappears to run his daily course across the heaven."

With respect to the meaning of the name, it may possibly be the same as Agamemnon, which has a prefix meaning *brave*.[2] It has been thought that Μέμνων and μνήμων, "mindful," are but forms of the same word, and that the prophetic power attributed to the head of the Egyptian Memnon, which was said to utter sounds at sunrise, is connected with this idea. It was said that the sound resembled the moaning noise or the sharp twang of a harp-string, and it may even be surmised that the syllables *mem-non* imitated the resonance. The Egyptian head is said to be a bust of King Amenophis;[3] but if the Greeks fancied it uttered the word *memnon*, they would have called it by that name. The tendency, however, to give a Greek shape and inflexion to words which sounded barbarous will sufficiently account for the misnaming of the statue.

Strabo, lib. xvii. p. 816, declares that he himself heard it in company with Ælius Gallus and several of his friends, and Pausanias (i. 42, 2) says "one would compare the sound most nearly to the broken chord of a harp or a lute." See also Juv., *Sat.*, xv. 5; Tac., *Ann.*, ii. 61.

Memnon, as an Ethiopian, was of course represented as a black; hence Virgil (*Æn.*, i. 493) speaks of "nigri Memnonis arma." The figure itself was cut out of black basalt, but that is a material not uncommon in Egypt. Speaking quite generally, it seems reasonable to conclude that the Memnon from Ethiopia (which the early Greeks placed in the far east rather than in the south) typifies the eastern sun summoned to oppose the enemies of darkness from the west.

MEMPHIS, the capital of the old Egyptian empire, founded by Menes, the first historical king; see vol. vii. pp. 731, 770. In the time of Strabo (xvii. p. 807) it was the second city of Egypt, inferior only to Alexandria, and with a mixed population like the latter. Memphis was still an important though declining place at the time of the Moslem conquest. Its final fall was due to the rise of the Arabic city of Fosṭáṭ on the right bank of the Nile almost opposite the northern end of the old capital; and its ruins, so far as they still lay above ground, gradually disappeared, being used as a quarry for the new city. The remains of "Menf" were still imposing late in the 12th century, when they were described by ʿAbd el-Laṭíf. In the Old Testament Memphis is mentioned under the names of Moph (Hos. ix. 6) and Noph (Isa. xix. 13; Jer. ii. 16; Ezek. xxx. 13, 16).

MEMPHIS, a city of the United States, and port of entry, capital of Shelby county, Tennessee, is situated on the east bank of the Mississippi river just below the mouth of Wolf river, in about 35° 8′ N. lat. and 90° 5′ W. long., 450 miles below St Louis and 826 miles above New Orleans. The bluff on which the city stands has an average elevation of 47½ feet above high-water mark, with a further fall of 36 feet to extreme low water. Memphis is methodically and tastefully planned, and is adorned with many elegant private residences and public buildings, conspicuous among the latter being the United States custom house, located upon the esplanade between Front Street and the river, and built of the best quality of marble, the product of Tennessee quarries. A small park in the centre of the city contains a bust of Andrew Jackson. The streets are mostly well-paved, and are supplied with water from the Wolf river by the Holly system. The bayou Gayoso, with several branches, intersects the city, and prior to 1880 received most of its drainage. Since that date over 40 miles of sewers and more than that length of subsoil drain-tiles have been constructed on the Waring system, providing the city with a superior system of drainage.

[1] *Mythology and Folklore*, p. 134.

[2] Sir G. W. Cox, *Mythology of the Aryans*, p. 263, ed. 2.

[3] Φαμένωφ, as the Thebans themselves said, according to Pausanias, cited below.

Memphis is the largest city of the State, and the most important commercial city on the Mississippi between St Louis and New Orleans. The largest sea-going vessels ascend the river to this point, and navigation is open at all seasons of the year. The city also possesses abundant facilities for transportation by railway in every direction. Memphis ranks as the largest interior cotton-market in the United States. The receipts for the season ending September 1, 1881, were 470,267 bales, with a value of $23,090,109. The aggregate receipts from the mercantile and manufacturing interests for the year ending September 1, 1882, amounted to about $60,000,000, of which the trade in groceries and western products contributed nearly $40,000,000; dry goods, clothing, boots and shoes, and general merchandise $15,000,000; and various home manufactures about $5,000,000. There are oil-mills and refineries, whose annual product of about 30,000 barrels of cotton-seed oil, together with oil-cake and re-ginned cotton, amounts to over $1,000,000. There are also numerous foundries, machine shops, flouring-mills, and manufactories of carriages, furniture, and tobacco.

The city contains, besides the usual religious, educational and commercial institutions, a public library of 9000 volumes, three daily and ten weekly newspapers, a chamber of commerce, and a cotton exchange.

Memphis was laid out as a village in 1820, and incorporated as a city in 1831. Its population at each census since has been as follows:—3360 in 1840, 8841 in 1850, 22,623 in 1860, 40,226 in 1870, and 33,592 in 1880. According to a census taken on October 1, 1882, the population within the city limits was 47,976 (29,130 white and 18,846 coloured).

During the civil war Memphis was early occupied by the Union forces (June 6, 1862) after a naval engagement in which Commodore Davis with a fleet of nine gunboats and rams defeated a similar Confederate fleet of eight vessels, and captured or destroyed all of them but one. The city was held by Federal troops to the close of the war, with the exception of a brief occupation, in August 1864, by General Forrest, who captured several hundred prisoners, but immediately withdrew. The decrease of population between 1870 and 1880 was due to the ravages of yellow fever in 1873, 1878, and 1879. The epidemic of 1873 resulted in over two thousand deaths. In 1878, according to the report of the Howard Relief Association, the number of those attacked with the fever was 15,000, and the number of deaths reached the total of 5150, of whom 4250 were whites and 900 coloured. At the return of the fever in 1879 better care and strict quarantine arrangements prevailed, but there were 1595 cases, with 497 deaths. During the epidemics of 1878 and 1879 fully two-thirds of the population fled from the city, many of whom died of the fever at other places, and a still larger number did not return. For three months during each year business was wholly suspended, and all ingress or egress except for the most necessary purposes was forbidden. The prostration of the business of the place left the city almost hopelessly bankrupt, and as a means of relief the legislature of the State in January 1879 repealed the city's charter, and, assuming exclusive control of its taxation and finances, constituted it simply a "taxing district," placing its government in the hands of a "legislative council." This anomalous proceeding has been declared constitutional by the supreme court of Tennessee. Under it Memphis is at least regaining its prosperity, and by thoroughly cleansing, repaving, and sewering its streets, and supervising the construction of buildings, is likely to become one of the healthiest cities on the Mississippi river.

END OF VOLUME FIFTEENTH.

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PRINCIPAL CONTENTS.

MALDIVE ISLANDS. Col. Henry Yule, C.B.
MALTA. Miss L. Toulmin Smith.
MALTHUS. Thomas Kirkup, M.A.
MAMMALIA. W. H. Flower, LL.D., F.R.S., Professor of Comparative Anatomy, Royal College of Surgeons, London, and G. E. Dobson, M.A., M.B., Royal Victoria Hospital, Netley.
MAMMOTH CAVE. Rev. H. C. Hovey.
MANATEE. Prof. Flower.
MANCHESTER. W. E. A. Axon.
MANCHURIA. R. K. Douglas, Professor of Chinese, King's College, London.
MANDÆANS. Prof. K. Kessler, University of Marburg.
MANDEVILLE, BERNARD DE. Prof. Minto.
MANDEVILLE, JEHAN DE. E. B. Nicholson, M.A., Librarian, Bodleian Library, Oxford, and Col. Yule.
MANGANESE. Prof. Dittmar.
MANICHÆISM. Adolf Harnack, Professor of Church History, University of Giessen.
MANITOBA. Prof. George Bryce, Winnipeg.
MANOMETER. Prof. James Blyth.
MANSFIELD. Alexander Gibson, M.A., Advocate.
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MANUTIUS. J. A. Symonds.
MAP. Sophus Ruge, Ph.D., author of "Geschichte des Zeitalters der Entdeckungen."
MARAT. H. Morse Stephens, Balliol College, Oxford.
MARBLE. F. W. Rudler, Curator of Museum of Practical Geology, London.
MARCANTONIO. Sidney Colvin, M.A., Slade Professor of Fine Art, University of Cambridge.
MARCION. Prof. Harnack.
MARINES. Captain C. C. King, Professor of Tactics, &c., Royal Military College, Sandhurst.
MARITIME PROVINCE. P. A. Kropotkine.
MARK. Rev. E. Hatch.
MARLBOROUGH. W. P. Courtney.
MARLOWE. Algernon C. Swinburne.
MARMOT. Oldfield Thomas, British Museum.
MAROT. George Saintsbury, M.A.
MARRIAGE. Edmund Robertson, M.A., Professor of Roman Law, University College, London.
MARSEILLES. Gaston Meissas.
MARTEN. Prof. Flower.
MARTIAL. Prof. Sellar.
MARTINEAU. Miss Clementina Black, author of "Orlando."
MARVELL. Osmund Airy, M.A.
MARY (the Virgin). Rev. J. Sutherland Black, M.A.
MARY (of England). James Gairdner, Public Record Office, London.
MARY (of Scotland). A. C. Swinburne.
MARYLAND. W. T. Brantly, Baltimore.
MASANIELLO. G. H. Bianchi, M.A., St Peter's College, Cambridge.
MASSACHUSETTS. Justin Winsor, Librarian, Harvard University, Cambridge, Mass.
MASSINGER. Prof. Minto.
MATCHES. James Paton, Curator of Corporation Galleries of Art, Glasgow.
MATHEMATICS. Prof. Chrystal.
MATTHEW OF PARIS. J. Bass Mullinger, M.A., author of "History of the University of Cambridge."
MAURITIUS. Rev. J. Sibree, Jun.
MAZARIN. H. Morse Stephens.
MAZZINI. Rev. J. S. Black.
MEASLES. J. O. Affleck, M.D.
MEASUREMENT. R. S. Ball, LL.D., F.R.S., Royal Astronomer for Ireland.
MECCA. Prof. W. Robertson Smith.
MECHANICS. P. G. Tait, M.A., Professor of Natural Philosophy, University of Edinburgh.
MECHANICS, APPLIED. W. J. Macquorn Rankine, LL.D., F.R.S., late Professor of Civil Engineering, University of Glasgow.
MECKLENBURG. J. F. Muirhead, Leipsic.
MEDICAL JURISPRUDENCE. Thomas Stevenson, M.D., Lecturer on Chemistry, &c., Guy's Hospital, London.
MEDICI. Prof. P. Villari, Royal Institute, Florence, author of "Savonarola" and "Machiavelli."
MEDICINE—
Synoptical View. C. Creighton, M.D.
History. J. F. Payne, M.D., Lecturer on Pathology, St Thomas's Hospital, London.
MEDINA. Prof. W. Robertson Smith.
MEDITERRANEAN. J. Y. Buchanan, late of the "Challenger" Expedition.
MELANCHTHON. Rev. John Wilson, M.A.
MELBOURNE. A. Sutherland, M.A., Carlton College, Melbourne.
MEMLING. J. A. Crowe, author of "Painting in Italy."