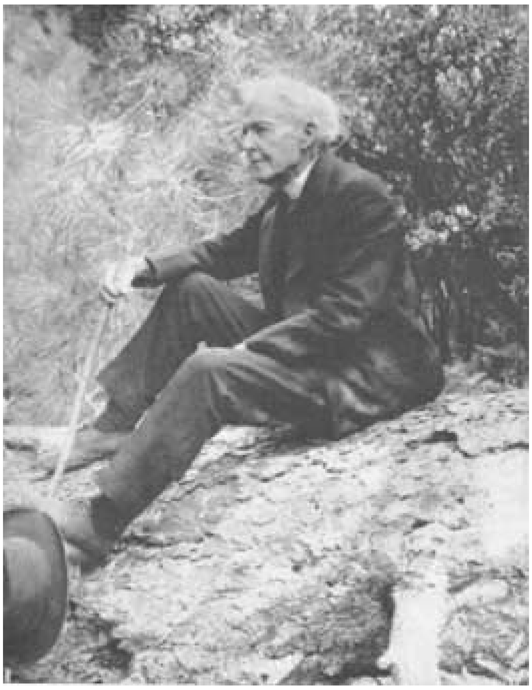
PARTNER OF NATURE

BY

LUTHER BURBANK

Edited and transcribed by

WILBUR HALL



To the end of his life Luther Burbank was a naturalist and a lover of the wilderness. This late picture shows him relaxing while on a mountain trail. He did not put on his "Sunday suit" to be photographed; these were the clothes he wore all his life-gray or black suit, stiff shirt, collar and cravat. Even in his gardens and at his grubbiest job he seldom changed.

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Foreword

IN his lifetime Luthur Burbank wrote or dictated many thousands of pages about his work with plants and the methods he employed in plant-breeding and improvement. Much of this material was published, but either in piecemeal articles that presented only phases of his work or his experiences or in sets of books that covered the whole field and offered more than the average reader required.

There were always requests for a single volume, written in non-technical language, that would cover the subject adequately--in short, for a compact and simple story of how Mr. Burbank went about his work of producing more useful plants, more desirable fruits and more beautiful flowers. Since Mr. Burbank's death in 1926 these requests have increased.

But it was a formidable task. There was so much material to sift and winnow in order to reduce the whole chronicle to so limited a space. It was my husband's own story, that must be told in his own words, yet what he had written had to be condensed into a smooth narrative.

However, the work was undertaken, under my supervision; it is here offered you, completed.

The experiences, theories, laws, methods and formulas set down are entirely Mr. Burbank's. The text closely follows what he wrote and dictated and said on the subject, though the "boiling down" process results in a transcription of Mr. Burbank's voluminous material rather than literal, word-for-word quotations. And, reading the manuscript, I am glad that this plan was followed, for Mr. Hall, who collaborated with Mr. Burbank during his lifetime, has a happy faculty for presenting him and his enthusiasms and adventures and work in almost the very words my husband would have used.

One of the sources for this transcription of my husband's writings was the eight-volume work, *How Plants Are Trained to Work for Man,* published in 1921 by P. F. Collier and Son Company, whose kind permission to refer to this work in preparing *Partner of Nature* is here gratefully acknowledged.

It is my hope that the work done on this volume will be justified by the interest it arouses, not only in Luther Burbank's experiences and methods, but in Luther Burbank as a naturalist-a true "Partner of Nature."

ELIZABETH WATERS BURBANK
Santa Rosa, California

Contents

The Life of Luther Burbank

LUTHER BURBANK was born March 7, 1849, the thirteenth child of Samuel Walton Burbank, whose forebears had been in New England since before 1640, and the third child of Samuel's third wife, Olive Ross, whose family traced its descent from the blood of Scottish kings. His birthplace--a large brick house with a wooden ell--stood on the sloping land that runs down from the old town of Lancaster, in Massachusetts, to the Nashua River. It was a house that threw its doors open hospitably to the learned, the cultured, and the scholarly who came that way or who lived--as many of them did--in the near vicinity. It was a house that heard many discussions of deep theological problems, of politics, of abstruse questions of philosophy and ethics; it was, moreover, the house of a successful and able father and a mother who was above even the high New England average of mentality and ability. It was a good house in which to be born.

There are many stories told of Luther Burbank's childhood that sound very much as though they had been suggested by his later career: the story, for instance, that as a mere baby his favorite plaything was a potted cactus plant; the story that he cried when flowers wilted or fell apart; the story that he instructed his mother how to plant and cultivate her garden when he was at an age when most youngsters are absorbed in teething. He himself tells of trying an experiment before he could walk, the experiment being the substitution of his chubby fist for doughnut dough in a kettle of boiling fat; he remembered in later life, too, that, while the rest of the family were picking strawberries one day and he was set in the field to amuse himself, he was delighted as well as alarmed by a big crow that tried to eat his pink toes. Whatever may the truth regarding his infantile interest in Nature it is unquestionable that his mind was bent and strongly influenced by the sober and thoughtful discussions he heard as he was growing up, and particularly and markedly by the long walks and talks he had with a cousin of his father's, Professor Levi Sumner Burbank, a personal friend of Louis Agassiz, a sound geologist, and a member of most of the learned societies that, at that time, were in existence in Boston.

It is agreed that he was a timid and sensitive child, which was partly traceable to the fact that he was of a delicate physique and so denied participation in the rougher sports of the other boys. But he was by no means diffident, nor soft; he played well the games he was strong enough for; he was a good skater; he was inventive and tireless in finding out the why of things; as he grew a little older he made himself liked and a sort of leader by figuring out short cuts in lesson-getting and acceptable excuses for having fun. Public recitation was his principal bugaboo, and "speaking a piece" utter misery for him. When he was entered at the Lancaster Academy, and by a sensible principal excused from declamation and permitted instead to write a composition, school lost most of its terrors for him and he became a successful student.

Meantime he had shown unmistakable aptitude for mechanics, experimenting with a tea-kettle until he made it operate a tin whistle; advancing from that stage to a cylinder-and-piston engine; perfecting that until it was practicable enough to run a small boat. He built water-wheels and set them to driving toys; he worked out labor-saving devices for his mother; he even planned a theoretical improvement on the process of brick-making, led to this by the fact that his father and uncle had turned their early pottery works into a brick-yard. His father began to think that Luther was wasting himself as a small and rather weak hand in the work of the home--the orchard, the timber-lot and the brick-yard; as there were plenty of older children who were rugged and capable, the youngster was at last apprenticed to the Ames Manufacturing Company with the belief that he would develop into a mechanical engineer and inventor. The guess was not far off, for the boy soon contrived a labor-saving device for the machine on which he was employed at turning plowrounds which multiplied the efficiency of both machine and operator many times over and which increased young Burbank's daily wage from a few cents to eight and ten dollars.

But the confinement and dust of the factory told on the fragile youth and, after his father's death, when he was about seventeen, he took the small patrimony that fell to him and, against the advice of family and friends, bought a seventeen-acre tract of fine land near Lunenburg, a few miles from Lancaster, and became a truck-gardener. It was the beginning of his real lifework.

Always groping about for an understanding of life and especially of the life of growing plants, Luther Burbank found his path brilliantly lighted by the first writings of Charles Darwin; what Darwin stated theoretically concerning the influence of environment on the heredity of all growing things the young gardener in Lunenburg began to demonstrate practically. His first experiments were simple; in fact they had probably been performed many times before. But he was different in this, that he began *to formulate laws* from his successful trials--to study the possibilities of that science which later brought him world renown and won him the first place in history for plant-breeding--the science of "training plants to work for man."

Out of many tests he made of the Darwinian theories and of the beliefs he himself was beginning to hold, two may be cited. In order to produce sweet corn for his customers ahead of all his competitors Luther Burbank set the seed to germinating in the house two weeks before the true coming of spring; this forced seed was planted, already germinated, on the day that other gardeners were sowing; two weeks before theirs was in the ear he was selling matured and succulent sweet corn throughout the countryside. He had proved that man's ingenuity could partially conquer the seasons. The second experiment he made was on the possibility of improving a common variety *by selection.* One day he found a potato seedball (a rare phenomenon, since potatoes have so long been grown from replantings of parts of the tubers themselves, and not from seed, that the potato plant has well-nigh ceased to bear fruit), and the twenty seeds contained he planted carefully. By shrewd selection, of which he was to become a supreme master, he eliminated the poorer potato plants that sprang from those seeds; when the little crop came to harvest he found that he had at least four vines producing potatoes considerably superior to any then on the market, and one so vastly better that it was practically a new vegetable. This was the origin of the Burbank potato--a product that statisticians once estimated added more than a billion dollars in fifty years to the wealth of the world.

All these early experiments in "training plants to work for man" had verified his expectations for them, in greater or lesser degree; the discovery of the improved Burbank potato gave him some cash; he decided to cut himself off from a family overconcerned to give him advice and from a climate and soil intractable and obstinate; in 1875 he removed to California and, that fall, settled in Santa Rosa, where he lived and worked until the day of his death. The satisfaction of all his obligations in Lunenburg had taken some of his capital, and for the first year or two he husbanded what was left to such an extent that he did some hard work for small pay and suffered some privations. But he was so fired with enthusiasm and so certain of the promise of his future that not even a severe fever which overtook him could conquer him and in 1877 he established himself as a nurseryman and began to finance his experiments (then kept strictly to himself) by propagating and selling nursery stock.

What Luther Burbank hoped to do with plants (to quote his own words)

> ran counter to all common experience. To think of changing the form and constitution of living things in a few years seemed grotesque even to many people who believed in the new doctrine of general evolution.
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> It was not generally admitted at that time that the plants under cultivation had been conspicuously modified by the efforts of man.
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> And even those exceptional botanists who believed that the cultivated plants owed their present form to man's efforts were prone to emphasize the fact that the plants had been for centuries under cultivation, and to question whether the modifications that could be effected in a single generation would have any practical significance.
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> So it seemed to most people who knew of my enterprise that it was a half-mad project and one that was foredoomed to failure.
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> Of course I had only enthusiasm, backed by the tentative results of early experiments in Massachusetts, to offer in response to such criticism. So it was necessary to trust to my own resources, and prove my case according to my own method.

In 1877 California was just beginning to show promise as a fruit-raising state; nurserymen who realized the possibilities at that early day required faith and patience but were rewarded presently by finding their wares in demand and their business respected. Luther Burbank, whose cards, letter-heads and advertisements announced him as "the Nurseryman south of the Iron Bridge" in Santa Rosa, took in $15.20 in 1877. In 1881, came the first opportunity to demonstrate some of his theories about training plants to accommodate and work for man; it marked the beginning of his career as a plant-breeder and experimenter, by proving that he was on the right track, by bringing him a substantial return in cash and by widely heralding him as an innovator and pioneer in a then almost undreamed field of activity.

A well-to-do business man and landowner of San Francisco, Mr. Warren Dutton, had become convinced that there was money to be made in the comparatively new dried-prune industry; he owned a suitable tract of land for growing the fruit; he wanted immediate results. Having heard vaguely of Luther Burbank he went to Santa Rosa in March, 1881, and asked the young horticulturist if it would be possible to furnish him twenty thousand prune trees ready for setting out that same fall. It was an unheard-of project, but Luther Burbank gave it a night's thought and decided that, if he were financed, he could deliver the trees. Dutton agreed to furnish the necessary money, and within two days Luther Burbank had secured and planted, in specially prepared beds, some 30,000 *almond* stones. Within a few days the almond sets were above ground and additional land rented into which to transplant them. The almond stock grew rapidly; in the latter part of June Luther Burbank obtained an ample supply of prune buds from a neighbor's fine orchard and for two months a force of expert men, under the close supervision of the young experimenter, was employed in placing the French prune buds on the almond seedling stocks. By the first of December, when Mr. Dutton was ready to plant his orchard, Luther Burbank was able to deliver to him 19,500 sturdy, budded, French prune trees.

Luther Burbank "botanizing" while on a vacation in the California mountains. Notice the concentration expressed in his half-closed eyes, which were said to be both "microscopic" and "telescopic" in their power; note also his fine, graceful hands--their power and sensitiveness--as he shakes the seeds from the pod of a wild red thistle.

The Dutton contract did all and more than was expected of it for Luther Burbank: it brought him in some much-needed capital, it gave him a statewide reputation that was almost sensational, and, of chief and most vital importance, it demonstrated to the plant-breeder and the horticultural world that, in one respect at least, plants could be definitely trained, directed, guided out of natural habits of growth and development, and made to serve man's urgent need somewhat at his will. Luther Burbank had from the first no doubts on this head, but it was something to prove the theory on a larger scale than ever before; it was more to make even a small part of the world acknowledge the point.

Gateway to Luther Burbank's Sebastopol Experiment Farm where most of his wholesale bulb, rose, and vegetable experiments were carried on, and all the larger fruit experiments.

Luther Burbank now bought a tract of four acres of land on the county road, west of his first location, and with the greatest care and at heavy expense began to prepare it for the work of his lifetime. Into the small cottage on the place he moved with his mother and sister, Emma, who had come out to join him; in that cottage he lived until 1906; on that four-acre-piece he performed most of the work with flowers and small plants that filled his life; under a Cedar of Lebanon which he planted there shortly after taking possession, he was buried when the end of his work came for him.

Luther Burbank's methods and technic in plant breeding and improvement, completely revealed in the pages that are to follow, and in his own words, were developing in his mind during the early years already sketched. Three have been outlined; that is--

(*a*) Bringing about unseasonal growth (with the sweet corn at Lunenburg).

(*b*) Taking advantage of the variations in seedlings (with the potato).

(*c*) Speeding up natural processes in wholesale lots (with the Dutton prune order).

Other experiments that he had successfully concluded had demonstrated to him that the field of possibilities in plant breeding were almost limitless; he had proved by 1883 that he could (*d)* acclimatize plants brought from other climes and make them useful and valuable in America; (*e*) "domesticate" wild things; (*f*) by hybridization combine or emphasize characteristics in plants; and (*g*) by selection add desirable qualities to plants of all kinds already known and grown, obtaining, for example, new colors, larger flowers and fruits, more compact growth, improved flavor or fragrance, and so on. He knew that he was at the threshold of discoveries and achievements unrealized by any man who had gone before him; from that time forward he was never in any doubt, never hesitated, never could be discouraged nor turned aside. The story of his life from those years of the early eighties to the end was merely the story of how he put his new knowledge into effect for the betterment of horticulture and the greater happiness and good of mankind.

In the fall of 1884 he received a large consignment of Japanese seeds and seedlings, and the year following he sent for more, including several plums. He had already realized that, to get done what he wanted to do in the short span of a lifetime, he would have to perform all his experiments on a large scale; this required room and so he added to his experimental gardens a sixteen-acre farm, of land as fine as any in the whole state of California, at Sebastopol, eight miles from Santa Rosa, in what later developed into the famous Gold Ridge apple district. He now had room, as he put it, "to swing two cats in"; he began to communicate with plant and seed collectors all over the world and presently the mails were bringing him all he outside material he could use, and sometimes more, for his new work.

By inference the reader will find the story of Luther Burbank's life in the following pages, for his work was his life and his life was his work. His fame as a nurseryman was local, his fame as an experimenter and plant-breeder spread very slowly. In 1893 he published a catalogue, simple in appearance and modest in form, that set horticulturists, botanists and nurserymen by the ears and that, at first, brought him scorching condemnation for what the wiseacres said was his unthinkable effrontery. But presently it began to be known that what, in that catalogue, Luther Burbank had called "New Creations in Plant Life," were bona fide and that he could prove every claim. Slowly his name began to command respect; presently scientists and botanists, seedsmen and nurserymen, were beginning to make a path to his door; they were followed soon by reporters, journalists, photographers, the curious, the garden-lovers, the general public. Before the beginning of this century Luther Burbank had become "good newspaper copy"; in the year that Santa Rosa and California joined in celebrating elaborately his "Golden Anniversary" of achievement he was one of the ten best-known men on the whole earth, his plants and trees and flowers were growing in practically every corner of the land and myriad's of them abroad, and he had been loaded down with honors, degrees, acknowledgments and the friendship and admiration of men and women everywhere, great and humble.

Even more pleasing to him, though, was the love children bore him, for he loved *them.*

His marriage, in the sixty-seventh year of his life, to Elizabeth Waters, was to him the crowning happiness of his life; with faithful helpers in his gardens, and with his beloved dog, Bonita, half fox-terrier, half whippet, continually at his heels, he counted his blessings as complete. So his last years were filled, almost without a break, with contentment, peace and--to the very day of the beginning of his fatal illness, in March, 1926--with the work he loved and at which he was tireless.

He was laid to rest under a Cedar of Lebanon in his gardens because he once said: "I should like to feel that my strength was going into the strength of a tree."

CHAPTER I

The Principles of Plant-Breeding

THE principles of plant-breeding are simple and may be stated in a few words. But to understand the why of those principles we who are interested in reasons and causes must begin with the facts of Nature that govern life-changes and improvements throughout the whole realm of biology and botany. If this chapter grows a little tedious, my recommendation is that you skip it; perhaps, later, you will want to come back to it when the more practical pages that follow stir your mind to questions and arouse your curiosity. But I will try to make even these dry statements as pungent and tasty as I can.

To begin with, every living thing is *what* it is as the result of the action of two forces: *heredity,* which is the sum of all the history and habits of *the race,* and *environment,* which means the numerous complicated outside forces continually working on the *individuals of the race.* The plant-breeder's work is to guide the action and interaction of these two forces--to take advantage of a plant's heredity and to influence its environment. And he is limited to these two means; there is no magic or wizardry in his business; he must work with the tools and according to the laws that Nature gives him, and his only improvement on her methods is to find short-cuts and invent devices for speeding up her processes.

When you look about you you see no development in the plants you know--they seem the same to you as they were when you were a child, and you wonder what is meant by "plant improvement." It is true that many varieties have experienced little change in the past few centuries--some of them little in the full breadth of man's history. Nevertheless we know that changes have occurred and are occurring; the very existence of the higher orders of plants was brought about by gradual evolution, step by step, from lower forms.

What is this "evolution" in plants? It is not so formidable as it may sound: it means that, through crossing--what in animals we call mating or breeding--variations came about; and these variations were such that a changing or new environment did not kill all the individuals, because some of them--those best fitted to survive--took root and grew and flowered and came to seed. And in the same way it means that there was a gradual improvement in the strength, adaptability and (as we shall later see) in the beauty and usefulness of the beneficent plant life on earth. At the same time and from the same cause there was an increase in the strength and viciousness of poisonous and destructive and harmful plants, for Nature plays no favorites and under her laws the gentle cow and the predatory wolf, the beautiful rose and the deadly aconite, the meadow-lark and the cruel "butcher-bird" have developed and become stronger through the generations. But on both good and bad sides weaklings and the unfit died.

All changes and improvements, whether good for man and animals, or bad for them, were made possible, I have said, through breeding or crossing. That is, through progressive developments in the *heredity.*

Close observation in your own garden or in any field or on any hillside will demonstrate to you that no two plants of any variety are exactly alike. Examine two heads of wheat, two violets, two pine trees, two apples, and you will find that each is an individual--as much so as people--even as much so as twins who, at a casual glance, appear identical. The plant-breeder, starting with this fact, searches for individuals having tendencies or powers or qualities that seem to him desirable, and by using them as "parents" presently finds himself with second or third generation individuals some of whom have those desirable tendencies or qualities *slightly accentuated.* It is thus that he makes his beginning toward the breeding-up of a new strain or variety. He also finds ways to speed-up this natural process of change, and because he can hurry Nature along he is able to do considerable in one lifetime--much more, you can see, than a horse-breeder can, for example, or a man who might be working with elephants.

Happily, Nature cooperates with the plant-breeder in his work, and when he understands the rules he can presently begin to use the second tool with which he begins--namely, environment. When we capture and domesticate plants and give them favorable surroundings--care, cultivation, water, protection from their enemies, and encouragement to put forth their best efforts--they have more leisure, so to speak--more surplus force--to comply with the demands we are making on them. There are plants that are obstinate and set in their ways; a little experience teaches us that these have always lived narrow, restricted lives--have been bound to a fixed environment, and therefore have had no experience in changing themselves. On the other hand all those that lend themselves easily to our efforts to change them are, we find, plants that have, through the ages, *been in the habit* of changing their environments--of adapting themselves to different climates, soils, and moisture conditions. You see, these latter plants have in them a heredity that has stored up life experiences under varying conditions, and therefore they will learn more readily, whereas the former kinds of plants--the one-type kind--have become set in their ways and don't know how to learn new ones.

Now, this *ability to vary* which is the plant-breeder's opportunity, arises from the fact of sex. There are living things that have. no sex and there are others that have the two sexes in one body; but those types tend to stand still, and have through the ages. Progress and change in nature, adaptability, and (for our purposes) beauty or usefulness to man are made possible through the fact that two individual plants, uniting, give their seeds all the powers and possibilities of *both* families, that may have come to maturity under considerably different conditions, even though they grew a few feet or a few rods apart. The mountain wolf comes down and mates with a plains wolf, and their pups are better fitted to live either in the mountains or in the plains than either parent was. So with the violet or the sunflower or the pine tree or the apple. This power to vary which results on cross-mating (what plant-breeders call cross-pollination, or hybridization), puts into the seed something invaluable to the work we are trying to do, because it enables us to select the individual plants that vary *in a direction we want them to go.*

The story of this influence of sex on all living things goes back to the earliest times, aeons ago, when protoplasmic forms multiplied by division--the breaking apart of cells. There came a time when some cells, we do not know why or when, developed specialized cells in themselves that had the job of reproduction given them; they were so simple in structure that they were dependent for transportation on *water,* and unless they were so carried they could not meet and mate with others of their kind. Naturally these primitive forms varied little.

Centuries passed and in long ages there appeared such plants as pines, depending for the mingling of their life-streams on *winds.* Now progress was more rapid, but it was still inconceivably slow until the next stage was reached--the stage when *insects* appeared. There followed an era of most astounding development. More than a hundred and forty thousand species of plants were brought into existence. At the same time a beginning of advertising was made--the use of beauty and color and fragrance and honey by the blossoms to attract insects so that they would not fail to do their job of transporting pollen and so mingling heredities. No plant or tree that depends on water or wind alone to carry heredity has bright colors, fragrance or a store of honey, while all that do have these allurements depend on insect life for hybridization. Later we will study the highly specialized appeals and devices that plants developed in this race to make useful friends of insects and birds; for the moment we merely observe that sex thus came into its full meaning and began to perform its real service in bringing together two different family heredities, merging them in one new-born individual, and so making possible the survival, through natural selection, of the fittest and best adapted and most adaptable "children" of a new generation.

It is plain that favorable conditions will enable any plant or animal or human being to reach its highest perfection *as an individual;* but the plant-breeder's task is not to concern himself with the individual as such; his task is to improve *the whole variety.* This job he begins with seed capable of variation; from the resultant plants he selects those that meet his demands; then, by repetition, he so *impresses* the improved characteristics on that variety that there is no slipping back into old inferiorities. You may observe in your own garden that, if you save seed from your sweet corn at random and plant that seed year after year, just as it comes, your sweet corn will deteriorate and become unsatisfactory and inferior in every way. But if you select your seed corn carefully you will get uniformly *good* quality. If, in addition, you weed out the inferior plants that result here and there even from the best of seed, you will get uniformly *better* results because you will be speeding up the action of improvement through natural selection. If, on top of this, you artificially cross-pollinate the very best plants and so accelerate the natural process of variation-toward-improvement, you will get the uniformly *best* results --you will, in short, be a plant-breeder. Finally, if you will persist, year after year, in this routine, you will fix the most desirable qualities in your corn and you may achieve what amounts to a new and improved variety. That, in substance, has been my work for sixty years. That is the formula for plant-breeding.

There are two questions all thoughtful people ask here, when they are thinking about the wonderful and beautiful machinery of evolution: first, why should Nature care what happens to a plant, or an animal or a man?; second, why does she care to improve the race, or any species? The answers give you a still clearer view of the wonderful scheme of things.

First: Nature cares little or nothing for the individual, but she jealously and continuously guards the *species*--the whole community of individuals--against extinction, and erects about it amazing and complex protective defenses to secure its perpetuation. To be sure she can only work through the individual, but her purpose is to equip that individual so that, if it lives and matures, it will be able, not only to reproduce itself, but to mingle its life-stream with that of another individual to give the next generation even a better chance than the parents had. You will read a lot about this subject later on in these pages; here it is only necessary to cite one example of Nature's indifference to the single plant as such, and her infinite care of the species. The example is the mustard that produces thousands of seeds and scatters them far and wide, even though it is certain most of them will never germinate or, if they do, will die; yet some few of the tiny black particles will certainly find root and life.

Second: Nature does not seem to be interested in the *improvement* of the plant or animal--her preoccupation is in making it ever more and more fit to survive in the universal struggle for existence. For man's purposes it may not be the *"best"* that live but it will certainly be the *most fit*--that is, the strongest, the most adaptable, the hardiest. Weaklings, the malformed, the unfit, are crowded out or pushed aside or destroyed by enemies, in the natural state. Civilized human beings are the only animals that seek to preserve their unfit and (what is worse) permit them to reproduce their kind. Everywhere else in her wide domain Nature eliminates them.

The natural process, therefore, is keyed all along the line to the preservation and reproduction of the individuals most fit to survive. These not only live but they thrive, for they are strong enough to seize the best food, the most favored environment, the safest spots for growth and for their descendants. And this is not a static process, but is a forward-marching process. Not only must the strongest and best individuals survive and thrive, but constantly changing conditions around them require that they reproduce themselves (through the mingling of strains by means of sex) in sturdier and stronger and more adaptable forms.

It would be easy to say that this process is one of improvement and therefore that betterment must be Nature's aim if it were not for the fact that, when Man speaks of improvement, he means betterment from *his* point of view--an improved condition to meet *his* needs or demands. There is a great deal of that sort of improvement in Nature, as when the pines and oaks grow strong enough and sturdy enough to withstand the fiercest storms and therefore to furnish Man protection from them. But you would not say that it was an "improvement" as far as you are concerned that the blackberry vine has, in past ages, learned to protect its seed-bearing berries by putting out a myriad of thorns! Nor that the tumbleweed is "improved" by becoming light as a feather when dry, and shaped like a ball, so that the wind can roll it across your field and scatter its vicious seed hither and yon to infest your wheat! No, Nature wants to protect the species from destruction and make it certain that it will reproduce itself-and there she stops. But under her laws it is Man's privilege and opportunity to take advantage of the plant's adaptability; to step in and actually *improve* her children for his own use and *better* them from his own point of view! And that, of course, is where the plant-breeder enters the picture!

This seems as good a place as any for me to say that the possibilities of plant improvement are infinite and that the surface has only been scratched. If the potato could be improved so that its value to the human family was increased in fifty years more than a billion dollars; if new fruits could be developed by one man during the course of his lifetime, while tens of thousands of experiments in other lines were continuously going forward, so that the whole history of orchards and fruit production was affected favorably; if hundreds of new plants and flowers could be introduced to brighten gardens and to increase the income of the truck gardener, while all the other work was progressing, then it must be obvious that the task is not finished. It is, in fact, barely begun.

The inventor, the chemist, the electrical genius have all contributed untold wealth and happiness to the world, and their work still goes forward. But I assert that the most priceless legacy which man has ever received from any source in the study of Nature lies in learning to guide the creative forces of plant life into new and useful channels. The possibilities are little understood, and can scarcely be estimated. It would not be difficult for one man to breed a new grain which would produce *one* grain more to each head, *one* more apple, plum, orange or nut to each tree, or *one* more potato to each hill.

What would be the result? In five staples only, in the United States alone, the inexhaustible forces of Nature would produce annually, without effort or extra cost, 6,000,000 extra bushels of corn, 15,300,000 extra bushels of wheat, 42,000,000 extra bushels of oats, 2,100,000 extra bushels of barley, 24,000,000 extra bushels of potatoes. If it is objected that we are now producing more than we should (which seems sometimes true, even though in fact it is not), let us change the hypothesis and suppose that the plant-breeder produces the same amount of grains and vegetables and flowers and fruit, but makes them richer, more succulent, more valuable to eat, or more gratifying to see and smell. Let him give us quality, rather than quantity, since he can do either, almost to your order. Would that not be of inestimable value to mankind?

And these vast possibilities are not alone for one year or for our own time or race, but are beneficent legacies for every man, woman and child that shall ever inhabit the earth. Moreover, who can estimate the elevating and refining influences and the moral value of improved flowers, with all their graceful forms and bewitching shades and combinations of colors and exquisitely varied perfumes? These silent influences are unconsciously felt even by those who do not appreciate them consciously, and thus with better and still better fruits, nuts, grains and flowers will the earth be transformed and our thoughts turned from base, destructive forces to nobler productive ones which will lift us to higher planes of action. On that happy day man shall offer his brother man, not bullets and bayonets, but richer treasures of the earth!

CHAPTER II
The Romance of Struggle

EVERY native plant growing on any desert is either bitter, poisonous, or protected by spines or thorns.

The sagebrush has a bitterness almost as irritating as the sting of a bee; the euphorbia is as poisonous as a snake; the cactus is armored like a porcupine not only with large spines that would frighten off the bravest but usually with microscopic needles that form a secondary and very adequate defense. Why? For the same reason that bees have stings, that snakes have fangs, that porcupines have quills--for self-protection.

Self-preservation comes before self-sacrifice in plant life as in most other living forms. Now if the bitterness, the poison, and the spines of these desert growths are there as a protection then they must have been acquired as the result of some urgent and compelling necessity, for there was a time when they were not needed, as we shall presently see. Here let me say that this is not a theory with me; it is a fact which I have proven again and again, and definitely with the cactus itself. For on my farms the cactus, given my protection and that of my fences and my helpers and my good soil and my planned care, has come to grow *without* those protective spines and to produce incredible amounts of excellent forage and of delicious fruits. And if the plant had not at some time been unprotected it could not have been induced wholly to *abandon* the habit of growing its armor.

"But," you say, "granting all that, do you mean that the cactus at some time in the past foresaw the coming of an enemy that threatened its existence? Is it possible that a plant, like a nation expecting war, could arm itself in advance?"

Let us look for our answers into the history of the cactus.

Those parts of California, Nevada, Arizona, Utah, and northern Mexico, that are now the home of most of our cactus, were once the bed of a sea. All around that inland sea grew perhaps a myriad of plants, of many varieties, thriving and multiplying in the climate made pleasant by the great body of water there. Among these was the cactus, undoubtedly with well-defined stalks, thin leaves, succulence, and more or less inviting fruits.

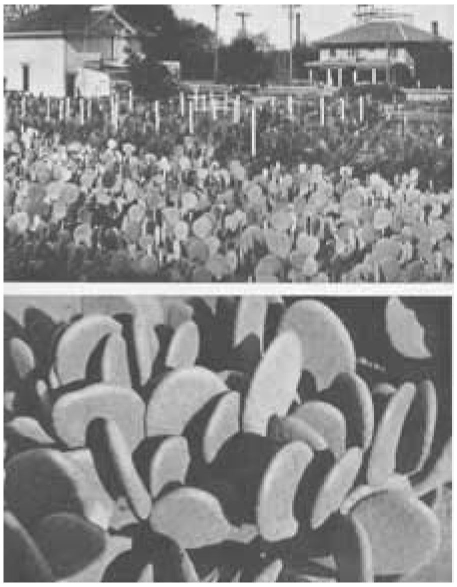
But physical changes in the region resulted in cutting off the sea; heat increased; the sea dried up and disappeared. In its place developed a wilderness of sand--a formidable desert. Here was a challenge to all living things in the region; animal life could flee before the increasing heat and aridity, but the plant life was doomed to stay. It must either adapt itself to new conditions or perish. And the cactus began the adaptive process at once.

It gradually dropped its leaves in order to prevent too rapid transpiration of the precious moisture. It sent its roots deeper and deeper into the damp substratum which the heat of the sun had not yet reached. It thickened its stalks into broad slabs. Thousands of *individuals* died, but the *species* persisted. At the same time there were probably other families of plants that failed to transform themselves rapidly enough and that perished. The sage and the cactus, the mesquite and the arrow-weed--a few lived, only because they were able to keep step with environmental changes.

But now we find another enemy entering into the life-story of the cactus: hungry animals, perhaps antelope. They fell on the succulent and moisture-laden plants (the cactus is, by weight, more than 90 per cent water!) and soon were threatening the desert growths with extinction. Therefore those that were to live must add to their heredities another protective device--armor without, or distasteful or dangerous elements within. Undoubtedly the cactus family lost millions of members here again, but a few thousand lived, because they chanced to have a tougher fiber and outer skin and because they had rudimentary spines. The few, even though eaten to the ground, were strong enough to send up new leaves, and with each new crop the "hairs" on the leaves became stiffer and longer, harder and more pointed, until finally, even if there was only *one* survivor, there was developed a cactus effectually armored against its every animal enemy.

Now observe that this severe testing and this desperate struggle, just as test and struggle give us humans greater strength and capacity, endowed the cactus with many truly remarkable powers and qualities, some of them almost unique in all horticulture. The cactus slab has in it a life-force that is incredible for strength and vitality. Lay one of them on hard ground, without water, and presently the "eyes" on the underside will begin throwing out roots. If they get the slightest foothold the "eyes" on the upper side will develop baby slabs and blossoms. Young cactus slabs that I laid on a burlap-covered trestle of boards threw out long roots in a few days that grew until they reached the ground, three feet below. A cactus plant pulled from the soil and tied in a tree remained there for six years and eight months, and at the end of that time was planted and grew. A slab, long forgotten in a closet in the dark, was found after two years--and on it was a puny, sickly, but living baby slab!

There is the answer of Nature to your question. The cactus did not "foresee" the vicissitudes and arm itself against them, but Nature had stored in the plant, as she does in all living things, the *power to vary* and, when environment changed, those variations were wide enough so that the whole life-story of the cactus was changed.



ABOVE: An early stage of the great spineless-cactus experiment. It was carried on for twenty-five years, ended in the complete achievement of the naturalist's purpose. BELOW: Close-up of spineless cactus. When perfected, it produced prodigious tonnages of smooth, succulent leaves, useful for feeding stock and entirely free from spines. Prejudice and neglect to follow his hints prevented the Burbank cactus from coming into wide use.

This power in any species of plants to vary is illustrated in another way by the algæ. In one form, or branch, it exists as the snow plant, a beautiful red-flowering spike that grows in the ice and snow of Arctic regions without touching earth; another division of the same family grows in the waters of Arrowhead Hot Springs, in southern California, where the temperature is so high that eggs may be cooked in the self-same springs. Another cousin is the mighty growth of the Sargasso Sea, made up of small algæ plants growing in dense and tangled masses; some algæ grow on and in animals, some on other plants, some on iron, some on dry rocks, some in fresh water, as in garden pools.

Another example of variation, remarkable because the divergent types are but a few rods apart, is found in a member of the lily family--the trillium--in mountain canons in California. The flowers of the plants growing on the shady side of the cañons are larger, the plant leaves broader, the bulbs smaller and nearer the surface; on the other side of the cañon, where the trillium is exposed to the sun, the bulbs are larger and grow deeper in the soil, and the leaves and blossoms are smaller, to conserve moisture.

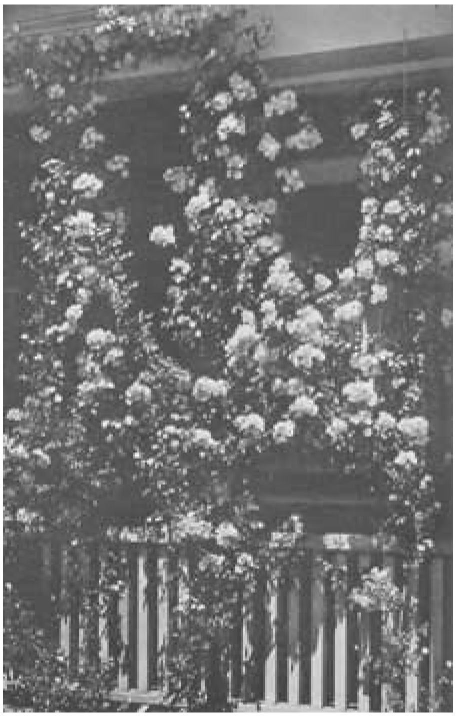
But I think the most sensational adaptation I have ever encountered is that which, in past ages, has been made by certain pines in parts of California where the presence of volcanoes must once have caused frequent and destructive fires. The cones of most pines take two years in which to mature the seed, therefore those cones open at the end of that period to release the precious germs for growth. But if these seeds do not germinate at once thereafter, they die. On the other hand the pines I am writing of in the volcanic sections of the Southwest produce cones in great abundance and at a very early age, some of them when the trees are only two or three years old. These cones remain closed on the trees so persistently that the new wood sometimes grows over them, but the seeds inside remain strong and alive. And here is the marvelous fact about these fire-challenged pine cones: the cones refuse to open until a fire has swept over the region; then the accumulated supply of cones open, even though thirty or forty years have elapsed, and the next year the ground all about will be found covered with baby pinelets almost as thickly sown as grass seed in a lawn. Of course, very few of these survive, due to the crowding, but the strongest of them persist and so, even after a destructive fire, those amazing pines spring into being again and, though *individuals* have been lost by the millions, the species persists!

Now let us consider another phase of the struggle for existence and its romance in the plant world: the infinite ingenuity of variations in Nature.

Did you ever stop to wonder where flowers get their colors? They have them as a response to the color senses of bees, butterflies and birds; they acquired them through ages of adaptation in order to attract the insects and birds that were useful to them in effecting cross-pollination.

Let us pick up a carnation or any other common garden pink (*Dianthus*), and examine the structure. If we strip off the petals soon after they have opened from the bud and slice the blossom in half we will find ourselves looking into a tiny, long, cylindrical nest of dianthus eggs--soft, white, moist, mushy eggs with only a tender, skinlike covering as shells. Neatly packed in a pulpy formation these eggs are incased in a well-protected nest, longer than its breadth and oval except that its top extends upwards in the form of a single tiny stalk. Surrounding this bag of eggs with its single upright stalk, and hugging it closely all around, are very slender, modified leaves, half an inch in length, each ending in a pointed spine about the size of the bristle from a hair-brush, arranged in circular form to shield the egg chamber and its central stalk from harm. At the top of the surrounding stalks we see crosswise bundles, neatly arranged, of beautiful slate-gray pollen dust, loosely held in half-burst packages. At their base we find the dianthus honey factory and the fragrance shopa group of tiny glands which manufacture a sticky confection that covers the bottom of the flower with sweetness and delightful odor.

Shall we take one of those egglike seeds from the nest and plant it? We might as well plant a toothpick! Shall we take a package of the pollen out and plant that? We might as well plant a pinch of flour!



Four seedling roses which were tested by being planted along the porch of Mr. Burbank's Santa Rosa home. They were all of the "cluster" type, most of them fragrant, all of them popular and widely planted after the introduction of the best of them by Mr. Burbank or by nurserymen who bought from him.

But let Nature combine a grain of that pollen with one of those eggs into a seed and in ten days in the soil it will develop into a living, growing thing--a new dianthus plant, with an individuality, a personality all its own; something that has never lived before, yet that has within it all the tendencies inherited from ages of ancestry, waiting only on environment to determine which of those inherited tendencies shall predominate. We all know enough to be satisfied that we could not ourselves cover the ripened seed with the pollen and get results, but we can work with Nature--become plant-breeders to that extent--and by this cooperation achieve results. How do we go about it?

Examining the central stalk that grows up from the nest of eggs we see that, as the flower grows older, the stamens fall away and a transformation occurs in that stalk. Its upper end, which at first was single, now shows a tendency to divide into two or three curling tendrils, moist and sticky, and covered with hundreds of microscopic fingers designed to catch and hold pollen dust. Our share of the task of cross-pollination is to take a few grains of pollen, place it on one of these *stigmas* as they curl from that central stalk, which is the *pistil,* and so start an immediate and vital process in motion.

Once planted on the stigma of the pistil the pollen grain begins to throw out a "root" downward through the stalk of the pistil until it taps the egg chamber and makes possible a union between the nucleus of that pollen grain and the egg below. The crossing or "breeding" of the dianthus is thus finished and it remains only for time to develop the seed in its tight little shell until, ripened and dry, it is ready to be planted and to furnish us with that new dianthus individual we have mentioned.

But here is the marvelous and ingenious difficulty made by Nature to insure *cross-pollination* in the pink: the ripe pollen dust is always gone in the flower before the pistil opens its sticky fingers to receive it. Therefore, to make a combination between pollen grains and the egglike seeds it is necessary to find a blossom that is in its pollen-bearing stage and then find another blossom which has passed this stage and shows a receptive stigma. We are compelled to make the combination *between the two* instead of *in the one blossom.* I have already told you that Nature insists on preserving the *species;* we may now add the law that she usually insists on cross-breeding to insure variation, which insures a commingling of inherited tendencies, which insures the power of adaptation to a changing environment. And now perhaps you begin to see what a field the plant-breeder has open before him! Taking advantage of this law of Nature he can produce, almost at will, new colors, new odors, new sizes, new plant-forms--even new varieties, and therefore an absolutely infinite number of combinations of these.

But we must not lose sight of the part that insects play in the normal development of Nature's scheme--the reason for color and perfume and honey in the flower. The dianthus, or common "pink" is a good object lesson, because it is one of the many flowers that have been so anxious to produce *variations* in the offspring that they have lost the power of self-fertilization, risking their whole futures upon the cooperation of insects and other means for bringing pollen from a neighboring plant! And that would be too great a risk for Nature to permit the pink to take if the flower had not clothed itself in beauty to attract the eye of insect and bird, developed a perfume to appeal to the sense of smell and baited its friendly trap with honey to induce the pollen-bearers to come inside where they would be sure to catch on wings and legs and bodies some of the precious grains.

Now compare the romantic struggles for existence of the cactus and the garden pink! The cactus had to arm itself, provide itself with ample water in an arid land, don a thick, crusty coat to prevent evaporation and develop amazing vitality so that it could lie neglected for years and then, when the opportunity was afforded, burst into abundant life again. The garden pink had no such problem, but it was seeking variation in its children, so it went to all the trouble of dressing itself up and perfuming itself and adding a candy-factory to its equipment, to invite bees and insects of all kinds to come and do for it the pollination work it could not do itself unless it were to inbreed over and over again and so degenerate or be snuffed out by an unfriendly environment. And it is worth while to note here that the reason the dianthus, among many flowers common to most of the gardens of the world, is found everywhere is that this habit of cross-pollination, giving it the power to vary, has made it able to grow in almost any soil, in almost any climate, and under almost any condition of cultivation that you choose to name!

Another example of the romance of the struggle for existence in flowers is furnished in remarkable fashion by the arum (*A. dracunculus*) that is sometimes called the carrion lily. This is of a color and texture like liver or an "overripe" beefsteak, and it gives off a most penetrating and distasteful odor very like that of spoiled meat. As there is a reason for everything in Nature, if we search far enough, so there is a reason for the ugliness and stench of the carrion lily. What is it?

Undoubtedly this arum, stranded sometime in the past in a place where flies were its only available messengers of reproduction, was compelled to make itself attractive to those flies. Now, flies prefer carrion to anything else, so the stranded flower gradually adapted itself to this fact and both in appearance and, in odor suggested to the insect that here was his favorite dish. And to make doubly sure that any visitor would receive its load of pollen the carrion lily developed so that it can close on the entrance of the insect and hold him there for a time, while he beats his wings and buzzes about angrily, seeking to escape. Slowly, then, the flower unfolds and the pollen-laden fly wings away, to find another carrion lily presently and, in crawling in through the narrow throat of the flower, dust off against the stigmas the precious pollen.

In order to vary so that the species may be certain to survive (this is the refrain this chapter sings for you!), let me quickly give you four out of the thousands of interesting tricks of flowers to insure pollination.

In certain varieties of sage the pollen-bearing stamens actually descend and quickly rub their yellow dust on either side of the entering insect, after which they fall back into their proper position.

Some orchids bear their pollen in small, compact bundles so placed that no visitor can come and go without having one of these bundles attach itself to his head. It glues itself there and curves upward almost like a horn. But once the insect is free the horn bends downward so that when entrance is made to another orchid there is almost no possibility of the pollen bundle failing to reach the pistil of the flower. There is another orchid that goes farther: as there are two stigmas it loads the caller down with two bundles so nicely placed that they will almost certainly touch *both* the proper receiving stations in the next flower visited!

The pollen of the milkweed is stored in two tiny bags connected by a sort of strap; in the strap the feet of bee or honey-loving beetle become entangled and so that delivery is guaranteed!

But we cannot linger longer with this fascinating story. We must get on, for Nature has many stories yet to tell us, and after that we have to come to the main job, which is to explain how all these devices, rules, tricks, subterfuges, and processes are used by the plant-breeder in "training plants to work for man."

CHAPTER III
The Rivalry of Plants

YOU have observed perhaps that the economists and other wise fellows who tell us about business, finance, commerce, and those complicated subjects, talk a great deal about this "age of competition" in which we live, and you might almost think that cut-throat competition was something man had taken out a recent patent on! But it is not true: for ages animals and plants have been competing--have been rivals in business, just as our merchants and manufacturers and shipping men are to-day, and the competition has been for the same purpose--a race for prosperity--that is, for "a place in the sun."

We have seen that flowers donned beautiful colored dresses and put up confections and gave themselves odors to attract the insects; but there are certain plants to which color is a disadvantage--for instance, the night-blooming flowers. At night a red or blue flower would not be seen, therefore you will find that the flowers that blossom at night only--and there are many of them--are invariably, as far as I know, either white or yellow. Why? Obviously, so that they can be seen by night-flying insects.

The fact is that the advertising business, which has grown so great because of the keen competition between men to sell their wares, is an old art with the plant world: color and odor and nectar are all advertising devices. And we find certain flowers that carry the advertising campaign to pretty great lengths, some of them with variegated gowns planned to please every taste; some set on stems so fragile that they dance with every slight breeze, thus calling attention to themselves with movement as well as color and fragrance; some have a pretty trick of pretending to hide, thus exciting the curiosity of and inviting visits from alert and inquisitive insects, which are the very kind best suited to do the work of pollination for the shy blossoms.

Let us look for a minute at the corn. Corn is a businesslike and efficient vegetable, with no time for foolishness and no taste for colors, therefore it must have long since given up hope of flirting with the insects and have decided to trust to the wind, which has always been a good friend of plants and trees. And so the corn grows tall and supple, holding its pollen-laden tassels at the top where the wind, swaying the plant, can shake loose the pollen grains that fall toward the ground and are caught on the way by the silk rippling from the growing ear. Trace each thread of silk back and you will find it ends in a kernel of corn. The corn silk is to the corn what the pistil is to the flower--a through-track to the seed that lies there waiting to be fertilized. And as corn depends on the wind, so do many other grains; so do pines; so do our grasses.

We have seen that the cactus was a stay-at-home body; let us look now at an inveterate traveler that has spread over many countries, thousands of miles apart--the cocoanut palm. In fact it grows in so many places, in the hotter climes of the world, that no one has yet decided just where it originally started from. The cocoanut palm is in business in a large way, and its zeal to claim new territories led to a clever and interesting development of its nut. The nut itself grows and comes to maturity encased in a tough, fibrous covering that clings tenaciously to it for a long time after the nut falls. As the palms grow along water courses and the sea the ripened fruit often falls into water; presently, even in salt water, one of the three eyes at the end of the cocoanut softens and from it grows a tiny rootlet that winds and winds itself about the nut itself but *inside* that outer coat of fiber. When the nut is washed ashore, perhaps hundreds of miles from its first home, the roots are so well developed inside the fibrous coat that they can catch hold at once in any bit of soil they find, and soon from another eye, or perhaps from two, a baby palm shoot appears and the cocoanut is established and sets up in trade for itself!

A tough little wanderer is the dandelion; it may be that there was a time when he became tired of growing in a limited locality and decided to go out and see the world. And his seeds are now well equipped for journeying, for each is attached to a lighter-than-air fairy balloon with sails--and how they go, up and down, here and there, far and wide, to settle at last in some distant spot! Millions of them fall on rocks, hard ground, the sea, perhaps, but there are so many of them that enough always catch root to make the dandelion a pest to home-folks, especially in lawns. And the dandelion is only one of a great variety of flowers with balloons or aeroplanes or sailboats to carry their seeds about!

One of the wild chicories, in this race to secure business, has even gone so far as to raise two kinds of seeds--those equipped to fly and those that are wingless. The first spread the chicory plant abroad; the second stay at home and keep house somewhere near the old folks; there is no danger of that chicory family dying out for a long long time with such a double provision made!

When I was a boy we used to get a lot of fun out of what we called "the squirting cucumber" which, when ripe, can shoot its seeds with such force that they are carried as far as twelve or fifteen feet away. Another device to insure the perpetuation of the species!

Most of the plants whose seeds grow in pods have, because of that, the power to cover considerable area with their seeds: when the pod ripens and becomes brittle and dry a slight touch or the heat of the sun will cause it to explode and scatter the precious seeds. In Mexico what is called "the jumping bean" has formed a strange sort of business partnership with a moth that, when the pods are green, lays an egg in each one. As the pods ripen the moth egg hatches and the larva begins to feed on the pulpy inside lining, but without harming the seed. The pod shrivels and curls as the larva hollows it out and as the season dries it up; now when the larva moves about it causes the pod to roll and jump in a fashion that is excessively funny to watch but that has, in Nature's system, a definite purpose--it gives the pod locomotion and so brings it to a new location where it can be pretty sure to find a crack or cranny in which to grow.

The "devil's-claw" (*Martynia*) has developed a power to bite and cling with cruel ferocity to any passing animal; it hooks its claws into leg or side and then, when the tortured animal runs or tries to scratch it off, the pod drops its seeds, one by one.

These are just a few of the ways in which plants, in the keen competition for growing space, for advantage in the struggle, for dissemination of their seeds to insure variation and so insure themselves power to adapt themselves to changing environment, compete with their brothers. Wherever we look we see some new display of ingenuity, and it is all, finally, for the sake of variation, which may mean retrogression in some cases but which, in the long view, means progress. Every flower that delights our eye, every fruit that pleases our palate, every plant that yields us a useful substance, is delightful or pleasing or useful simply because of the improvement that has been made possible through variation.

In every plant that grows we see two tendencies--one to ward off enemies, the other to make use of friends.

To plants growing wild, frosts, winds, storms, droughts and vegetarian insects and animals are their principal enemies. In the wild state, again, bees, birds, and butterflies, the warmth of the sun, the moisture and fertility of the soil--these are their principal friends.

But when we transplant these growing things and put them under cultivation, we upset their whole environment.

When we build fences around the blackberry we remove its need for thorns. We save the seeds of the radish and the bulbs of the lily, and with our human organization distribute them and plant them wherever they will grow. We cut grafts from our apple trees and ship them the world around. We select and improve, we cultivate and tend, we water and protect all seedlings and give them every favoring condition possible; we remove what for ages have been the chief problems of their lives--we take over their two principal functions--self-protection and reproduction. And presently these favored plants begin to grow more and more for man, catering to his wants, advertising to him their strong points, and working for him to the best of their several abilities.

Here is an example of precisely what I mean.

The common "snowball" in its wild state wears a mere fringe of blossoms around a thickly populated community of egg-nests and pollen; it is advertising to the bee with those flowers, because it needs the bee in its business. But the snowball in my yard, the child of many generations grown *from cuttings* and carefully nurtured, knows no need for stamens and pistils and has therefore turned them into petals and its eggs are sterile. Cultivation, in brief, has relieved it of the necessity for reproduction and what was once a fringe of flowers has become a solid mass.

Another example is the violet that, in its early history, had a bitter struggle for existence because it grew so close to the ground and must have been more often crowded and perhaps killed by other plants than enabled to mature. There are violets that put out advertising blossoms at the top of the plant, inviting bees to help pollinate them, and at the same time grow small, dull-colored, closed blossoms near the ground that, because the bees cannot even find them, have gained the power to self-pollinate. Other violets produce only the advertising flowers, having got their flowers up off the ground and therefore having no further need of those low-growing basement egg-nests.

Into the life of one of the violets a few hundred years ago man came and the flower found itself tended, cultivated, properly watered and encouraged to thrive. Soon this particular violet, as if assured of reproduction, abandoned all its strenuous efforts and devoted itself, in gratitude and confidence, to making bigger and more beautiful and more variegated blossoms for the creature who had been so kind to it--and there you have the life-story of the violet which we now call the *pansy!*

For a moment let us turn to a common fruit for one further illustration of how plants change their whole life histories to please and gratify man. On my experiment farm at Sebastopol grow two ordinary looking pear trees: one of these produces delicious pears, a delight to eye and palate; the other yields pears that are juicy but that never become mellow and that in their uncooked form are almost indigestible. The trees look much alike; it is only in their fruits that they differ.

To understand this difference we must go back to the beginning of the story of the pear. It originated in Eurasia, and gradually spread or was carried by man east and west, north and south, so that there is probably no variety of fruit now more widely propagated. The pear tree on my farm that bears the luscious fruit is a Bartlett, the child of pears that moved steadily *westward* from its Eurasian native land, going to Europe, to England, across to North America in the early days and so gradually westward to California. The pear tree next it that bears the hard and unpalatable fruit is one I imported from China--the child of pears that worked slowly *eastward* from the Eurasian land of its origin.

Why are they so different? Simply because the American prefers his pears large, sweet, juicy, aromatic, and delicious in the raw state as well as when cooked; in Japan and China they do not understand this notion of eating pears raw--they must have theirs hard but juicy and suitable for pickling, preserving or making into a sort of candy, like our glacé fruits. Neither of the two pears is anything like its Eurasian ancestor: each has changed, in the centuries, one toward one set of ideals, one toward another. The pear had the difficult and constant struggle for existence that all other plants have had; it depended for its variability on crossing; it changed and developed and grew sturdy and able to take care of itself in arid land (the pear even now can not stand too much moisture--underground moisture that is too plentiful will kill it every time!)--then, at last, man entered on its scene. In Europe and later in America we informed the tree that we liked fruit that was ready to eat; we refused to have anything to do with it unless it could furnish us that sort of product; gradually we weeded out all those pear variations that did not meet our taste, so that at last we have practically nothing else from it. In the Orient they taught the pear tree that they must have fruit that was juicy and flavorsome, but not soft nor sweet nor mellow when ripe; in time the pear quit trying to foist on the Oriental gardener a fruit that was anything but exactly and specifically what he desired.

Man is the most important influence in the life-history of plants; by this I do not mean those few of us who have devoted our lives to their training and development, but man in the mass--and not only modern man, busy with his store or shop or mine or mill, occupied with his law or his finance or his medicine, but all mankind, back to the primitive. Perhaps even prehistoric man (and woman) scratched at the ground to help their plants grow. Certainly the earliest records we have of the race show that he dug the soil, planted, watered, harvested.

For instance, it was the Indian who gave us the most important crop America produces--corn.

On one of my experiment farms I have grown the original variety of corn which the Indians found and improved until it became the staff of life for two continents--South and North America. The Mexican Indians called it *teosinte.* It bears tiny ears with two steel-armored rows of barleylike kernels on a central *rachis,* or spine, not as large or as strong as the central stalk of a head of wheat.

When those ignorant savages discovered, either by chance or by study, that the few grains borne by the teosinte were palatable and nourishing they began to make crude garden beds, plant the seed with care, perhaps carry it a gourdful of water in the hottest weather of the spring and certainly to give it the best chance they knew how so that it might develop and not be choked out by weeds or burned up by the sun's heat. The *teosinte* responded. Since it had in its life-germs the power to vary it inevitably varied in some cases in the direction of sturdier stalks, or larger ears, or more numerous rows of kernels, or with kernels themselves of greater size. Or, in rare cases, perhaps in more than one of these particulars.

From two the rows of kernels increased to four--to eight--to twelve and more. Slowly the corn plant itself changed; the larger and sturdier it became the greater necessity it found for changes in root structure, so this developed and spread out to support the taller and more luxuriant growth above; the tiny ear became a sizable affair; the kernels grew to many times their original size. The Spanish called it *"maiz"* and carried it north into the regions that are now California, Arizona, New Mexico; the use of it spread rapidly. Originating in a hot climate it found itself slowly moved into areas colder and colder, so that it was forced to change its growth-habits--come to maturity faster, for example, and germinate in the chillier mornings of the northern summertime. It had to adapt itself, in short; it was able to do so because it had the power to vary and because it had the friendly--though selfish--assistance of man.

Oddly enough it has not been only an increased usefulness, sturdier growth, or more generous production of fruit or grain or blossom that has resulted on man's interest in plants. Even his eccentricities of taste and other characteristics have been impressed on his growing things. Let me tell you a story that illustrates that angle.

Peter Barr, a great English bulb expert, once bought the entire daffodil gardens of two of his countrymen who were persons of an almost directly opposite build, nature and taste, one from the other. In some way the two collections became mixed, so the bulbs were planted indiscriminately. Yet, when they came to blossom, Mr. Barr could tell you without hesitation which daffodil originated in the collection of Mr. A and which in that of Mr. B. When I asked him how this was possible he explained that Mr. A was a large, florid, ostentatious man; B was quiet, cultured and had fine taste and great discrimination. A's daffodils were like himself--showy, brilliant, big; Mr. B's were delicate, dainty, charming. A had only grown and bred the kind he liked--unconsciously, perhaps, he had liked the flowers that resembled himself. The same for Mr. B.

I have often said that your garden tells a story of yourself and your nature and character that any discerning man can read. It is, in fact, a sort of photograph, in pattern and color, of your disposition, habits of mind, tastes, and likes and dislikes. To that extent have flowers varied to please and gratify man; to that amazing extent have they developed, and will continue to, to meet his wishes!

CHAPTER IV
New Flowers and New Colors

AMONG our human acquaintances we know those who are sturdy and those who are weak; those who have well-developed minds at the expense of their muscles and those with well-developed muscles at the expense of their minds. We know some who are tall and some who are short; some with brown eyes and some with blue; some who lean toward commerce and some who lean toward art; and so on and on and on through an infinite number of variations and an infinite combination of these variations, each variation representing the result of present environment reacting upon all the environments of the ages, stored in us at birth--that is, upon heredity.

Let us observe one of the enormous advantages to the race of these varying characteristics and temperaments in people. As a means of locomotion we had our feet, first; then we rode horses, made crude carts, improved them and made carriages and wagons and stages; then, suddenly, the railroad came. On the day the first successful engine and passenger car moved along fixed rails there were not more than three or four men who knew anything about railroading in any of its branches.

And yet, in a generation, we found variation and adaptability enough among us to develop surveyors to carry their transits over the plains, rivers, mountains, and lay out a route; draftsmen to put the plans on paper; we found woodchoppers to make ties, bridge-builders to erect stout bridges across the streams, steel-makers who for the first time in their lives designed and modeled and made steel rails; we found engineers and firemen and switchmen; we found superintendents and presidents; we found every man we needed to make this unheard-of experiment a complete and permanent success as the world's primary means of land transportation. The variation of characteristics, temperaments, abilities was there in the race, and when the need arose the individuals peculiarly adapted to the purpose were at hand, thanks to variability, to perform the function.

Sometimes people marvel that a heterogeneous group of colonists could think out, frame, set up, and put into working order a new government in America in 1770-90; but there is nothing strange or marvelous about that fact except as the laws of Nature are strange and marvelous and amazingly exact. For, when you examine the facts, you discover that the great majority of the people who made up those early American settlements were people who had rebelled at the old forms of government, whether in England, Scotland, Ireland, France, or the Palatinate of Germany; they were dissatisfied with the conditions of their lives, principally because they had been persecuted for the sake of their several religions; they were bold, desperate, and resourceful men, or they would never have undertaken the long, hazardous journey across the almost unknown ocean, or braved the dangers, known and unknown, of the wilderness.

Why did they not set up a king, give power and land to barons and aristocrats, volunteer as slaves and serfs and peasants to serve the chosen few, establish a priesthood to tell them what to believe and how to worship? The question answers itself. Not only had they come to America to get away from all that old-world environment, but they *varied* from their brothers who were willing to stay where they were--and from those with fixed or habit-made ideas about religious freedom and politics. It took scores of generations for this variation to become widely implanted enough to furnish the men and women to start an experiment in government, but when the time came there they were-frontiersmen, makers of a constitution, builders of government, financiers, lawyers, manufacturers, laborers, strong men, weak men, leaders and followers, statesmen and failures, but all containing in themselves the power to make and give permanence to a United States of America!

On and on we go, then, in this wonderful world of ours, one step backward sometimes, then two steps forward, marking time here and making a sudden spurt there--the pear tree, the violet, the animal world, and we humans. Each individual is a little different from the rest, each with a separate combination of old environmental influences stored within him, finding always an infinity of new environments to bring it out, and all of us depending on the others, as we go forward playing each his separate part in the march of progress through adaptation.

Knowing that this infinite variation is to be found in every living thing let us see now how we can use that provision of Nature to add new flowers to our gardens and new colors to the flowers already there.

An architect, in selecting materials for his structure, may send for limestone to Indiana, for granite to Vermont, for hardwoods to South America, for bricks to New York state, for pine and redwood to Oregon and California. In the process of turning his blue-print into a building he draws on the whole world for his materials.

So, in the production of a new flower or color, we must go to the place where the working materials are to be had--in our case, to the store-house of heredity in the plant itself. Of course, if the quality we are looking for isn't there, we are wasting our time. "Do men gather grapes of thorns or figs of thistles?" But Nature has stored in all plants so many possibilities and so many tendencies, perhaps dormant for centuries, that we can do surprising things by taking advantage of those inherent qualities. Our task is to isolate the particular characteristic or "leaning" that goes along with our plan, accumulate it by careful selection and cross-pollination, intensify or multiply it--and presently we have induced the plant to do our bidding.

But we must work *with* heredity, not against it. True, it is possible to drive a plant against the current of development that is carrying it along, but there are so many flowers and trees and vines and shrubs that are already going our way that it seems extravagant to choose the difficult ones. You may take it is a rule that a habit, whether in a plant or a human, once fixed, grows continually more fixed and set: if you are accustomed to rising at seven you will for a time find it difficult to sleep through till eight or to waken at six; but once you have acquired the six o'clock hour in your sub-consciousness, or the eight o'clock, you will presently find it increasingly difficult to return to seven. Every one who has been governed by the "daylight saving" rule will testify to this. The cactus, which produced its first spines as a weapon of defense, did so with difficulty and took many generations at the job; it was not easy to induce it to abandon spines, even when they were no longer necessary to it; but once that was accomplished and the spineless characteristic was *fixed* it would be almost as hard to get the cactus to grow its needles once again.

Let us take a practical experiment in color.

We procure first the seeds of two African wildflowers: the African orange-colored daisy, and a white one of the same family. The orange daisy is a sun-loving flower, as its beautiful, rich tint testifies. The white daisy shows unmistakable evidence of having lived for a long time in the shade. But it is easy to see the family resemblance between them. Leaf formation, root development, arrangement and number of rays, stamens and pistils, all bespeak a relationship. The white one is a little taller, more graceful and less hardy, which would serve to indicate that it began by being a sun-plant like its cousin, the orange one.

If we plant the seeds of the orange daisy in the shade it will grow, though not so flourishingly as in the sun, but it will have orange flowers; plant the white one in the sun and it will continue to bear white daisies. That is stored-up heredity, clinging to its latest habits. If either daisy lived, bloomed, went to seed, bloomed, seeded, grew, and bloomed again, and so around the. cycle for many generations we might reasonably expect the two to change colors. Environment gave them their colors; environment could change them. But the process is too slow. We are in a hurry.

ABOVE: Two variants of the Shasta Daisy. Note embryo or rudimentary ray-flowers near the edge of the disks, six being observable on the larger daisy and one quite clear in the left-hand edge of the smaller. Note also the faint "veins" in most of the ray-flowers, indicating that these were once tubular in shape and made up of five petals each. BELOW: Giant Shasta Daisies, showing the enormous blooming power gained by selection through many generations

Very well; let us take a twenty-foot flower-bed, divide it in the middle, plant one side solid with white daisies, one side with orange, and let the bees and butterflies and breezes *combine* those differing heredities. We disturb--mix-up--the life-germs of all the resultant seeds; from the millions that develop many will produce white daisies, many orange, some muddy-colored and useless ones, but some with the orange pull predominating over the white and some vice-versa. More than this, since in disturbing the heredities of the two varieties for our purpose (namely, of affecting color), we have stirred up all the latent differences between them, in the second generation and increasingly in later generations we will find ourselves with daisies varying widely in every particular--height, sturdiness, number of blossoms, thriftiness, and all other qualities. And even as regards color we will get unexpected results; for example, some orange flowers may be more deeply orange than any planted; white daisies may appear of a more perfect and waxy white than the parent flowers.

Shasta Daisies, with Mt. Shasta in background. The charming little girl gave this photograph a touch that made it one of Luther Burbank's favorite pictures. He always had a copy on his desk.

We shall, in short, find all of the old inheritances of the flower and of the combinations of them that have ever been in the orange and in the white daisy in the generations and centuries during which they grew apart, the one to become a shade plant, the other to remain in the sun. Now our only puzzle is to pick the color that pleases us best. From the second, fifth, fiftieth, planting--*sometime* we will get precisely what we had in mind in the way of color.

But it is not at all unlikely that, though the color pleases us, the plant which produces it is not exactly what we consider ideal. It may need to be stronger, taller, more prolific; or the flower, we fancy, might be larger or bear more rays, or it might be one color inside and another out; or it might have a darker or a lighter heart--a smaller or a larger. Very good; then it becomes merely a matter of continuing the experiment, planting selected seed, letting the bees do their work, or taking a hand in it ourselves with artificial pollination, selecting again and re-planting, and so on. Eventually we will be rewarded, not only with the color we set out to get, if it was in the heredity of the original plants, but also with the sort of flower and plant structure, form and thriftiness that meet our needs.

"But," some one asks, "will the seed of this new daisy produce more daisies with the same new qualities?"

Of course not! Not yet! For you must remember that you have deliberately upset the heredity to get this new combination, and the life-germ in its seed is still upset, mixed, disturbed by your interference with the habits of the family. So your ideal daisy will produce perhaps two or three plants with its characteristics and its flowers--the rest of the brood will be regular stepchildren, continuing to amaze you with an infinite variety of peculiarities. At this point we must begin to *impress* our ideal daisy with its new duties in life; it would tale us many generations; by repetition, repetition, repetition we would, however, get that seven o'clock sleeper to wake at the stroke of six every morning!

With the daisy, as with many plants, there is a short-cut we can take here that greatly simplifies our problem. By dividing the roots of our ideal plant, or by making slips or cuttings from it, we can propagate that very identical plant, itself, without variation in any particular. Presently we have a whole bed of ideal daisies and (perhaps protecting them now from the visits of bees and butterflies who would not know what we were up to and might carry their kind offices too far), we will get second-generation plants with narrowed hereditary influences working on them--tending toward our ideal, you see!--and so in a short time we would find our ideal plants producing seed that, in turn, would produce more and more frequently the ideal plant again. This is that repetition, repetition, repetition which is a refrain with me, because it is another key to "the secret and magic and mystery" of plant-breeding that enables man *to train plants to work for him!*

Let me take another example of practical work with flowers, leaving fruits and vegetables to later chapters.

In my boyhood days I was very familiar, of course, with the New England oxeye daisy, so prevalent, so hardy, so prolific as to be a pest--a weed. There were, as far as I knew, none of these daisies in California, so I sent for seed from the home-folks and soon had some fine New England oxeye daisies in my garden. It occurred to me to work with them, with a view primarily to developing the size of the flower, so I cast about for a cousin-daisy that would help me, and I lighted on the English daisy, which bears a large, rather coarse flower. Presently I had these, too, growing in my garden; when I crossed the two I found many of my cross-bred plants sending forth blooms that were a considerable improvement on both the parents.

So far, you see, I had some daisy-heredity from rocky, rugged New England, and some from old England. My new daisy plants were sturdy, hardy, luxuriant growers and profuse bloomers, with large flowers.

But there were several faults with them, including a plant-growth that seemed to me too rank for beauty, a tendency to run too much to foliage, and finally, a blossom that left much to be desired in purity and waxiness. Years and years of patient (and expensive) experimentation would have effected an improvement in all regards, but I was looking, as I always have done, for a short-cut.

It was at this juncture that I encountered information concerning the Japanese daisy. I was told that it was a rather coarse plant with an objectionable, leafy stalk, and with flowers so small and inconspicuous as to be scarcely desirable in a garden. But the flower had one quality that I wanted--and the principal one--a pure, waxy white color. Promptly I sent across the Pacific to get my hands on this entirely new bundle of hereditary tendencies, and soon I was busily mixing up the heredity of my oxeye cross with the Japanese blood.

The first results were not wholly reassuring. But in a subsequent season, among innumerable seedlings from this union, one was found at last with flowers as beautifully white as those of the Japanese, and larger than the largest of those that my own hybrid had hitherto produced. Moreover the plant on which this blossom appeared revealed the gracefulness of the New England daisy, and presently demonstrated that it had all the hardihood and thriftiness of both the earlier parents.

From this exciting plant, with its combined heritage of three ancestral strains from three continents, thousands of seedlings were raised each year for the ensuing five or six seasons, the best individuals being selected for seed-bearing and the others all destroyed, according to my custom. And at last I had a flower surpassing all my hopes and expectations--a plant at once graceful enough to please the eye and hardy enough to live in any soil; of such thrifty growth that it reached its blooming time in its first season, though its ancestors had always refused to bear until the second; of such quality and quantity of bloom as to present a glorious picture through a very long blooming season; finally, with flowers from three to six inches in diameter, of crystal whiteness, and borne on long, graceful stems devoid of superfluous leaves.

It was, as I say, a daisy that surpassed my dreamsits name: the Shasta.

It is too long a story to tell here of the varieties of the Shasta that later appeared. It must be sufficient to say that, having stirred up these three remotely related heredities in the experiments, I could scarcely stop the progress, and in time there were growing in my gardens Shasta daisies of the size of dinner plates, daisies with double rays of leaves, daisies with a cream and a yellow color, serrated petals of great beauty, daisies with their petals so curling and ragged that they scarcely resembled their brothers, and an almost countless number of other variations, some of them valuable enough to deserve separate names, which they promptly received, and to be sent out to the world under those other names, among which were the California, the Westralia, and the Alaska.

Yes, we march forward, on and on, step by step, sometimes losing a little ground, next time gaining a good deal in a burst of speed, but always contributing to and participating in the great miracle of evolution. Towards what goal? Ali, that we can not know! But we do see all about us the immediate fruits and results and, in the broadest sense, all of them make the world a better place in which to live!

CHAPTER V
Harnessing Heredity

WE have seen that we can put nothing into a plant that is not contained somewhere in the bundle of its family tendencies, habits and qualities that we call heredity. Therefore the first duty of the plant-breeder is to learn all he can of the laws which govern inheritance in Nature.

There are two which we may well consider at this time, because they are all-important in beginning an experiment. The first is a mathematical determination known as Galton's law; the second is one of the rules formulated by the great student of genetics, Gregor Mendel, which deals with the fashion in which inherited qualities reappear in later generations.

Sir Francis Galton, studying men who came under his observation, noted that a myriad lines of influence converged in every individual, inasmuch as that individual had not only two parents himself to give him inborn tendencies and characteristics, but that they in turn had two each, they two each, and so on back to the very beginning of the race. In other words he came to realize that what a man is at birth can only be determined by inquiring into the lives and characters, qualities and habits, of the two, four, eight, sixteen, thirty-two, sixty-four, one hundred and twenty-eight (and so on indefinitely), of men and women whose blood flows in his veins.

After much inquiry and study he set down as a general rule that the individual inherits approximately one-half his qualities from his parents, one quarter from his grandparents, one eighth from his greatgrandparents, one-sixteenth from his great-great-grandparents, and so on in a mathematically decreasing scale to the beginning of the race. A moment's thought and the contemplation of your own family or a friend's will give you startling proof that here is a profound truth. I have a friend who is tall, rawboned, powerfully built; his father and mother are both of medium height and the father is very slender--almost frail, and has been since childhood. But his mother's father was a big frontiersman, powerful and large-framed. That is as far as I need to go to see Galton's law working out, though I can go much further with my friend and find where he got his blue eyes, his inclination to be an adventurer and wanderer, his aversion to cities, his fondness for music, his ability as a fisherman and hunter, his lack of ability to understand mathematics of the simplest variety, and the fact that his youngest daughter is a natural mathematician!

Presently you see that this rule of Galton's offers an explanation of many manifestations in plant experiments that might baffle and, perhaps, discourage you. For we find our hybrids and seedlings developing wide variations--popping out with forms, habits, dresses of leaves and ornaments of color wholly different from those of either of the parent-plants. When we recall Sir Francis' law we are reassured; here we recognize out-croppings of the heredities of some of those forefather-plants, perhaps many generations back along the line. Instead of being surprised at the variations, we may well wonder why there are not more of them!

Here I should like to trot out a favorite theory of mine that has to do with this subject.

Some of us are very proud of what we call our "family tree"--a drawing that shows us and our cousins and aunts and parents and more remote ancestors all stemming from the trunk of the tree, which is labeled with the name of a great or famous or stalwart old fellow whose blood, we like to boast, is in our veins.

That pet notion of mine is that the family tree is almost useless as telling us anything worth knowing about our ancestry. I maintain that the drawing should be done the other way about: the trunk of the tree should be labeled with *your* name and, instead of going up into the air, the artist should go down into the ground, drawing the roots of the tree--the sources from which you got your heredity. The farther the artist goes, the more roots he would have to put into the picture. Somewhere deep in the ground below you, you would, of course, find one rootlet labeled with the name of that fine old ancestor of whom you and your relatives are so proud. But there would be hundreds, thousands or millions of other roots and rootlets in the drawing. They would represent all sorts and conditions of men and women, good, bad and indifferent, famous and ordinary, successful and defeated, large and small, blondes and brunettes, and undoubtedly a few red-heads! But they would explain you. They would present a picture of the great stream of heredity that resulted in you and your relatives and that makes you what you are.

But, in studying this upside-down "family tree" I am referring to, as well as in experimenting with plants, you will have to know something of the limitations that Nature seems to have put on hereditary influences--and that is where the Mendelian theory comes in. Let us try to get some glimpse of that principle, even though it be a sketchy glimpse.

Gregor Johann Mendel was an Austrian monk with a garden and a flair for observing Nature and asking questions of her. He was interested to observe that certain characteristics of parent-plants were passed on to the hybrids--the children-plants--and others were not. Yet, in later generations, those missing characteristics would sometimes reappear. Going further, he found that it was possible to entirely *breed out* some traits and to permanently *fix in* others. He wondered why and whether there was a law governing the phenomenon.

After a long series of patient experiments he discovered that, in his plants, some characteristics were strong and some were weak; he called them *dominant* and *recessive,* respectively. Those dominant traits persisted in coming out; the recessive traits were inclined to give up the struggle and only appear in a few of the later generations of hybrids. In pea-vines, for instance, he found that the tendency to produce round, smooth peas was dominant; the tendency to bear pods containing wrinkled peas was recessive. There was an almost infinite number of these characteristics in peavines, of course. There were dwarf and tall plants, there were those with luxuriant foliage and those with sparse, there were heavy and light bearers, there were those with many peas to the pod and those with few and so on and so on.

Many of these he could "pair off" as occurring in units where one characteristic was dominant, the other recessive. In short, here was a marvelous discovery in genetics, since it gave all breeders an explanation of why certain variations occurred regularly and infallibly, according to a law and not simply by chance.

Starting here Mendel went on to another discovery, namely that the dominant traits would predominate over the recessive according to a pretty fixed pattern in later generations. That pattern it will pay you to study. You will find it explained and diagrammed in any standard text on biology or genetics and, if you want to go very far with plant-breeding experiments in your own garden, you will find the Mendelian theory a useful tool. Here it is only necessary to say that a cross between plants having a pair of those linked-trait characteristics will result in a majority of the hybrids inheriting the dominant characteristic, a few inheriting the recessive characteristic and a small proportion of them inheriting the dominant with a trace of the recessive hidden away in them, to keep reappearing (always according to the pattern) in later generations, clear to infinity.

You see, once you are convinced that a certain desirable trait in your experimental plant is dominant, you can avail yourself of this short-cut to eliminate the opposite trait by destroying the few plants in which the recessive trait shows up. On the other hand, if the trait you think desirable is a recessive characteristic, you know right away that you are going to have a struggle against that dominant tendency and so your experiment will be confined to the use of the far fewer recessive-type hybrids you can expect to get.

Possibly all opposing characteristics in our plant world are actually paired off in this strange fashion, but that we are not yet sure of. And, in thinking of this pattern as a helpful tool, we must remember that every plant with which we deal has an almost infinite number of traits or characteristics. If we are going to think of all of these as falling under the Mendelian law we have a problem so complex as to baffle us. And so we turn to it only when it is definitely helpful and a time-saver to us in our work. And we also recall it when one of our experiments seems to go off at a sudden tangent or when a quality we are seeking disappears inexplicably out of a hybrid which, as we had thought, had that quality impressed on it by its heredity.

I had precisely this experience in my own experiments that led to the development of the white blackberry.

I found reason once to think that a blackberry of a translucent and attractive white color could be produced and I set about the trial. By the usual process of taking advantage of observed tendencies, crossing, growing seedlings, selecting those that seemed to be "going my way," crossing again, again growing seedlings and so on, I developed a fruit like a blackberry in vine-habit and in form, but with white fruits.

But not exactly like, for my white blackberry fell far short of the parent strains in both flavor and sweetness. It was now necessary to go back and try to add these two qualities. To accomplish this I chose as one parent-plant for the next enterprise the large and deliciously-flavored Lawton, took pollen from it and pollinated the white-blackberry blossoms.

The immediate result was the complete disappearance in the hybrid plants of those white berries!

My first thought was, of course, that the characteristic of whiteness was recessive--a natural assumption. But further experimentation convinced me, surprisingly enough, that the newer trait of whiteness in this white-black pairing was dominant, which I soon discovered to be a law. And so, repeating the crossing with the original Lawton, I was rewarded in later generations with white blackberries fully up to my former ones in translucence and beauty but now flavored with the luscious Lawton tang and sweetness.

We are beginning now to get some general knowledge of the way that heredity is harnessed to our purpose in plant-breeding, and of some of the results we may expect when we start practising with living organisms. And while we are on the subject, let us take up a question that has been often asked me, and that may before this have occurred to your mind.

"If what you tell us about crossing varieties is true, and if you can harness heredity to your purposes, why is not the world full of naturally crossed varieties and why are there not constantly developed new plants?" That, in one form or another, is the question to which many people come in this study.

The answer is that crossing of varieties is constantly going on everywhere in the world, and that new varieties are constantly appearing. But, as I have pointed out before, Nature has an infinity of time; she is in no hurry, she has no interest in white blackberries, luscious plums, beautiful pansies, variegated sweet peas, fleeter or stronger horses, one dog that will chase rats and another that will "freeze" into a "point" at a flying grouse or quail; in having a Persian cat different from an Angora, or a canary that can live in a cage and still have the heart to sing and be happy; Nature's first interest is in preserving *the species*, and that she does very well. We, on the other hand, are concerned with making the individual produce plants more to our liking and we are definitely in a hurry. And so we use Nature's methods but speed them up and direct them toward a different end.

Examine a patch of common "tar-weed" and you will almost certainly find the greatest variation among the plants even in a limited area. Go into the woods and you will find wild flowers of any given variety growing luxuriantly, thickly, with flaming colors on an open place and the same plants smaller, more pale, less plentiful, in shaded glades--two flowers of the same family, but as different as cousins can be different because of their divergent environments. And in between you will find plants that are only half-way in the change--that are compromises which variation and the law of natural selection have made possible, and perhaps able to live either in the sun or in the shade, which neither of their cousins could successfully do.

But presently, in your search, you will awaken to the fact that plants do not cross with totally unlike ones; the rose does not mate with the violet, nor the peach tree with the plum. You do not expect such wide crosses, of course, but do you wonder why they do not occur and whether Nature has a hand in preventing them? Well, you are now on the track of another phenomenon that the plant-breeder must learn more or less about and that he must take into account in his work: the phenomenon of physical and chemical walls which keep species apart. (I have myself succeeded in isolated instances in crossing species, but for our immediate purposes we may take it as Nature's law that they are not expected to, and that many of them absolutely cannot.)

In the first place the physical laws that keep divergent species apart are observable in numerous cases. Almost all species have a different arrangement of the stamen, pistils, corolla, and so on, so that the visitor that can enter one cannot gain access to the other. Also it is well known that insects specialize in visiting certain flowers; even bees, that might take honey from almost any of them, will choose one particular variety and go zooming directly by all the others. That is why we have onion honey, clover honey, orange honey, and so on; for some reason one hive of bees, or a group of hives, will select a coöperative brand and specialize in it exclusively. There are flowers that advertise to accommodate only hummingbirds and will have no traffic with bees or butterflies; there are others with a very limited, accurately timed season when they are willing to give pollen or when they are receptive to it if brought them, and thus another sort of physical barrier is set up between them and their neighbors of a different variety. I could go on indefinitely enumerating these physical walls between varieties and species.

But more important and more generally in use are the chemical walls. We have a great deal to learn about these, still, but we know positively that every living species, or "family" as we call them popularly, has its own peculiar chemical composition or structure, and that you can no more cross the grape and the blackberry, the apple and the orange, the dog and the sheep, the butterfly and the bee, than you can multiply six boys by nine marbles! It just isn't possible, because you are dealing with different things, even though some of them (for example, the poppy and the peony) may, to the casual observer, seem a good deal alike.

Finally, even inside the same variety, where there is no mechanical or chemical bar to a union, we find difficulties often that are due to the fact that the two plants, though related in heredity, have grown far apart in centuries or ages of existence in different environments or with different habits and purposes. In harnessing heredity this is a factor the plant-breeder has to take into consideration. Two varieties of blackberry, for instance, may have stemmed from a common parentage not more than a dozen or fifty or a hundred years ago, but it is plain that the blackberry and the rose, owning common blood ages ago, are now so far separated by habits and practices of growth and their purposes and uses that they would offer more trouble to the plant-breeder, not so much to effect the cross, perhaps, as to effect one that would offer any advantages to us.

These are some of the essential facts important to be known by the experimenter who wants to harness heredities in plants and hitch his team up to do useful or interesting or valuable work. They indicate to us some of the boundaries of our investigation and experimentation; they point out directions in which we can not go. Inside these boundaries again there are, of course, many more limitations, many lines of least resistance to be seized on and many routes of utmost difficulty that are to be avoided. Gradually, as our work goes on, we learn more and more what to do and how to do it; we started in by deciding that we could only work with the tools Nature gives us--heredity and environment--and now we find that she restricts the use even of those tools.

On the other hand she leaves us a field so vast for exploration, discovery, achievement, that it will be a long time before man will more than scratch the surface of the possibilities. So, while we outline the prohibitions and limitations and mention some of the least profitable avenues of research, we know that there remain open to us more ways to train plants to work for man than any of us will ever see exhausted. The world of plant-breeding is our oyster--inside there are still plenty of pearls to be uncovered to enrich mankind and make the old globe a better place on which to live.

CHAPTER VI
Breaking the Rules

IN the previous chapter we agreed that Nature has made some laws and built up some walls that limit and bound the plant-breeder; but now we come to the discovery that man occasionally is mistaken as to what those laws and walls are. When I started my work as an experimenter, spurred on by Darwin, Lamarck, Huxley, Galton, and the rest of those wise men, I was told by botanists that a combination between two varieties of the same species was possible but that crosses between different species were outside the pale of possibility.

A little later on, when I succeeded in crossing the plum and the apricot--parents of undeniably different species--the rules were moved up a peg. It was admitted (grudgingly in some quarters) that it might be possible, under particularly favorable circumstances, to effect combinations between different *species,* but that combinations between the next higher division--*genera*--were beyond the power of either man or Nature. And yet, after further study and experiment, I was able to take parents of different genera--the crinum and the amaryllis, for instance--and to bring about successful crosses; thereafter I began to hear less and less about *fixed* rules and laws.

The fact was, not that I had performed some great magic, or succeeded in smashing the rules, or even in getting them temporarily set aside for my benefit, but that the rules and laws were largely man-made and some of them framed too hastily, without sufficient data, so that I was able to prove them to be nothing more than mistaken *conclusions.*

As I study it all over I begin to think of Nature's processes as endlessly flowing streams in which varied strains of heredity are ever pouring through the riverbeds of environment; streams that, for ages, may keep to their channels, but each of which is apt, at any time, to jump its banks and find a new outlet. Just about the time we decide that one of these streams is fixed and permanent, there is likely to come along a freshet of old heredity, or a shift in new environment; an overflow occurs, a gap widens in the channel, a flood sweeps over the surrounding field of plant or of life activity--and we must rebuild our bridges and revise all our maps!

Probably, if we take our knowledge of botany as a whole, time will prove that it is pretty generally accurate--that our maps and charts are dependable. In order to know where we are going in this study and to understand what it means when we have to make a new diagram, here and there, let us take a look at the classifications we now have to guide us in the pursuit of the subject of plant life.

To begin with we will have to recognize that truth is only relative, that we can not know all there is to know about so great a subject as life on this planet, that men disagree on innumerable points, and that a great many things are still either not understood or in dispute. For the sake of clearness, then, we will avoid minor divergences of thought and stick to the broad general outline on which most students are agreed. We begin, of course, with the three great *kingdoms:* animal, vegetable, and mineral. They are fairly distinct; fairly well bounded. Between the inorganic mineral world and the world of sentient and mobile animal life lies the world with which we are concerned in this book--the vegetable.

This world--this kingdom--divides itself into six (perhaps seven) branches called *phyla:* in the first are found the lowest forms of vegetation--organisms of the simplest type, which reproduce themselves by splitting or division. In this subkingdom are bacteria, which bring about such human diseases as tuberculosis and malaria; or such plant diseases as black rot, and other bacteria that are helpful and lifegiving, such as those that help us digest our food, or that consume otherwise menacing wastes and without whose alliance the higher subkingdoms of plant life could not exist.

The second subkingdom, higher by a step, includes the microscopic vegetables which we call yeasts, those that, through the agency of hops, turn grain juices into beer, those that turn apple juice into cider, and so on. The botanists who prefer to chart seven subkingdoms, instead of six, divide this second phylum into two, giving the "slime molds" a classification of their own.

The third phylum includes mosses and liverworts, among others.

The fourth comprises the ferns-the highest type of *flowerless* plants, and the first in the ascending scale to exhibit a complete development of root, stem, and leaf. You note here that root, stem, and leaf *precede* blossom bearing; in other words the ferns are the simplest of our "plants" as we ordinarily think of plants, and they bear no blooms.

The highest phylum or subkingdom contains two branches that have something in common but must be divided because of their seed-bearing habits: these two are called *classes,* and one is distinguished by bearing its seeds in enclosed organs or packages called ovaries, while the other bears exposed or naked seeds. The first of these classes includes the vast majority of seed-bearing plants; the second principally those trees, like the pine and the cypress, which bear their seeds in open cones.

But in this highest subkingdom, already comprising two classes, we find we have rather more than a handful of growing things, and we divide the classes into *orders.* The order represents a collection of *related families.* As an example, the order Rosales is made up the rose family, the bean family, the cassia family, the mimosa family and some twelve others, closely allied.

Below the order, you see, comes the *family*--a division that is still broadly inclusive, the rose family, for instance, taking in not only our friend, the rose, but the apple, blackberry, and sixty-two other plants whose close relationship might not at first be very evident.

From the family we next narrow down to the *genus;* here the roads of the rose, the apple, and the blackberry separate, and each begins to take on its own dignity of classification.

Under the *genus* (the plural is *genera*) comes the *species.*

And the species is made up of *varieties.*

We have already seen that the simpler the form of life, the less tendency there is to variation; as we get higher in the scale we find those variations increasing and making it more and more difficult to put the multifarious varieties into pigeonholes of classification where they exactly fit; it is for this reason that there is a wide divergence of opinion among scholars and scientists concerning names of things and labels for groups. But with that argument we have, here, nothing to do. Our concern is to observe immediately that there is *one certainty* in the world of plants, even though there may be only one!

That certainty is that the *individual* plant is something on which we can put our fingers--; if we but watch it and give it an opportunity, it will speak for itself, beyond dispute or denial, telling us what manner of plant it is and just what we may hope for it and expect of it. When we learn this fact we realize that, after all, classifications, theories, indices, learned discussions--all these are created by man; but the individual plant is created by Nature, or by God, or by Evolution--however you choose to phrase it!--and is a sure and certain beginning for our study and our work.

In this book we are studiously avoiding scientific formulas and dogma and scientific jargon and technical expressions, because it is planned as a practical book. But it will make it easier for the reader if we make one concession to science and follow, the scientific method of labeling the plants we are writing of. This scientific language, as most of you know, is Latin, because scientists all over the world employ it and therefore can understand one another readily.

Now, as to the scientific names of plants, observe that no mention is made of *class, order,* or *family.* The first name is the name of the plant's *genus.*

The name of its *species* follows.

And the name of the *variety,* if given, comes last.

Thus, in writing the name of an apricot, a plum, or a cherry, we should first set down its *genus* name: *Prunus.*

If our fruit (say, a cherry) were of the species *Avium,* the Latin designation becomes *Prunus Avium.*

But, if we want to specify a particular variety of the cherry, as, say, the Mayduke, we would set down the full title thus: *Prunus Avium Mayduke.* And, finally, to save repetition, if our chapter or our article concerned cherries only, we would, after the first naming of the variety, thereafter write *P. Avium Mayduke,* taking it for granted that *P.,* to the reader, would always mean *Prunus* until we changed the subject.

Now, having made that aside in order, to clarify things, let us go back to this subject of the Breaking of Rules with which this chapter is concerned. I use that title because that is the mistaken notion many people have of the work of the plant-breeder--that he is "breaking the rules" of Nature in "training plants to work for man." As a matter of fact, as I have hinted above, there is no such a thing possible as the breaking of Nature's laws, for they are immutable and unchangeable. What is possible, and what we do every day, and what Nature herself simply delights in doing, is the breaking of rules that *men* make and try to pass off on the world as natural laws. Natural fiddlesticks! They are only human *guesses* as to what the true facts are! And so, of course, they are broken constantly, and have to be revised constantly, and often have to be discarded altogether as out-moded, or false, or insufficient.

One of the most hopeful and encouraging evidences of our progress in free thought and in civilized progress is the evidence we see all about us that men are very rapidly recognizing the truth of what I have set down above. Only a few centuries ago such a statement as I have written would have caused me to be burned at the stake, I suppose; even thirty or forty years ago it would have caused my expulsion from any society of scientists or any learned body. But to-day, thanks to the bold courage of a few independent souls, even the most bigoted scientist or educator admits that we have not yet arrived at any final and definitive truth, and that instead of laws we should set down opinions or evidences of *apparent* natural ordinances, and leave for some vague future time the codification of any set of rules whatever. Why, I don't think it was more than a dozen years ago when people said, with bated breath: "Mathematics is the one pure science"--meaning that it was absolute and immutable. And along come such men as Dr. Einstein and upset the whole apple-cart of the positivists by proving that perhaps even Newton was mistaken! Now, there's a pretty kettle of fish, as my mother used to say!

I have no quarrel with Botany and its labored classifications and set rules, but what I do maintain is that, at best, Botany is a science of dead things--of counting stamens, examining leaf and root structure on the laboratory bench, of minutely diagramming the physical character of plants after they have beep torn up and picked to pieces for these purposes. The only living science of plants is the science of breeding and crossing and encouraging them to become more useful or more beautiful--and let the rules go hang!

To realize the point more clearly let us observe for a moment the common tomato, which belongs to the large division known as *Solanums.*

Just as the rose family includes not only the rose but the apple, the blackberry, and hundreds of other widely variant plants, so the solanum includes seventy-five genera and more than eighteen hundred species.

The classification of this great family in botany is based on structural facts, such as that plants of this family originally had alternate leaves with five stamens and a two-celled egg-chamber, or ovary, each cell containing many eggs. Undoubtedly all true solanums developed from a single parent plant, back in the dim ages of the past, but the marvel and wonder of our study is that environment, cross-breeding, accident, and change of conditions have wrought such amazing variations in the great family of children.

For instance, we now find in this oddly assorted tribe the poisonous bittersweet and the homely but enormously useful potato; the egg-plant and the Jerusalem cherry; the horse-nettle and the weed; the tobacco plant and the beautiful petunia, and a vegetable which has made the eating of salads a pleasure--the tomato.

We should see, if we looked at our botany in this way, seventy-five different plants with structural similarities traceable clear back to the old Adam of the race, yet differing in every other. (and in my opinion, every important) respect as widely as night differs from day. If we observed closely enough we should be able to trace out and learn why one branch ran to the poisonous bittersweet, another to the potato with its food stored below the ground, another to the tomato, with its luscious fruit borne in the air, another to the tobacco plant, with all its potentialities for good and evil to mankind, and so on. Do you wonder, when I look on such life-stories as these, that I consider botany a pretty dead and dull subject compared with plant-breeding?

And these wide natural variations in plants properly classified as belonging to the same families are only the beginning of the story. At some point way back in history, or before it, the tomato left the family home and started out for itself. But once it had cut itself off from its seventy-four brothers and fixed itself as a separate species, its progress was slow and its development unsensational. Man came along and, we may imagine, thought the tomato plant a rather attractive weed, especially with its pretty, bright-red fruits. But still nothing much had happened. No one dreamed of *eating* a tomato. In fact it was generally supposed that the fruit was poisonous--as, considering its relationship with the bittersweet, it may once have been. In any event the tomato's life-story was rather a drab one.

Then some bold experimenter or some hungry child tasted a tomato and found it good. It was small, full of seeds, probably pithy and certainly highly acid. To recommend it there was only its unique flavor. But that was enough to cause men to seek it out, looking for larger, better, sweeter fruits and, when they found them, to plant the seeds of these *improved* individuals. Thus began a course of selection, unconscious and unsystematized, but resulting in a constant and steady bettering of the tomato. Time passed, then along came some primitive plant-breeder who began to *search* for bigger, better, juicier, and less acid tomato fruits; later some of us added active breeding to mere search; the result to-day is a whole series of tomatoes as different from the original as the Woolworth Building in New York is different from the mud-hut of a prehistoric Indian!

Suppose that we had only botanized the tomato, examining its leaves, roots, sepals, shape of seeds, size of ovary, and so on; supposing we had been content to give it a name and a classification. How could we have expected to gain from such study even an inkling of what the tomato could become with less than half a century of cultivation? Knowing what the Oriental did for the pear, what the American Indian did to corn, what we have done to the tomato, can we not see that, while the counting of stamens and the classification of plants are important, they bear little relation to the vital thing, which is the improvement of the plants--making them better to serve and delight mankind?

So, every once in a while, when we come to a crossroads where so-called scientific theory clashes with the facts that we have adduced from practical plant-breeding, let us stick to what the living plant tells us, and assume that evolution, or improvement, or progress, or whatever we choose to call it, has stolen another march on the plant historians.

And let us remember that, though our knowledge of plant breeding is not a fixed science, we can console ourselves with the compensating circumstance that there seems no limit to the achievements that painstaking and patient experimentation will yield. We have only scratched the surface so far in our new and fascinating occupation--training plants to work for man! I have said this before. I will say it many times again. For, in one sense, my belief in that statement is my main reason for writing what you read here.

CHAPTER VII
Planning a New Plant

It has been said that an artist is a man who can see the picture in the landscape.

In similar fashion it may be said that the plant-breeder, to be successful, must see in old and familiar, or in wild and untried, plants, new ones useful to mankind. It does not follow that he will succeed every time in achieving his goal, but it is true that he must have a pretty definite idea of where he wants to go in an experiment, or he will score a decidedly disproportionate number of completes misses.

What are the factors with which we have to deal in "planning a new plant"?

First, foremost, and vitally important is heredity. Worlds and atoms, plants and animals, have been shaped and formed, and their natures, characters, tendencies, and functions have been molded into them by the ever-varying influences of environment through the ages: on the one hand this sum total of environments that we call heredity gives the individual a certain direction and character that can not be changed; on the other hand those environments have stored in the individual a complex and countless myriad of *possibilities* which we may be so fortunate as to draw on to gain our purpose in improving it. To illustrate: The cactus has been so long accustomed to hard living conditions that it is difficult to make it at home in rich garden soil; it has so long warded off the elements and predatory animals that it would be impossible to teach it to bear leaves like a plum tree or the tempting fruit of the apricot. But while the cactus was learning its lesson of hardihood and self-reliance, it passed through a period when it had no prickly spines because it did not need them, and by working patiently we are able to bring that sleeping characteristic to life again and induce the cactus to shed its armor of vicious needles.

We are learning that everything in Nature, organic and inorganic, is made up of chemical elements, each in a different combination and order--that there is not a single thing in all Nature that could not be reduced to a few kinds of chemical particles--carbon, hydrogen, nitrogen or the like--and that, more wonderful still, there are probably not more than a hundred of these chemical elements themselves. In short the *bases* and the building materials of our universe are few in number and simple in character: it is the combinations--the pattern--into which these materials are put together that make the difference between the diamond and the jellyfish, the college professor and the glow-worm, the sweet air we breathe, the clear, cold water we drink, and the fire that warms our bodies and cooks our food.

Therefore it comes about that there is another factor in the developing of new plant varieties: the factor of possible change in the organization and tendencies of plants due to a changed environment. We do not, to be sure, know enough about this factor to make positive statements about it, but certainly it *is* one of the tools that Nature puts into the hands of the studious and persistent plant-breeder. Give a plant an entirely new environment and, if it survives the shock, it may show you suddenly a new and unexpected ability or characteristic that a study of its heredity does not seem to explain or account for at all.

These, then, are the three life-factors in the plant that the experimenter has to begin with: (a) heredity, (b) a power to vary because of hidden powers given the plant by past environments, and (c) the delicate adjustment of the "pattern" of chemical constituents of the plant that may be slightly altered by our labors or by the chance of new living conditions, and so bring to our eyes an improvement.

In considering this subject of the planning of a new plant it is necessary both for you and for me to remember that my own experience has been wider, perhaps, than that of any man who ever tried his hand at plant experimenting. Therefore I must describe to you some of the details of the method that are, to me, second nature and elemental; you, on the other hand, must not forget that my almost fifty years of experience qualify me to take short-cuts and make jumps and assume conclusions that you probably could not understand or follow. But there are two parts of my program of breeding that may help you to understand why success has been achieved in ways that have rather astonished the rest of the world.

First: It has always been my practice to *speed up* the machinery of evolution as Nature practises it, in order to get results in a few weeks, months, or years, instead of waiting, as Nature is satisfied to do, for years, centuries, or ages to come to the same end.

Second: I have always carried on plant experiments in wholesale lots--not with a hundred plants, but with ten thousand; not with a handful of bulbs or corms or a teaspoonful of seed, but with pounds or bushels or a hundredweight. As we go on with this subject you will begin to see, I think, why this *speeding-up* process, applied by *wholesale,* has brought results.

You must understand again that Nature does not care about what we call a *better* sweet corn or a *more beautiful* rose: all she is interested in is seeing that neither the corn nor the rose families die out. She is not interested in individuals at all, but she is enormously and jealously interested in the species. Man, on the other hand, pays little heed to the mass of plants (probably because Nature is well able to take care of that part of the business!), but he is intensely interested in bringing about improvements that will supply the world with food, clothing, luxuries, beauties, greater quantities, and better qualities, preferably with less labor and at a lowered cost. That has been my interest and has given me my life-work.

The question is often asked: How do you start out when you are seeking to create a new form of plant life or to improve a variety?

All scientific experiments proceed in one of two ways:--by the "trial-and-error" method--a sort of skilful fishing expedition, or by theorizing from known facts and then constructing a pattern of experiment by which to confirm or disprove the theory.

In plant-experimentation the first is always full of interest, and many worth-while results may come from it. When a cross was made between the petunia and the tobacco plant a thousand fascinating variations resulted, with some most unexpected angles that were quite exciting, but with no final achievement that was of any immediate possibility of benefit. Facts came to light, however, which were of help in formulating rules about plant-breeding and that were important in mapping the boundaries of the field of plant experimentation. Generally speaking I should say that the "trial-and-error" method, so much used by scientists and research students in all branches of human knowledge, yields more in helpful facts and less in results that can be marketed or incorporated in practical articles.

The bulk of my experiments in the later years have been made with the second method. I have increasingly set out for a definite goal, with a clear-cut program based on knowledge of Nature's rules and my experience in employing and working under those rules. And I have been able more and more regularly to reach my goal.

Four sharp variations--in color, size, petals, and form--out of many hundreds resulting on a single experiment with single dahlias. These are hybrid chill dren of dahlia varieties brought together from distant parts of the world by Luther Burbank.

Let us take an example.

Inquiring among our friends who grow cherries for the market we learn that the best prices are paid for early cherries--that a few days gained may make a difference of as much as one hundred per cent in the profit to be taken. So we ask ourselves: why not develop a new cherry, delicious and satisfying, but bound to ripen a week or two earlier than any known variety?

But at once we encounter other important factors. Not only must the cherry be luscious, large-sized, of beautiful color, but it must be of firm texture to stand shipping and must have a short stem to facilitate packing. Moreover, we discover that the tree producing these cherries must be hardy, capable of withstanding both cold and wet winters and dry summers, and that it must have a vitality that will make it as resistant as possible to the attacks of insects and fungoid pests.

There is a large and complex order: have we any warrant for supposing that it can be filled?

Yes, we agree that we have. In the first place, an examination of the best cherries already on the market reveals that there is a large measure of variation between the present varieties, and also between the fruits of individual trees within each variety--there is even a certain amount of difference in the individual fruits on the same tree. Here is a tendency in the cherry that we are quick to seize on. In imagination we look far back into the past of the cherry, and at once we discover that, while the fruit probably appeared first somewhere around the Mediterranean, it had soon so adjusted itself to environmental changes that it grew, throve, and bore, far to the north, in definitely cold climates. In short, we see at once that the cherry has always had a great power to vary. It is not a stubborn fruit-tree, with a single-track mind, but one willing to work with us--able to accommodate us in any reasonable request. This is only one of the characteristics of the cherry, but it is sufficient to give us hope that we can carry out our plan for an earlier variety. So we go to work.

Mr. Burbank called these Evening Primroses "handkerchiefs spread on a lawn." In the photograph they look identical; in fact every plant, every blossom, varied. Those variations made possible the "creation" of a new variety, introduced by Mr. Burbank soon after this picture was made.

At once Galton's law occurs to us-as a guide to remind us that the immediate parents we choose for our proposed cross will control the hybrid only halfway; as a warning that we must not be surprised when unexpected and undesired traits show up, from some grandparent, or even some remote ancestor, whose blood-finger is still in the heredity-pie.

But we must choose our parent stock to be sure that the one-half influence goes in the direction we want to take, so we take pollen from a cherry variety that is observed to bear somewhat earlier than neighboring trees, and with this pollenize blossoms of other varieties that have been observed to produce fruit of exceptionally good quality. Of course, in both cases, we have been forehanded enough to select sturdy, healthy, and pest-resistant individuals, and if we have any choice it will be in favor of trees that are generous bearers.

Now our pollenized blossoms lose their petals, turn into pips, the baby fruits form; in time these ripen and we pick them carefully and carefully preserve the pits that contain the seeds. It may be timely to warn you at this point that the fruit will be precisely like every other fruit on the tree, and will not be influenced by the fact that a foreign bit of pollen has been used to start its development. This is so obvious that all of us would understand if it were riot for the fact that most of us give such matters no thought at all. But that moment of consideration tells us that the effect of the pollen--let us call it the male germ--of the outside variety, fructifies the egglet us call it the female germ--in the ovary of the blossom only to effect the *seed* and not the fleshy covering, which is the *fruit.*

Now, when spring comes, we plant our hybrid cherry seeds, and by the next spring they are sturdy little cherry seedlings, but not replicas of the parent trees, for there are two blood-strains in them, with all the variegated and widely different, blood-strains that went to make the two parents. Are we surprised now to find these seedlings varying in every conceivable fashion, and in some that are not conceivable? No! We will find trees that start early and grow rapidly, others that are tardy and stunted. We will find broad leaves and narrow, bright greens and dull, thick growths of limbs and twigs, and sparse, and so on. Long before we could possibly expect to get fruit that will show us how successful our cross has been we demonstrate conclusively that the mixing of blood-streams, in the cherry as well as in the human being, is bound and certain to give us wide variations.

Let me pause here to call your attention to two methods in plant-breeding, perfectly illustrated by our cherry experiment. I have said that my scheme of experimentation included (a) speeding up Nature's methods and (b) working in a wholesale fashion. As regards the latter, I may say here that, instead of having at this stage of the cherry experiment twenty or thirty seedlings I would prefer to have ten thousand. And, once I had ten thousand seedlings, I want to take a short cut to results that Nature does not take because she has more time than I. And so I do not wait for those seedlings, in four, five, or six years, to bear me full crops of cherries. Instead, I bud or graft from the seedlings into old tree-stock and, as early as the second year, will have hybrid fruits to test.

A friend of mine once said: "Burbank uses a tree just as he does a garden-bed. He plants scions as I would seeds, but his scions go into the only soil in which they will grow--the living branches and limbs of a tree." My friend hit it exactly. I have trees on my Sebastopol Farm with twenty or thirty or even a hundred or two varieties of fruits annually borne on their frames; I find that one of the most interesting sights to visitors is a plum with twenty or even sixty entirely different plums ripening on it, or a cherry with twenty or thirty quite different cherries, and so on. Such sights are, of course, a commonplace to me because from the beginning I have speeded up fruit experiments in that way.

Very good! Now we return to our early-cherry experiment. At the proper season, usually about June, we take buds from the most promising of our cherry hybrid seedlings and "plant them" in older stocktrees. Within a year blossoms appear, buds form, little fruits begin to swell--and in the second autumn there are at least a few hybrid samples ready for us to taste, look at, experiment with as to sugar-content, shipping qualities, ability to keep, and so on. We are not surprised to find these fruits widely different in quality or size, color or texture. No, because we are now sufficiently acquainted with the subject to expect that--to know, in fact, that we can expect nothing else. We will have as many different fruits as we have different hybrids bearing; some of them will be utterly worthless, some will be like one parent or the other in some respects, others will be good, while differing from both, a few will be toothsome and--if we are fortunate--one or two may show a slight tendency toward the result we are aiming for: namely, a delicious *early* cherry.

But a slight tendency that way is the most we can expect, and we will probably not get even that. What we will be far more likely to find is a cherry or two with a willingness to bear early fruits but sour, or small, or with too long a stem, or with a poor color, or with some or many other faults that condemn it as hopeless *except as a means to an end.* A means to what end? Why, to the end that is still far ahead of us--the ideal we seek. We have, perhaps, influenced the cherry to start going our way--that is all. So our experiment is only begun--our work only initiated. Repetition, repetition, repetition--in building our fruit, first; then in training it to stick to pattern and become fixed in its new form permanently; that is our method, and the only method.

In short, we start over again with the hybrids, just as the year before we started with the parent varieties. We cross-pollinate, perhaps with one or the other of the parents, perhaps with a third variety, perhaps even with another hybrid, although this is certainly the trial-and-error method with a vengeance and is almost bound to present us with a mongrel brood of seedling-children of little use for any purpose and certainly not for ours. You see, when you stir up the heredity of any living thing too much it is like stirring up an ant-hill--you find the results much more startling and unsettling than useful or helpful.

I think I do not need to go on farther with this exposition of the plant-breeder's methods in planning and trying to build a new fruit, or any other tree. In later chapters we will carry the experiment further, and in the next will discuss some actual results of the use of the above scheme. What we must learn from this chapter is that it is possible to build a new variety of fruit--or vegetable or flower, any plant!--and that it is not by guessing, chance, or a hit-and-miss formula that we succeed, but by well-advised, patient, persistent and intelligent steps! If those be taken the plant-breeder has a great and almost boundless world in which to work--and the possibilities of his success are limited only by his own faithfulness and good sense.

CHAPTER VIII
Goals Achieved

LET us take a hurried glance at some of the cases where plans for new plants have been consummated and the result given to the world.

We have already observed that there are certain definite limits to what can be done in "training plants to work for man." We can not develop apricots on the cactus; we can not induce the walnut to grow as fast as the hop vine; we do not expect to cross the milkweed with the egg-plant (as some wag accused me of trying to do!) "and get an egg-nog!" No, we are reasonable people and recognize the limitations and boundaries fixed by the very nature of things and their constituent elements, age-old habits and immutably settled characters. So we work within the bounds of reason, recognizing natural limitations.

There is a law of which I have not yet spoken that is useful to plant-breeders, as well as being a limitation on them. It is called the "law of the Reversion to the Average."

I know from my experience that I can develop a plum half an inch long or one two and a half inches long, with every possible length in between, but I am willing to admit that it is hopeless to try to get a plum the size of a small pea, or one as big as a grape-fruit. I have daisies on my farms little larger than my fingernail and some that measure six inches across, but I have none as big as a sunflower, and never expect to have. I have roses that bloom pretty steadily for six months in the year, but I have none that will bloom twelve, and I will not have. In short, there are limits to the developments possible, and these limits follow a law. But what law, and why?

It is the law I have referred to above. Experiments carried on extensively have given us scientific proof of what we already guessed by observation: namely, that plants and animals all tend to revert, in successive generations, toward a given mean or average. Men grow to be seven feet tall, and over, but never to ten; there are dwarfs not higher than twenty-four inches, but none that you can carry in your hand. You know those things from observation; if you will think of it a moment you also know that the children of exceptionally tall parents tend to be shorter than either father or mother, while the progeny of dwarfs are seldom, if ever, themselves dwarfed. The tendency in both cases, of course, is toward the parental heredity in size, rather than toward the perfect average, but yet that heredity in size does not keep increasing, either toward greater tallness or toward a more dwarfed state. In short, there is undoubtedly a pull toward the mean which keeps all living things within more or less fixed limitations, but there is also a strong pull toward what we sometimes call "a family trait."

And so, as a corollary to this law of reversion to the average, we find a law that seems to indicate the establishment, in time, of groups tending to reproduce offspring marked with the group characteristic, and these groups are said to be "pure type." Thus from any mixed stock may come at last groups or families of relatively tall men and groups or families of relatively short ones. In our work with plants we find this "pure type" continually appearing, as the results of our experiments--one good example is the zinnia, where, on the one hand, we have the "giant" and the other the "baby" or dwarf flower. Both are from the same parent stock, but they have both been bred so long now that they are practically "pure types" and will come giant or dwarf, according to their groups, from seed.

Now we are ready to understand some of the experiments that have been brought to approximate perfection on my farms. I turn to the prune, as the first example.

As you probably know, the prune is merely a plum with a sugar content high enough to insure its drying without fermentation. The first prune we know of in America was brought to California some time in the fifties by a Frenchman named Louis Pellier; it was of the "pure type" we know as the prune *d'Agen,* and for half a century was the only variety grown in the great prune orchards of this state.

Undeniably that d'Agen (or so-called French) prune has its good qualities, but it is by no means a perfect fruit for its principal purpose, namely, drying. It is a clingstone, which is a serious defect. The stone is rather large in proportion to the flesh. The fruit ripens so late that in some sections the harvest is interrupted by rains, often to the complete ruination of the crop. Finally, the French type prune-tree is not a strong grower, it does not have a symmetrical form and it is not a reliable producer.

Obviously, when I began to consider experimenting with this fruit, I had plenty of leeway for improvement. I saw that there would be a great demand for a prune that ripened early, that bore freely and that produced a larger, sweeter freestone fruit. And in the year 1879 I started toward that goal.

It occurred to me at once that something might be accomplished in the beginning by hybridizing the French prune with another variety known as the English Pond's Seedling, but called in California the "Hungarian prune." This was a large and handsome fruit; the French d'Agen has a relatively high sugar content and a rich flavor. So I began experiments, with the usual--and always expected--wide variation in the seedlings. But in the year 1883 I was able to exhibit at a meeting of the State Horticultural Society more than seventy seedling prunes that were improvements, in one way or another, on either of the parent varieties, and exactly ten years later still I introduced two entirely new prunes--the Giant and the Splendor. The former was large, not too sweet, and had a tender skin; it was obviously unsuited for drying, but it happened to be exactly the thing for canners. The Splendor was a vast improvement on all other known types--larger, more profuse bearer, higher sugar content and texture and flavor better. But, alas, it had one fatal defect--it clung to the tree when ripe and would stay there and dry rather than be shaken down by the pickers! I had come a long way in these two prunes, but I was almost as far from my goal as ever, as far as selling the new trees was concerned.

There was only one thing to do, and that was to go on with the experiment. Six more years of tireless, patient, costly experimenting followed, but in 1899 I produced the so-called "Sugar" prune which experts pronounced practically perfect for orchard use on a commercial scale. It grows on a vigorous tree that is astoundingly productive, the fruit is of good color, excellent flesh texture, has a sugar content of 23.92 per cent, as against 18.53 per cent for the French prune and around 15 per cent for prunes in general; it is two or three times as large as the French, the skin is thin enough so that the lye bath breaks it easily and makes drying swift and certain; finally, it ripens a week or two ahead of any other variety, at a time when the weather is hot and dry and the danger of loss is reduced to a minimum.

That is, briefly, the story of the development of an ideal prune--a new variety, of inestimable value to mankind, and built up on a plan definitely laid down and patiently followed.

Let us now take an example of a goal reached in plant-breeding that brings out an entirely different method--the use of the process of deduction. This is the story of a walnut tree.

Born in New England, I was familiar with the use of that beautiful, fine-grained aristocrat of hardwoods in the building of furniture and the paneling of interiors; I was also aware that our native forests have been reduced so that now walnut is too expensive for use by manufacturers of any but the highest grade and most costly wares. When I came to California one of the first things I noticed was the California "black" walnut, a tree ranging in size from a height of forty or fifty feet to a mere shrub in the southern California mountains. But few of these California native walnut trees were of a size to make it profitable to cut them for lumber. [The California soft-shell walnut, planted in commercial groves, was an entirely different tree with an entirely different use.] I began to wonder where the walnut furniture of the future was to come from.

It is clear that our American native walnut could be planted in forests, on suitable land, so that in fifty, sixty or perhaps a hundred years this magnificent tree would be yielding timber enough for a revival of its universal and economical use. But we are not a people satisfied to wait fifty or a hundred years for results, especially for results from investments. If anything were to be done it must be with a tree that would come to maturity in a much shorter time. But where was it to be found?

I determined to try to produce one. I began studying the subject closely; presently it dawned on me that I might go outside the history of the walnut tree itself and find a clue that would help me. I turned to Nature, our greatest teacher, and asked my questions direct of her.

She had showed me often before that hereditary tendencies and strains may lie hidden and dormant for untold years or even centuries and then suddenly crop out, in their original strength and potency. She had also taught me that, when two different species are crossed, the tendency is toward a greater virility in some of the offspring than either parent knows. With these two facts in mind I took a quick plunge. I crossed the black walnut of California with the black walnut we call the Eastern. The seedlings amazed even myself, accustomed as I was to surprising results from such hybridizations.

Many of the seedlings were puny, helpless, crooked, weak dwarfs, but a few were sturdy, strong, virile young prodigies, with a capacity for growth and development that were nothing short of marvelous. Named the Royal, these best seedlings simply shot up. In five years they were as large as many California walnuts at ten, or as the eastern at eight; in fifteen years they had passed both their parents and were still shooting up and out. At twenty years of age these Royals were big enough to cut and each would provide many hundreds of lumber feet of the finest possible material for furniture.

This result, remember, was achieved in one single generation, where the prune experiment required about twenty. But I was as sure of my result in the case of the walnut, with one crossing, as I had been in the case of the prune with twelve or fifteen, not reckoning the wholesale quantities necessary nor the infinite time and patience required for selection and elimination in the case of that prune. The explanation is that I had taken a natural law for the basis of my experiment, and had achieved the very result anticipated from that law. It was not an experiment by trial-and-error; instead I had deduced a certain result from a well-established rule.

Naturally you ask me: "Why, though, does that rule exist? What causes the hybrid from a cross of two species to excel the parents in virility and rapid growth--that is, in this case, in size?"

For answer we must go back to our original studies in heredity. In the case of the walnut we must go beyond our own times, beyond the time of recorded history, into the prehistoric ages of the dim past. Paleontology tells us, from records found in the everlasting books of the rocks, that in what men have named the Cretaceous Age vegetable growth, at least, was prodigious--ferns like trees, trees of gigantic stature, even shrubs and bushes reaching up into what now we would call forests. In such a period of lush growth, beyond a doubt, ancestors of our walnut trees--no matter what they were, or whether they were anything like our present walnuts or not--were undoubtedly giants. This power to reach great size was planted in the heredity of the trees we have to-day. Environment, changing conditions on the earth, the incidence, perhaps, of an era when all vegetable life was dwarfed instead of forced to great size, cut down the giants of the Cretaceous Age, and to-day we have only a very few animals such as the elephant (although it is small compared to the mastodon of the past!), and a very few giant California redwood forests to show us what may have existed in the past.

There is first-rate proof of the correctness of this theory, as a matter of fact, in the story of that very Royal walnut of which I am writing. Would it surprise you to learn that, in the nursery rows of seedlings that grew from those hybridized walnuts, there were scores and scores of walnuts that were actual dwarfs-puny, ill-formed, stunted, and determined never to become anything more than shrubs? Well, that is a fact. And this was true, not because of unfavorable conditions, or chance, or the size of the nut planted (which has nothing to do with the size of the resultant seedling, by the way!), but entirely due to heredity. In short, as there were giants in the life-history of the walnut, so were there dwarfs, as suggested above. Implanted in the California or the eastern native walnut, either or perhaps both, were hereditary tendencies, on the one hand toward the giant size, on the other toward a dwarf state. And that heredity came out in the hybrids, just. as surely as the number 2 will come out of any even number, or as the number 10 will come out of any number ending in zero. Because, in both cases, the factor is there, and can not be lost nor covered up nor lessened, whether we do our sum to-day or ten thousand million years from now!

You may put this down as a rule to add to the others with which we are trying to become acquainted in this science of plant-breeding: Nature sets no limit on the length of time during which a submerged characteristic may lie hidden, nor throughout which it may be transmitted.

But what is it that so often brings these long-hidden tendencies and characteristics to light again in *hybrids?* Why, the chance--one in a thousand or a million, or a million million--that brings together such characteristics in *both* parents, and so into the life-germ of the hybrid, accenting and multiplying the influence of that characteristic-in-germ-form. You will observe the operation of this phenomenon in the human family often. Two parents of ordinary height or ordinary mentality, with giants in stature or intellect in their family trees, will often produce a child of unusual size or extraordinary ability: when cousins marry it does not at all follow that their children will be halfwits or cripples, as some assert, but that the parents are taking the chance of doubling (and probably more than doubling) in their children *both strong and weak* characteristics that they have themselves in their common ancestry.

I cross two walnut varieties that have gigantic trees somewhere back in their family lines, and if two tiny germs carrying the giant-tendency are intermingled in the life-particle within the seed I am certain to get a doubled size-tendency in the seedling. On the contrary, if the two germs happen to have the dwarf-tendency, I am sure to find a dwarf walnut in my experimental bed.

The fact is that we may look with confidence for increased *strengths and weaknesses* of all sorts in hybrids of any kind of plant, and it is this power and inclination of plants to vary and to implant their variations in their seeds that make plant experimentation the continual fun it is. You will get seedlings inferior to the parent plants; you will get seedlings like the parent plants; but, to your great joy and encouragement, you will almost invariably get, at the same time, better or stronger or bigger or more beautiful seedlings--and so you may pat yourself on the back and, like little Jack Homer who pulled out the plum, may cry with gusto: "What a brave boy am I!"

We might go on without end discussing experiments in plant-breeding that have been successful and in which a definite plan has been followed to a definite and worth-while conclusion. But enough has been written to show what is meant by plant-breeding by design rather than plant-breeding by mere chance. The possibilities are unlimited for thoughtful and patient effort, and when you consider what has been accomplished by a few men to date, the promise of the future seems limitless and very rosy. The field is there: it remains for earnest workers to enter it-to learn and practise this art, science, business, or what you will, of "training plants to work for man."

CHAPTER IX
Interesting Failures

IF every novel begun by a writer proved a best seller or if every field sketch made by a painter developed into a salon picture those two artists would have a pretty dull, even though a highly prosperous, career. Similarly, if every experiment I have performed in plant-breeding had resulted in a successful new fruit or flower, my life would have been an easy one--and intolerably dull!

The fact is that the successful commercial varieties of plants and fruits introduced from my gardens and orchards to the world have been few in number compared with the long list of those that have been attempted, at enormous cost of labor and money, and have proved unsuccessful. Of course the public hears of the achievements of science; it does not hear of, nor usually care about, the failures that, necessarily, make up the greater part of the tale. But some of my own failures are in themselves highly interesting, and I have thought it worth while to take you into my confidence to the extent of telling you about three or four series of experiments which produced nothing but material for the bonfire. Do I say nothing? That is a mistake. When you are working with Nature almost nothing you do is completely sterile and a waste of time, effort or money, because she always contrives to teach you something, even from your abortive activities.

One of the most unusual hybridizing experiments that I have performed consisted of crossing the common garden petunia with a variety of tobacco plant known as *Nicotiana Wigandioides rubra.* In this cross the petunia pollen was used to fertilize the pistil of the tobacco plant. The seeds thus fertilized were planted in the summer, as soon as they ripened, and some two hundred plants were raised.

When about a foot high the plants were placed in boxes in the greenhouse for the winter. They revealed no inclination to bloom nor did they vary greatly from the parent tobacco plant, except in the matter of growth, which was very uneven. Some of the hybrids were two or three times as large as the average and in several I noticed a strong tendency to trail--a trait of the petunia tribe. The foliage was somewhat unusual, but not enough so to attract the attention of any but the most careful observer. In general the hybrids were strongly influenced by the tobacco parent.

But toward spring when the plants were again placed out of doors, they soon began to change and to show their mixed heredity more plainly. Some of them turned crimson and others pink. They displayed a great diversity of habit: the tendency to trail like vines increased in many; some grew four or five feet in height with large leaves like the tobacco, and others were dwarfs that might have sprung from an entirely different race from their fellows and even from the two parents.

Of course the first move thereafter was to weed out all that closely resembled either parent, because what we were looking for was a true hybrid. These last were carefully nurtured and given every encouragement; but as fall came on it became plain that there was in them all a fundamental weakness in root strength. The tops grew splendidly, but when they came to a certain size all the plants took on a "pinched" appearance, some died off entirely, and even the strongest of them succumbed to the cold weather early. Here was an end of that project. For without sturdy plants the breeder can not even make a beginning, and all the petunia-tobacco hybrids went to the bonfire.

What happened, of course, was, that for some reason traceable to hereditary influences the hybrids had the flourishing, greedy tops of the tobacco plant and the small and inefficient roots of the petunia. A facetious visitor suggested that the petunia had been stunted in growth and vitality through acquiring the tobacco habit; as a joke that is all right, but as a cold scientific proposition it is misleading, for the poison in tobacco is as inherent as the habit of growing large leaves and could not affect the experiment, but only the poor foolish humans who make the mistake of taking nicotine into their own bodies that were not originally designed to carry such a pernicious load! Also, as I said to my friend the wag, in this case the poor petunia was helpless, as I was responsible and the use of tobacco had been thrust upon it.

My early interest in potatoes never quite disappeared, and I performed thousands of potato experiments, with some interesting results and with hundreds of interesting failures. For instance I made many crosses of our commercial varieties with a variety common in the Southwest and known to the Indians as "the Squaw potato" (*Solarium Jamesii*). This I did because of the great hardiness of this wild plant; my object, of course, was to fortify our common potato vines with greater strength and an ability to produce a crop under unfavorable conditions. But, alas, the tendency of the wild thing to sprawl and spraddle all over the county was too strong for the tendency of the domesticated parent to concentrate on the job in hand, and I gave up.

Another potato experiment gave interesting results, but none of value. It was that with *Solanum Commersoni,* native to central South America, which, like all wild potatoes, tends to spread out over too much territory, but which does have large and handsome blossoms with the merit of fragrance. But although I succeeded in persuading the hybrids to bear seedballs--a habit gradually atrophying in most potato varieties--they produced useless tubers, and their blossoms, while varying in color and in some cases being attractive, offered no advantage over numerous flowers already in existence, so the experiment was dropped.

The most interesting of all the potato-hybrid experiments was that between the "Darwin" potato (*Solanum maglia*), a yellow-fleshed tuber producing an abundance of large seed-balls, and the common potato and other tuberous solanums. One of the hybrids brought forth a plentiful harvest of large fruits (seedballs, not tubers) that were juicy, fragrant, white in color and in taste resembling a firm, very sweet tomato.

And here I took a step that brought on all sorts of confusion and many sharp criticisms of my veracity. Because the fruit came from a potato hybrid and resembled a tomato in flavor I called it the "Pomato." The name seemed appropriate enough to me, but inside a few weeks I regretted its choice, because my friends, the newspaper boys, got the idea that it was a potato-tomato cross and printed that yarn. I was dodging epistolary brick-bats from scientists and plant-breeders for some time after that. As a matter of fact no such cross seems possible by pollenization; later you will learn what came of *grafting* the two. But the "pomato" was a *potato* hybrid.

But it was a disappointment because it followed the rule of Nature in the end and, putting its reproductive energies into the fruit (seed-balls), neglected the job of producing tubers. As the seeds were hybrid, they never came true when planted, and the result was the termination of this most interesting failure in experimentation. If I had had more time and ground at my disposal I should have gone ahead and, by selection, fixed the desirable qualities of this strange hybrid in the seed, thus eventually adding a new and I think valuable vegetable to the gardens of the world. But I was unable to do this and my only hope is that some day it will be tried again by some one else, and brought to a happy conclusion.

As you probably know, one of the most important and largest families of the plant world is the rose family, for it includes such extremes as the beautiful rose bushes of our gardens and the mountain-ash, the raspberry and the pear, the hawthorn and the apple. Naturally I have spent a lot of time associating with the members of this heterogeneous tribe in my lifetime, and the interesting failure I am about to describe was one of the results.

I had on my Sebastopol farm one bush of the California dewberry (*Rebus vitifolius*) which has the unusual habit of bearing staminate and pistillate flowers on different plants. This bush bore only the pistillate flowers, and as it was isolated from all other members of its family it was a perfect subject for my inquisitive tampering. I pollinated the lonesome dewberry with pollen from a score of its diversified cousins, working at this assiduously during the blooming season of 1886, and I raised some six thousand of the resulting seedlings.

Never before on earth, perhaps, was there seen a more widely varying lot of plant-children from a single father. Most of them were absolutely thornless, though many of the staminate parents were thorn-bearers. Many grew upright; the leaves were generally smooth, some resembling the pear's, others partially trifoliolate, and most of them assuming strange and unusual forms. When this motley company came to blooming the flowers were as varied as the foliage. Some of the blossoms were crimson in color and half as large as an apple blossom; some were small and pink; others were white. Necessarily (for when you interfere with any plant's orderly hereditary evolution you throw it out of step!) a large number of the seedlings did not bloom at all, though they were attentively cared for over a period of some years and were otherwise normal.

I did not expect all of the hybrids to bloom, but I did expect most of those that went that far to go on and show me some kind of fruit. I was doomed to a second disappointment. Out of the five thousand plants, more or less, that bore blossoms only two *produced a single fruit!* Neither variety was edible nor even interesting. But I had set great store on the experiment and so I persisted in nurturing the pair until their fruits were mature. Alas, when their seeds were extracted and dried and I cut into them, I found them all hollow. They were nothing but shells, containing no kernel.

The whole experiment was a complete and total failure, but I never destroyed a lot of plants with more sincere regret.

A cross that you might think idle was made at another time between the raspberry and the strawberry; a whole series of strange and dramatic surprises resulted on this experiment. The raspberry was selected as the pistillate plant, and pollen was supplied from whatever strawberry blossoms came to hand. This first stage of the experiment resulted in a gratifying crop of fruits, not markedly different from normal raspberries, but the sequel showed that the influence of the strawberry parent was most potent. For when the raspberry seeds were planted the young hybrids came up looking almost exactly like strawberry plants. In the matter of foliage, certainly the strawberry was prepotent or dominant and the raspberry latent or recessive.

The seedlings were transplanted to the open row in the spring and for some time continued to grow and look like strawberry plants. About the first of June, however, the hybrids began to throw out underground stolons, suggesting the raspberry habit, yet the new plants that sprang up here and there were, again, exactly like strawberries. So far, you see, the influence of the mother plant had been slight.

But along in July came the transformation!

Rather suddenly each main plant sent up two, three, or more strong, smooth canes, which grew to heights varying from two to five feet. These canes were thornless and the leaves and stems were smooth, as in the strawberry, but their form and manner of growth now departed widely from the traditions of the trailing parent. The raspberry heredity had at last begun to appear! Some of the second-stage canes were yellowish, some reddish. There were no blossoms the first season, but in the ensuing year clusters of great size were put forth, some of them measuring twelve inches in breadth. In a single cluster were sometimes several hundred flowers. As to the individual blooms, they were generally larger than the flowers of the raspberry, though smaller than those of the strawberry. Finally, in the center of each blossom was a tiny berry so small that no one could say which parent it took after.

I felt that I was on the trail of an interesting and perhaps valuable cross; but here, again, I was doomed to disappointment, for not a single plant produced seed. The miniature fruit remained unchanged until, in the fall, it fell to the ground and there shriveled up. Once more I hoped that later seasons would reward me with at least one seed, but no! The hybrids were as sterile as mules, and the strawberry-raspberry hybrids followed the hybrid dewberries to the brush heap!

If we now consider the results of these various experiments it will be clear that they have several elements in common. In all cases the relationship, while actual, was distant, and I have learned that Nature does not encourage successful and fertile crosses between varieties that, through the long years of the past, have grown more and more markedly apart. And Nature never does anything without a good reason. In this case the reason is plain. The changes that would be produced, if the crosses I have described were to result in virile offspring, would probably be too divergent to fit into their environment successfully. The strawberry, for example, is hardy and a very early bloomer and bearer; the raspberry has learned to be more leisurely and to prefer warmer days for its functioning. A hybrid from the two would find itself blooming too early and would die of cold, or too late and die of too much sunshine. The raspberry has accommodated itself gradually to increasing amounts of water and takes it up greedily, whereas the strawberry can do with comparatively little. The strawberry grows low and compact, doesn't mind shade, and hides its berries away from birds and the sun; the raspberry is bold, erect, invites the birds to feast on its luscious fruits and loves brilliant hot sunlight. No, if we had started perhaps a million years ago and persisted we might have crossed the raspberry of that age with the strawberry of that age, finding them much more alike than they are at present, and then we might have been successful. Now we have waited too long. We're not going to teach those old dogs new tricks!

It must be clear by now why I said in the opening of this chapter that these "interesting failures" were not entirely devoid of enormously important results, at least to the student of plant-breeding. For they serve to emphasize a great fundamental truth of heredity, which has a bearing on all the problems of racial development, including that of man himself. It is beyond question that the human family comprises widely divergent races; if we will look around us a little we will see that Nature does not approve of crosses between such of them as have, in the ages, grown widely apart.

No permanent good results have been generally achieved, for example, through the commingling of Mongolian and Aryan blood, or of Aryan and Negro. I have said before and say again that part of America's greatness and part of our country's enormous possibilities for influence and leadership in the world are due to the crossing of races--the mixing of blood. But when we consider the long future, we must of necessity be warned (by such obvious lessons as those taught me in the above cases, for example) that there is a limit in the crossing of diverse strains beyond which it is not politic to go. Common sense tells us where that line or limit lies, and we are playing with fire when we ignore obvious danger signals and try to do, in "the melting pot" of America, what Nature, by dividing continent and continent and by isolating people from people, has so expressly avoided over a period of many hundreds of thousands or perhaps millions of years.

CHAPTER X
Fixing Good Traits

IT is traditional that you can not teach an old dog new tricks. The maxim applies as well to old plants. But the plant-breeder is under the necessity of teaching new tricks to his "pupils," and very early in his experience he begins to learn something about where the line has to be drawn between amenable and stubborn subjects.

Most of our garden plants, fruit, vegetable, and flower, are comparatively new in their existing forms; the tendency to variation is still strong in them, and hybrids produced by crossing them can be made to adapt themselves to new environments without great trouble; moreover, by selection, they may be developed into divers and sundry new varieties.

By far the greater part of the plant life of the earth has evolved or developed to its present condition through natural selection, untampered with by man. In the ages following the Glacial Period this evolution and development probably went forward at a comparatively rapid rate, since plants, like man and like the animals, were all forced to adjust themselves to new climates, new conditions of soil and weather, and so on.

This means that it has been a long time now since any new adaptation has been forced on the average plant or tree. And many of them have, therefore, acquired fixed and persistent habits that are difficult to change. The pine and the palm, the sage and the sedgegrasses, for instance, are largely what they were when this globe settled down to its present climatic distribution. The time element, then, has become a factor in the variability of such plants.

In a previous chapter I told of the happy chance by which a cross I made between Eastern and California black walnuts resulted in stirring up, as I believe, a long, long dormant quality of rapid growth to large size--a quality that may have been planted in the walnut before the Glacial Period. But, as I indicated then, I was surprised and delighted to have that dormant quality appear in the Royal; it is something not to be expected in work with such old-established families--the old settlers of the plant world. On the contrary we find those old settlers generally obstinate about taking on new lessons.

Turning to plants that do lend themselves to suggestions, urgings and lessons from the plant-breeder, we see at once that the most amenable are those that, through centuries of living with man, have grown accustomed to making changes in their habits or even their personalities. Either he has deliberately crossed them or he has thrown them together where the bees and other insects could get at them; he has cultivated and fostered the varieties that pleased him most and, in short, has encouraged variation rather than fixity in them.

This does not mean that your field cereals or garden vegetables, your sweet peas or phloxes will offer you variations wide enough to forward experiments, just through sowing their seed. Something must happen to "stir up their heredities," as I am fond of saying--to excite in them the variability that normally lies dormant. And this is particularly true of cereals and the lentils, among other plants, because they are self-pollenized and therefore more than ever inclined to staying on the track. They have the power to vary, as you can immediately prove by hybridizing them, but that power will remain generally unused if you leave them alone.

Yet here we must take into account a fact most important to us in plant experiments: that all plants grown from seed vary more or less (a sure evidence of that latent power), and that the only way we can be sure of getting plants exactly to type is by "division"--that is, from the bulblets developed, or from a part of the tuber, as with the eye of the potato, or from buds taken from the tree and implanted in rootstock where it will be made at home and accommodated with a life-giving supply of nourishment.

That variation in plants grown from seeds will be instantly observable if you will step into your garden. Take two heads of wheat. Would you say they are all exactly alike? Look more closely. This one has more kernels, this one fewer. Here the kernels fill the head from top to bottom; in the next head the top kernels are ill-formed or, perhaps, empty of meat. Some plants are tall, some shorter, some dwarfed. And wheat comes more nearly true than most seeds. Consider the wide variations in pansies, daisies, or such instable flowers as zinnias!

On the other hand, with small differences, apples come pretty true. There will be small and large apples, and those illformed or lop-sided, but usually there will be a mechanical explanation for these variations. The truth is that plants, such as our orchard trees, our potatoes, most of our roses, our berries, and so on, that are grown from subdivisions or parts of a parent plant will vary little. As you probably know, orchard trees are all grown from buds or grafts taken from healthy, fruitful parent trees. But plant a thousand Baldwin apple seeds and, no matter how nearly alike were the apples from which they were taken, you will grow a thousand different apple seedlings, many of them not even remotely like a Baldwin, either in tree form or in the fruit borne. You see, there are many different apples in the Baldwin family tree, and the minute the seeds have a chance they open the family closet and trot out all the skeletons!

And so, as you have already discovered and will frequently be reminded, the plant-breeder's work deals, first, with seedlings--plants grown from seed--and, secondly, with divisions or parts of growing plants that, as in many cases, can be caused to grow into new plants that are actually continuations or reduplications of the source-plant. At the risk of being tedious I have gone over this subject in detail because it is so important to an understanding of the work of plant-breeding in all its phases.

And now we return to the subject of fixing good traits in our experimental plants.

I have said above that many plants, and particularly field cereals, are protected from variation by their habit of self-pollination, that is, inbreeding. Inbreeding is one of the vital processes of race improvement, whether in animals or in plants, and really all breeders owe as much, perhaps, to the breeders of race-horses as to any other one group of specialists, because they were among the first to discover and codify laws concerning heredity and the means for influencing and harnessing it.

It is, I believe, a matter of record that practically the entire stock of trotters as developed in America in the past hundred years, descended from the single ancestor, the celebrated "Messenger." Through some accidental mixture of ancestral strains this individual horse chanced to combine the particular qualities of nerve and muscle, instinct and spirit, that adapted it for speed at the gait called the trot, as against the more natural run or gallop. Breeding this horse early demonstrated that he was amazingly prepotent--that is, that he put his stamp on his get more than did any of the females to which he was bred. As the Messenger trotting ability developed in his colts, horsebreeders began to try to get more and more of the female line bred out and more and more of the Messenger blood bred in; obviously it was never possible to get ten-tenths Messenger blood, but it was possible to get as high as nine-tenths, or even more, in time, and this sort of "inbreeding" was continued until the American trotter was brought to the high state of perfection that made it the champion of the world.

ABOVE: Old Bert, one of Mr. Burbank's assistants, winnowing seed of the naturalist's last flower specialty, giant, zinnias. BELOW: Old Bert selecting corn for seed.

The principle applies with equal force to the breeding of plants, and is simplified for us by the fact that in most cases we can pollinate the individual from itself and therefore eliminate the second parent entirely. But unfortunately it is not as simple as it sounds, because, whereas the breeder of trotting-horses sought one characteristic only--that is, speed--the plant-breeder is almost always seeking a number of qualities. It is as though the race-horse breeder had not only to develop a breed that would trot a mile in two minutes or less, but also to produce all of them in a bay color, make them large and powerful enough to be draft-horses, give them all sensitive but kindly temperaments and, finally and most important of all, develop animals as hardy as a broncho and capable of taking care of themselves whether in a stable or when turned out into the hills to graze. For the plant-breeder who seeks to develop a new and valuable fruit or flower has more goals than above suggested and a more complex problem than anything required of our imaginary horse breeder.

To illustrate, let us return to the story of the Shasta daisy. It was my design to assemble in the finished product the following characteristics: (1) extreme size, (2) dazzling whiteness, (3) broad- and (4) double-rays (what you call petals), with (5) a graceful, drooping habit, (6) a good keeping quality, both on the plant and when cut, (7) a smooth stem, (8) early and persistent blooming, (9) hardiness, and (10) long life and heavy bearing. The perfected Shasta not only presented me with all these desired characteristics, but went further and eventually gave me, in addition, innumerable improved variations in petals and size. But to achieve this result took fifteen years of persistent effort and the handling of probably not less than half a million individual seedlings, with the attendant expense and the labor of roguing out and destroying the unfit.

ABOVE: An old photograph, taken, about 1895, showing Mr. Burbank holding one of his Oriental poppies, with the experiment bed in the background. Note white "neckties" on plants selected to provide seed for carrying on the experiment. BELOW: Winter scene: stored seeds in Luther Burbank's barn. Each box may contain a hundred kinds of plant seeds, each sack a dozen varieties in envelopes.

Generation after generation the plants were cross-pollinated over and over again, the most careful and painstaking selection was being practised constantly, and these, not with an eye to a single quality alone, but to all ten. Moreover, we were always confronted with the difficulty that, in reaching out to bring in or accent some desirable tendency, we might be disturbing and endangering the other nine. For example, when the final cross was made with the Japanese daisy to secure if possible the waxen whiteness of that flower, we brought in, of necessity, some undesirable traits of the Japanese plant, such as crude ungraceful stems and undersized flowers. It was necessary to inbreed, interbred, select, rogue out and repeat, again and again, working with a multitude of seedlings from the cross, before a plant was finally secured that retained whiteness in the flower but rejected uncouth plant habits or small size. And here let us recall, once more, that such intensive (but artificial) work with the Shasta has so upset its heredity that, from the seed, will come undesirable variations for a long time yet, and if you have such seeds and discover undesirable aliens in your Shasta daisy bed, you had better uproot them at once and consign them to outer darkness quickly! For the present the best way to propagate the Shasta daisy is from the root, and then you can be sure that no vagrant strain will come bobbing up in your garden to disgrace you!

What, then, can we say about fixing good qualities or traits in our plants?

To begin with, it is not necessary where we are concerned with plants that will reproduce themselves from offshoots, as above discussed--from buds, grafts, root-divisions, or what-not. No Burbank potato has grown from seed since 1872 when I grew the first one in Lunenburg, Massachusetts: the millions of carloads of these valuable tubers that have been raised, shipped and consumed are all parts of that original potato I produced. No Seckel pear has ever been grown from seed, though there are hundreds of thousands of Seckel pear trees on earth: they are all growths from the original limb that, in the form of an unaccountable "sport," appeared suddenly in the orchard of the Pennsylvania orchardist whose name they bear. If you can perpetuate your successful hybrid or plant-creation thus simply, why disturb yourself over the difficult problem of fixing it in the seed?

But where propagation must depend on the growing, ripening, harvesting, and planting of seeds you must work to give your new discovery or achievement as stable and permanent character as possible. How is this to be achieved?

As a rule to guide us we may accept this general proposition: if the same process of selection and inbreeding and growing and re-selecting, by which the plant is perfected, is carried on for a sufficient number of successive generations, eventually a "fixed" habit will be established. This is that requirement for repetition, repetition, repetition, to which I have referred before. That is to say, if we continue to rogue out plants that fall short of perfection, inbreed persistently to establish the form we desire until it becomes a habit with the plant, and again select and destroy those that disappoint us, the time will come when the undesirable qualities will probably disappear.

There enters into the business at this point, to qualify that last paragraph and to save you from some disappointments, a complex law governing all breeding that may operate to defeat you in some of your plant experiments. That complex law derives from the experiments of Mendel, elaborated by many who have followed him in studies of heredity and genetics. Frankly I urge you to go to the authorities on those subjects if you care to master the theme, for its full discussion would take too much room here. It has to do with the "pairing of unit characteristics" in the germ-plasms of living things.

Let us go back for a moment. Up to this point we have been concerned with "upsetting" heredities in order to bring to light dormant, hidden, latent characteristics--to excite variations. Having succeeded in "un-fixing" the habits of the plant, we now propose, having brought out the characteristics we desire, to turn face about and try to "fix" those new or improved habits in the plant. And, of course, in so doing, we run the risk that we will overdo it and bring back characteristics we have been at such pains to eliminate--at least, to render dormant--in our plant pupil. Having tamed and quieted the noisy boy, in other words, the teacher now runs the risk of going too far and making him shy, self-conscious, and repressed, and so of making him unhappy!

What Mendel's successors have demonstrated is that opposing characteristics are *paired* in the chromosomes; one being dominant, the other recessive. So sweetness--shall we say?--is opposed to sourness, largeness to smallness, profuse bearing to scanty, thorny brier to smooth stalk, and so on. We can and must take advantage of this law in order to do our work with accuracy and technical proficiency. But if sweetness and profuse bearing, for instance, happen to be dominant in the fruits with which we are working, while small size and undesirable thorny stalks, which we want to get rid of, are also dominants, we have to inbreed in order to take advantage of the sweet and profuse-bearing characteristics and to eliminate those small-size and thorn-bearing qualities.

Mendel's experiments demonstrated, and later research has established, that, if you cross White Roughness and Black Smoothness you will get, in the next generation, Black Roughness, proving that Blackness and Roughness are dominant characteristics. But, in the succeeding generation, the Black and Rough progeny being interbred, you will get some Black Rough individuals, some White Rough and some White Smooth. The White Smooth progeny, then, constitute a new race, unlike either of the original parents. They will continue to breed true--that is, to produce progeny that are never black and never rough, but smooth and white. Black and Rough have been "bred out"; White and Smooth have been fixed because the paired units have been divided--have been side-tracked, we may say, and gone off on new routes, leaving our train now made up of what were formerly recessive "cars" in the two strings of freight-cars from which our original train was made up.

This is "line" breeding; it is not easy to understand without study, but that, study is so fundamental to all of the life sciences to-day that, if you feel equal to it, you will be amply repaid by going into it. For the rest of you, remember that this complex law may happen to operate in your favor, especially in experiments with annuals; if it does not, you are bound to trip over it and take a header! The law remains unchanged and unchangeable; it may be your good fortune, if you ignore it, to chance on dominant factors that are going the way you want to go. But if, by the same method of chance, you happen to favor some trait that is actually recessive you are going to be in for some hard work and perhaps for eventual disappointment.

CHAPTER XI

Building a New Fruit

IT has been possible, in the course of my work with plants, to make flowers more beautiful and pleasing, to give them new petal forms, to add fragrance to them, to give them adaptability to new soils and climates, and so on. Shrubs and vines have been trained to be more useful to man, as well as to be more attractive. Vegetables have been through a regular course of training to give them greater succulence, more flavor, new features that add to their desirability, a longer producing season and a greater productivity. Not the least interesting and, perhaps, important has been the creating of new fruits and new varieties of old fruits; in this chapter let us go into that branch of the business a little in detail.

You will remember that the plant-breeder has to keep in mind and include in his plans, when starting an experiment, the numerous factors which must enter into the completed new variety. He must begin with a sturdy tree with a good root system and plenty of leaf surface, and the tree must be developed with power to resist disease and pests. Fortunately here, in most cases, we are able to proceed with confidence, for our buds or grafts can be put into (really "planted in"), proven stock in the nursery. Experiments are continually going forward, all over the world, to produce sturdy and resistant stock into which to put scions; for example, you may not be aware that most of our California grapes would have been wiped off the earth by the vine louse known as *Phylloxera* had it not been for the development of a rootstock that was entirely resistant to the pest. In short, we can be fairly confident now of good, sturdy, healthy roots and trunks for our new variety, and can give our entire attention to other qualities we seek.

We have learned something in earlier chapters about unit characteristics and the way in which they are blended or joined together to make up the "personality" of any given offspring-plant. You will recall that where two parents have opposing qualities--say whiteness in the one, blackness in the other--it is quite often the rule for one quality to *dominate,* and one to be *latent* or *recessive.* We have also learned that the recessive quality thus subordinated will reappear in later generations, if the experiment is continued, with a fixed mathematical regularity.

Bearing in mind that dominant and recessive characteristics will develop, however, let us go on. The one quality we will consider at the moment is, let us say, the matter of *size.* We wish to develop a cherry that shall be a giant among cherries, yet which will, of course, give us also quality--as flavor, juiciness, color --and a generous yield, or quantity.

Now we have at hand a cherry that bears very large fruit of poor quality. We have also a tree that bears small fruit of a delicious quality. Our first step will be to transfer pollen from the stamens of one of these to the pistils of the other--(and I may say here that it does not matter which tree we chose as recipient and which as pollen-giver).

We carefully mark the branches bearing the hybridized blossoms, and subsequently we gather the fruit, save the seed, and in due course plant it and nurture the resultant seedlings.

So, when we have waited a year and a half, we have a row of seedlings from which to take scions for grafting. Here enters the factor of experience in the plant-breeder; it is entirely possible for the man who has spent some years at it to predict, from the appearance of the seedling, a good many things about the quality of the fruit it will subsequently bear. Moreover, at this particular stage of the experiment, selection is not so important, for the first generation hybrids show no very great tendency to variation. That comes later.

In fact, as a moment's reflection tells us, the seedlings in our row are really all of one quality as regards their innate tendency to bear either large or small fruit, and our lesson at the moment has to do only with *size.* One of the parents bore large fruit, the other small. Now we assume that the quality of *largeness* will prove dominant, therefore, when three or four years have passed and our cherry seedlings blossom, we may find just the great luscious cherry we started to develop.

But there are perhaps millions of chances in this lottery we are playing, and we are not likely to be so lucky as to draw the grand prize at the first playing. However, if we continue the figure, our tickets are still good and we can play again. How do we do this? By cross-pollenizing among the seedlings themselves, thus keeping the ground that we have gained, even though it is not yet apparent that we are progressing. At least we are not yet ready to admit any new blood into the life-stream of our seedlings, so we cross them one on the other, repeat the cycle, and in time plant more seeds from our heterogeneous seedling fruits. By a system of trial and error we continue to pursue this simple but fixed program and eventually we may be rewarded with that grand prize we seek.

But, remembering first, that, while smallness is assumed to be the recessive quality, it is still in the lifestream of our seedlings, and remembering also that there is no certain way to tell from foliage or stem or blossom which individual carries it on, we may very easily discover that we have been so unlucky as to save only cherry seedlings bearing small cherries. That would be most discouraging, and might tempt the beginner to consign the whole row to the trash pile and the whole experiment to the dickens! But not the experienced breeder; he remembers that, despite this apparently discouraging situation, *the quality of largeness is still there.* Yes, no matter what results your seedlings show, you have been breeding largeness into all of them, and however it may be hidden, that quality only wants the proper pattern of life-influences to emerge. So let us not give up until we have taken a little side-trip, with a story or fable.

There is a tradition among dog-breeders which I do not vouch for, but which suggests a condition so comparable to that of our cherry experiment that we can afford to glance at it. It is said that the greyhound had been bred so exclusively for speed that, at a certain stage in its history, it was able to overtake the quarry but lacked the courage to make the kill. To overcome this defect, so the story goes, some one crossed the greyhound with a breed notorious as a killer, thus breeding in a strain of almost ferocious courage. Temporarily this gave the hybrid greyhound-killer pups qualities undesirable in the greyhound which had to be bred down carefully through succeeding generations by selective breeding. But eventually that unwanted ferocity was tamed and diluted, leaving the original greyhound his natural speed with an added quality of courage.

This greyhound legend seems much more plausible to-day than it once did, thanks to the advances science has made in the study of genetics and heredity, but whatever its truth, it strongly suggests a lesson for us with our black-sheep cherry-the result of our patient experiments to get size. For, now that we are fairly sure that most of the qualities we want are securely bred into our seedlings, and that only size is wanting, we may go outside and bring in an alien strain with safety.

What we do, therefore, is to search out a cherry-tree that bears large fruits, even irrespective of its other qualities, and inject its characteristics into our cherry, by means of pollination. The theoretical result is now easily foretold, even though, in practice, we may still have some way to go along our road. That theoretical result is a cherry with all the fine characteristics we have been seeking, but at last rewarding us with the final quality of size--and the grand prize in the lottery. I say, this is the theoretical result, because there are two possible happenings at this juncture that would delay us. The first is that the new strain may bring us, for a generation or two, undesirable characteristics that temporarily crowd themselves into the picture and that will have to be bred out or will themselves disappear after further work. The second is that, even after we think we have fixed the dominant qualities we so desire in our seedlings, the perversity of fate might possibly bring up some of the *undesirable* qualities that are, perforce, latent still, even in our carefully trained youngsters.

I have presented here the most gloomy picture possible in an experiment in pursuit of a giant luscious cherry; but I have tried to indicate, first, that at any stage you may be fortunate enough to develop what you seek--and win the grand prize in an early drawing, as it were!; second, that patience and the skill which experience will surely give you will bring you to your goal at last! Plant-breeding is still guesswork in many ways, but Nature's laws are fixed, and one of them is that the characteristics we desire can surely and inevitably be bred into plants if we persist in following them.

And here I must emphasize again another point, that is invaluable to remember in work with *fruits.* It is that, once you have come, either by chance or design, either soon or late, on the fruit of your dreams, you have finished your work, for you will thereafter produce nothing but that perfected variety so long as you propagate it from the tree that bears it. When you are experimenting with plants that can be propagated only from *seeds,* you have to go on, perhaps for several generations and, by repetition, repetition, repetition, fix your ideal qualities in *the seed itself.* But the fruit scion is an integral part of the original tree, and can not change nor vary. If, on the other hand, you planted seeds of your perfected cherry, the resultant seedlings would all vary, and you might be very fortunate indeed to get even one out of ten thousand closely enough resembling your ideal to satisfy you. As we have seen before, there is a tendency in all seeds to vary--it is part of Nature's universal law, and in fruit culture we avoid difficulty by propagating only from accepted varieties, except when we are experimenting to improve or change those varieties.

I have thought that by thus tracing in detail the history of a single experiment, paying heed chiefly to a single quality, but reminding the reader from time to time that other qualities can not be ignored, we could perhaps gain a clearer notion than would otherwise be possible of the practical steps through which a new variety of fruit is developed.

It is through such series of experiments, leading sometimes obviously forward and sometimes apparently backward in successive generations, that the four hundred cherries of my patrician colony have been developed on Sebastopol farm. No two among the four hundred show precisely the same combination of qualities, but all of them show one combination or another, of good qualities. Those that reverted to undesirable ancestral traits hate been weeded out. The rest grow on sturdy trees, are resistant to our local visitations of pests and our local epidemics of disease, and most of them have been tried here and there in other parts of the world to determine which of them can also fill the bill outside the home orchard. What has been accomplished with them is an augury of still better things that may be expected from later efforts.

And so the practical question arises as to what, specifically, are the qualities that the world's improved cherries still lack, and as to what further experiments should be undertaken to remedy the defects. For, despite success already attained with this fruit, the perfect cherry has not yet been produced.

The first and perhaps the most important development to be desired, particularly in the sweet cherries, is the quality of hardiness. They grow to perfection in California--or nearly so--but as yet they are little grown in the eastern United States, and not at all in regions north of Ohio and Missouri. Yet the race of cherries, taken as a whole, constitutes a hardy stock. The *wild* cherries of the eastern states grow far to the north and are able to stand the winters even in the coldest regions.

It should be possible, and doubtless will be so proved, to combine the best existing varieties, for instance, of California, with some of the wild trees and thus to develop a variety that will retain the present qualities and yet be able to grow and thrive and produce anywhere in the United States.

There is another weakness inherent in cherries, which ripen so early in the year, and that is their susceptibility to damage from early, warm rains. When spring brings rain as the cherries are coming toward harvest time, drops of moisture are caught in the little cups of the stem ends and, if the weather is normal, these drops soak the tender skin tissues, soften the cherries and cause them to begin to rot or to drop entirely. One of my cherries has an interesting habit of hiding its fruits beneath the leaves, and to some extent, besides cheating the sparrows, this protects the fruits from the rain. But that is not sufficient. A cherry must be developed, and I think will be, that will not crack even after a shower.

Again, many cherries are subject to blight. A bulletin recently issued by the State Commission of Agriculture of California lists more than twenty insects--leaf-hoppers, scales, mites, caterpillars and borers of various kinds--that prey more or less upon root or bark, leaf or bud of the cherry tree, or that attack the fruit. In addition there are inherent maladies of several kinds; the most serious of these is gummosis, a disease that, because of a tendency to the overflow and condensation of the sap, forms an injurious gum and eventually kills the tree.

Studies of these diseases and of means for combating these pests are going on continuously and intensively, but hybridization with some wild species known to be immune might easily fortify our cherries against attack, as well as add vitality and sturdiness to the trees, with resultant benefits to the cherry grower.

It has long been my belief that a solution of the problem of protecting our fruit trees from both insect and fungus pests must eventually be found in the development of immunity in the trees themselves, rather than in resort to such expedients as spraying and "gassing." In this regard we may well take a leaf from the note-book of the physician, who has learned that immunity to disease often depends more upon the condition of the patient than upon the presence or the absence of disease germs.

To suggest one other line of improvement, it is sufficient to call attention to the familiar fact that the cherry has a very brief bearing season. The Burbank cherry fruits a week or two earlier than most others, but even so the total period of production in the best of them is very limited. By the usual process of raising numerous seedlings, or by crossing and selection, a variety with a longer season might be produced, or, with less difficulty perhaps, new varieties developed offering fruit later than our present commercial varieties do.

I have attempted to show some of the work that plant-breeders have yet before them to do as regards the cherry. I have outlined briefly (I hope, clearly) the process of building a new fruit. It is important to understand that the cherry was only chosen for convenience and that everything said here applies to the other fruits. The field, as I often have occasion to emphasize, is unlimited--the possibilities can only be vaguely imagined. We have been forerunners and pioneers--some of us oldsters--but beyond our discoveries are uncharted lands of discovery and experimentation illimitable in extent.; in the hands of the younger generation and of generations yet to come must lie the application of the principles we have divined and the boundless rewards to mankind that will result from the training of plants to a fuller and more complete service.

CHAPTER XII
Our Friendly Fruit Trees

I HAVE commented before, and doubtless will again, on the amazing way in which plants cooperate with man and meet his demands and preferences, by a gradual process of adaptation, even without the planned work of the plant-experimenter. And this is particularly true of edible fruits and vegetables, for here man's preferences induce him to take a hand in the development of the plant or tree, even though he is unconscious of doing it.

Let us suppose that a small company of humans is cast ashore on a tropic island. There are trees and plants there producing food products, but none of them precisely to the taste of the castaways. In fact, they may even be unpalatable to them, at first, though they will scarcely starve rather than eat a potato that is bitter or a wild plum that is too sour.

However, the exiles will search about for the plum or the potato that is least displeasing to them; if they are intelligent, or even normally cunning, they will save a few of the best potatoes for planting; they are almost certain to throw around their camp the pits of the wild plums, as they eat them.

If we imagine that this colony of Crusoes is passed by and not rescued, the first-comers will, in time, die, and their children will follow them, and theirs them, and so on. Since they all prefer the more mealy, succulent and flavorsome potatoes they will unconsciously employ selection in planting, and gradually are pretty certain, especially if they can somewhere stumble on a potato seed-ball and plant the seeds, to develop a potato, in time, that is vastly superior to the ones first discovered on their island. Also the plum pits they toss away so carelessly are certain to take root, in a few cases, and from these seedling plum-trees the exiles will select those bearing the fruit most palatable and pleasing to them. And so, if we imagine many generations to pass, we will find this group of castaways with improved fruits and vegetables to eat, because of the friendly coöperation of the plants with them.

As a matter of fact something like the above is precisely what has happened in the course of the centuries since man or his predecessors began to eat. At first unconsciously, then, perhaps, with some developing instinct, then rationally, then--with the advent of the science of plant-breeding--deliberately and according to a carefully worked-out plan, humans have been training plants to work for them and to provide them exactly what they want in the way of fruits, berries, vegetables, melons, and all the grains we have to-day. And it is a remarkable thing that Nature has appeared to meet, at last, all the reasonable needs of man with this sort of food: you will find it difficult to imagine any sort of vegetable-kingdom product that can not now be found in use by mankind somewhere on this round globe.

So the trees in orchard or garden are particularly friendly things, to me, and in my long study of them I have grown to understand them and to have an affection for them that is not sentimentality but, I think, sound sense. There is no child of Nature more friendly or helpful to man than a tree, especially one that bears, for his use and delight and sustenance, some delicious food-product. Perhaps it will not be amiss for me to write down here a few notes on my observations of trees and on my work with some varieties of fruit-bearers.

Those close cousins, the apple and the pear, may very well be considered the two orchard trees that are friendliest to man, and have been of the most service and delight to him through the ages. They have always been associated with his life; they have gone with him on his migrations; they have proved themselves adaptable to all soils and nearly all climates; and they jointly produce fruits in a class by themselves and quite without competitors as far as universal popularity and appeal go.

Which of the twain was first adopted by man no one can say, but it is certain that both were friends even of prehistoric men, because, for example, there is evidence from the ruins of remote civilization of the lake dwellers of Switzerland that the pear was known then and there. We are led to believe, by such evidence as we now have, that the apple traveled mainly eastward always, but there is direct proof in my Sebastopol orchard, that the pear traveled both east and west, since they have met there and now grow there side by side, one from China and one from our own eastern states whither it came from England.

As is true of perhaps a majority of plants, both the pear and the apple undoubtedly originated somewhere around the Mediterranean Sea, but as these two fruits traveled they developed, each in its own way, in response to changes in soil, climate, and the diverse tastes of the peoples. When able men began to turn their attention seriously to scientific breeding of plants, great changes immediately appeared: a French horticulturist called Jean Baptiste Van Mons and Andrew Knight, an Englishman, about a century ago gave pears their first impulse toward radical improvement, and our modern fruits of this variety owe much to these two men. Van Mons produced, by selection, about four hundred new varieties of pears. It is interesting to observe that he did this while working on a theory since definitely abandoned--namely, that young plants produce the best progeny. We now know that the older the plant, of any sort, the more likely it is to give you a desirable result from breeding, and one may speculate on the possible achievements of Van Mons if he had known this.

Meantime, in America, one of the most famous varieties, the Seckel, appeared by chance in the early part of the nineteenth century, in a fence corner on the farm of a man whose name was given the "sport"; at that time the Seckel was pronounced superior to any variety of fall pear then known in the world. Some time later there was another accidental advance made, when a pear of European strain became hybridized from an ornamental pear from the Orient. I have myself developed at least a dozen pears that have certain advantages over known varieties, but there still remains a great deal of work to be done with this fruit, particularly in reducing its susceptibility to disease and in increasing its vitality when bearing vigorously.

Far and away the most popular and widely grown fruit in the world is the apple. Regan's *The Nomenclature of the Apple,* lists no fewer than eight thousand varieties by name, and this includes only such selected kinds as have attracted more or less attention in America alone! This leads us to an interesting truth--that apples will come nearer to breeding true to type from seed than any other fruit. You will understand this if you give it a moment's thought in the light of what we have already learned regarding plant-breeding. The fact is that apples, instead of being *varieties,* have been developed along so many different lines as to be almost *individuals.* In other words, if you plant my plumcot seeds--a new fruit unheard of in the world before--all the strains that I brought together to produce this new *variety* are actively present in the life-germ; in the Newton Pippin, however, or the Greening, or the Northern Spy apple, is very little but Pippin, Greening, or Northern Spy; it is almost as though all these apples came from the same tree. And yet there will still be some variation.

The family of apples has had some valuable additions, however, and will continue to have. The remarkable Delicious is a great contribution; it originated in a "sport," for which there is no complete and satisfactory explanation. And, despite the large number of varieties of apples, I myself have grown not less than 200,000 seedlings in my time, from which I have culled perhaps half a dozen valuable new apples. What future breeders of apples will produce are hardier trees, capable of withstanding very cold winters or very hot summers. Also, again, resistance to disease and the inroads of pests will always be a mark to shoot at.

Another interesting friend in the orchard is the peach-tree. The peach is unique among fruits because of the bloom or "fuzz" it bears, and it is common knowledge that this characteristic makes the fruit unbearable to many people. As a plant-breeder I am at once filled with curiosity to know from what this bloom originated, and I am soon led to the conclusion that it was a protective measure the fruit put on at some stage in its development, perhaps to combat an environment of too much moisture, wind or heat, but more likely to build up resistance to the inroads of some insect, fungoid, or bacterial enemy. Under these circumstances the incipient "fuzz," perhaps microscopic in nature, would be developed by natural selection, and a race of. fuzzy-skinned peaches would appear.

It is quite simple to prove that some such change did occur, by cross-pollinating varieties and producing seedlings. Among the variants will appear those bearing peaches characterized by all the physical aspects and forms contained in the peach heredity; this is a familiar result to us. But we should not be surprised, on the other hand, to find several of our seedling peaches appearing with comparatively or almost altogether smooth cheeks. And when we carry out this experiment we discover, also, a few peaches that are very similar to one familiar to us all--a distant relative but unquestionably originating in the same ancestral household--the nectarine. Moreover, my own experiments prove conclusively to me that back of both is a combination from a plum-peach-apricot-almond mixture. I have crossed the nectarine and peach with good results, getting either a peach-flavored-and-fleshed nectarine, or a nectarine in a peach overcoat. Going further I made thousands of almond-peach crosses and produced some of the most beautiful and decorative "flowering almonds" and "flowering peaches" ever seen by mortal eye, including some with fluted, some with double and some with very fragrant blossoms, and colors in these blossoms varying from a bright pink to the deepest and most sensational cardinals, crimsons, and scarlets. A few of the seedlings developed fruits of good size and flavor, but nothing worthy of introducing for themselves alone.

For those interested in the possibilities for plant-breeding that are inherent in the peach or nectarine I may say that a stoneless fruit is desirable and could be produced. To the consumer this would be a great advantage; to the grower it would mean tremendous savings in cost of shipment; to the peach-tree itself it would mean a release from a burdensome and now wholly superfluous necessity--that of manufacturing a seed and pit that require of the tree as much energy and plantfood and strength, per pound of pit, as it takes to produce twenty or thirty pounds of fruit pulp, juice, and sugar!

A fruit that I believe to have been overlooked to the detriment of the race is the quince. Henry Ward Beecher once gave as a recipe for cooking this fruit: "Take one quince, one barrel of sugar and sufficient water, and flavor to taste." The sarcasm had a certain justification in the past, but it has little now, for I have myself produced several new quinces that are entitled to stand high in the estimation of fruit lovers, once they become known.

As in all such instances the inquisitive student of plant-breeding finds an interesting and important explanation for the neglect of the quince. It started, doubtless, with a bad name, but more than that it labored for hundreds and perhaps thousands of years under the handicap of a false theory that amounted to a superstition. This theory was that the quince thrives best in poor soil and without cultivation or care. As soon as I exploded this theory I found the quince ready and even eager to respond, and from our association came, for example, a quince that can be eaten and enjoyed like an apple, with a fine, smooth texture, a certain amount of juice, and a flavor strongly resembling that of the pineapple; also one with a smooth skin, attractive color, and fine, spicy flavor that I was graciously permitted to name Van Dieman after Professor H. E. Van Dieman, then chief of the Division of Pomology, United States Department of Agriculture. This last quince received the Wilder medal of the American Pomological Society for the year 1891, and was accredited with being the outstanding new fruit discovery of its time. These and other meritorious quinces resulted on my work with over 75,000 seedlings--not to mention, again, that care, cultivation, and proper appreciation which the quince was proverbially supposed to abhor!

There are two fruits with which I hope some patient and ambitious young plant-breeder will do work which I had not time enough for, though I gave more than one side-glance to the first and did some interesting things with the second. The two are the apricot and the loquat. The apricot is a delicious fruit, unfortunately now confined by its nature to the most favorable temperate climates; you who have never tasted an apricot fresh from the tree, when it is at its best, can have no appreciation of what its wider propagation would mean. The loquat, a Japanese fruit, is comparatively little known, even in California, where it thrives well; it has a peculiar and unique flavor and bouquet but, in its more prevalent varieties, too little flesh and too much seed. My experiments proved that the flesh can be greatly increased and the seed reduced: here is a job for some one, and one that would prove both interesting and profitable.

The apricot grows sturdily and is not, at present, particularly susceptible to disease or pest-infestation. But its particular point of vulnerability is its blossom: as it fruits early the tree must have the most favorable conditions if it is to bear fruit. Here, you observe, is a new kind of problem for the plant-breeder. I am firmly convinced that the apricot may be persuaded to fruit later in the summer than it does at present, and also that its blossoms could be caused to become hardier, just as those of the almond--earliest of bloomers--have become, through breeding and also through natural selection.

What we call citrus fruits form an entirely different and separate branch of pomology; I found after years of patient and sometimes costly work that I was too far north in California to make friends with the orange, the lemon, the grape-fruit, the lime and their cousins, and must leave them to some one else. Citrus fruit trees are evergreens, with enormous leaf spread, requiring extraordinary amounts of water for that reason and also because they are about 6o per cent juice. This means that they must be irrigated and also that they must have a subtropical climate and rich or heavily fertilized soils if they are to continue to thrive and produce. Work is being done to produce hardier citrus trees, and also to make them more resistant to insect enemies. But if we go back in our minds to an earlier chapter we will realize that Nature will undoubtedly refuse to let us make these fruits hardy enough to withstand great cold, for they are of tropical origin. If she had wanted them to spread far she would have made them adaptable, like the apple or the potato; she did not and that is the end of the subject. All we can do is extend the citrus-area boundaries within reason.

Among important fruits there remains the plum to be discussed, but my work with that fruit has been so extensive and there is so much of interest and value to be learned from it, that it will best be left to another chapter for consideration. The main purpose of this chapter has been to present to the reader some interesting side-lights on fruit-development, and also to suggest just a few of the many ways in which our fruits may yet be improved upon. What impresses me most as the result of nearly half a century of labor in orchard and garden is the illimitable possibilities in this field. We who have pioneered have laid down a few rules, made a few discoveries, built up a simple technic and shown a few results that are mainly useful as evidences of what can be accomplished. It remains for others in the future to delve deeper and really develop the mine of riches that we, as prospectors, have only been able to lay claim to and expose, as it were, with a few scattered "prospect holes."

CHAPTER XIII
The Plum

CLEARLY to comprehend the problem that confronted me when I first undertook to put into effect on a comprehensive scale my early ideas about plant improvement, it will be helpful to note briefly the characteristics of the different races of plums that were brought together in my California "melting pot." Let me outline them.

I have said above that the Japanese strains played an important part in my work with this variety of fruit. And I have also said that most fruits, as we find them to-day, no matter where in the world, typify in many respects the tastes and habits and even the characteristics of the people by whom they have been developed. The Japanese plums, for instance, modified to meet the needs of an island people occupying a relatively small territory, yet one which runs through several degrees of latitude, differ a good deal among themselves as to their hardiness. But in general they are rapid growers, early and abundant bearers, and with unusual adaptability to wide ranges of climate. The Japanese plum is unique in form. It averages large in size, with a high percentage of flesh as against stone, and with both skin and flesh of a high color.

But while the Japanese plums have these signal merits, they are not without their faults. Many of them lack flavor; most of them are clingstone types; they ripen too closely together in point of season; many of them bloom so early that the crop is entirely destroyed by late frosts or heavy spring rains. Moreover, since our Japanese friends use many of their fruits for pickling, their plums often lack juice and sweetness, even when ripe.

The Chinese developed plums of a different type. Their most common variety is really a sort of apricot-plum, known to the botanist as *Prunus Simonii,* with a form and color suggestive of a tomato. Apparently Chinese fruits have not been developed nor improved measurably, at least through centuries of time, and therefore they tend to be of stubbornly fixed types. Here is an excellent example of the manner in which plants mirror the characteristics of the peoples who grow them. Or, as is often suggested, perhaps both peoples and fruits take their natures from the climates that produce them.

In any event the Chinese plum, when combined with other species, brings to the union characteristics that are highly . important. For example, the Chinese plum has a delightful aroma, it is of unique form and rich color, and the stone is very small in proportion to the flesh. On the other hand the Chinese plum is best adapted, naturally, to semi-tropical climates; also the fruit is likely to be bitter, and the skin is subject to cracking.

Fortunately the plant-breeder may eliminate undesirable traits and retain the desirable ones, in the hybrid descendants, as we have seen, and shall see often again, in this study.

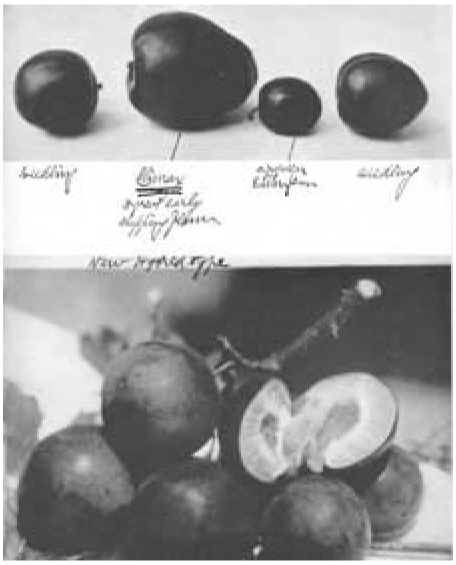
Turning eastward we find that European plums are as diverse in character as the races that develop them. Doubtless both the Oriental and the European plums had a common ancestor, back in the dim past, but the Continental people, both by accident and by intent, molded the fruit to suit their several appetites, whereas, as we have seen, the Chinese and, to a lesser degree the Japanese, took the plum more or less as they found it. Therefore the latter varieties have a fixed and stubborn heredity and the European plums one with a complex lineage, and one, therefore, that it is easier to bend to our modern American purpose.

Summarized in a few words, the advantages of the European plums are: wide diversity as to colors, qualities, flavors, and adaptability to a wide range of climate. Their faults are: stones disproportionately large, flesh too juicy--sometimes almost watery--and many undesirable textures, including stringiness, brittleness, and a spongy quality. Moreover, in them large-size and delicious quality are seldom combined. The Green Gage, the standard of excellence among the hardier European plums, is quite small, and the tree is a light bearer. And all the large plums from that territory lack texture and flavor.

There remain now for our consideration the native American plums--those indigenous varieties that our forefathers found scattered the length and breadth of the land when they came. With hardiness and adaptability to various climates, this American plum also developed productivity; against it is the fact that its crop is uncertain, the trees are often dwarfed, and the fruit, notwithstanding that a fine, very tart, flavor predominates in all varieties, is often soft and watery, and small in size.

Obviously, now, the plums of each of these countries offer for the purposes of the fruit-experimenter certain good qualities and present definite defects. For forty years and more my work has been to take all these plums, combine and recombine them, select and try, redistribute qualities, balance good and bad, eliminate defects, and emphasize desirable traits; finally, to submit the results, year after year and variety after variety, to rigid examination as to all the essential qualities, and finally to offer to the world the results, most of which I am safe in saying are superior in a few or in all qualities and characteristics to any possessed by the varieties with which the experiments were begun.

It is quite clear that we hoped to do in a few short years what Nature would take many centuries for; instead of natural and therefore largely chance selection we substituted scientific selection; instead of permitting seedlings to grow to full maturity and to bear, we expedited the process by grafting and budding, so as to compress great progress into a short time; instead of working with two or three varieties or in half a dozen experiments, we went at the matter wholesale. And, as though to encourage the experimenter who was, for the first time in history, entering on the project with such a huge program, I may say here that notable results were achieved almost at the outset.



ABOVE Photograph, captioned by Mr. Burbank, of four plums, showing variation. The smallest was from one of the parent trees used in the cross that resulted in seedlings that produced the other three plums. The largest is extensively grown throughout the world today, though mostly under names given it later by nurserymen or orchardists. BELOW: Also captioned in Luther Burbank's own hand, this is of one of the more than three thousand new plums he produced, by crossing.

As illustrating this: the first hybridizations between the Japanese seedlings and the plums of European and American stock were made in the year 1888, and in 1893, only five years later, there were six hybrid varieties in my orchards that were introduced and that immediately took rank as superior to any plums at that time known in the whole world. Two of these, named respectively the Delaware and the Hale, were hybrids of a double Oriental stock, one parent being the Kelsey, a Japanese plum introduced by an orchardist who gave it his name, and the other my own Japanese Satsuma--an acclimatized and improved native plum from the Land of the Rising Sun. A third was a hybrid Japanese x Robinson, the latter being an American variety. Two others were crosses of this same Robinson and an improved plum called the Abundance. The sixth was a Kelsey-Burbank plum cross, with both its parents originally Japanese. This was first named Perfection, but renamed the Wickson, in honor of Professor Edward J. Wickson of the University of California.

A "fruit record" card, typical of Luther Burbank's method of identifying tree and describing fruit, with remarks on quality and subsequent tests. His own mark (#) was a symbol of approval. Note eight on this card.

All six were superior plums, but the Wickson outshone them--was really preëminent. It had and has to-day almost no faults; as for its virtues, it offers a tree of perfect shape, vaselike and strong, it branches gracefully, it is productive *almost* to a fault (but--as above!--not quite!), the fruit is large and handsome, the stone is small and free, and the flesh is of fine texture, firm, sugary, and delicious in flavor. It will keep two weeks or more after ripening on the tree, or it can be picked before it is riped and it will still come almost to perfection in transit or storage.

But while these successes followed so early on the inception of the work, it must not be supposed that there were no difficulties encountered. In fact it was, first, not easy to effect the cross between Japanese and European varieties. Some refused to combine at all, and of the thousands of hybridizations patiently and painstakingly made only about a hundred proved in any way satisfactory. It was also most uniformly true that the first generation hybrids produced a poor quality of fruit, and only by a recombination was any good purpose achieved.

You see, I was like a builder who is about to erect a fine edifice: I had the bricks and mortar and hardwood and glass and finely finished woods for my purpose, just as he has them before he can begin. But I was unlike him in that he has a blue-print of every feature of the whole structure, whereas I had only a mental picture of what I hoped to achieve. And, in order to understand the process of fruit improvement thoroughly, let us take the problem as it confronted me back in those days of beginning.

Let us start with the root of the tree--something that is of the greatest importance if we are to produce a commercially valuable plum that will yield profits to the orchardist. At the outset we find that the root systems of many of the plums with which we are to work are inadequate. It is a remarkable fact, but it is true, that you can tell pretty closely what sort of a root system any tree has by observing its upper structure--trunk, branches, twigs. For the root system, if it could be entirely exhumed, would prove to be very like the superstructure of the tree--if the latter has a fine, straight, strong trunk, spreading branches, innumerable sturdy twigs and a fine development of leaves, it will be found that, below ground, is a strong, lusty tap-root, plenty of auxiliaries, and a network of hair- or feeder-roots, the whole system extending down and laterally very much as the tree spreads up and all about in the sun and wind. This, of course, makes selection of seedlings easier, for the growth of the little tree is an index of the sort of root system it has hidden below.

Very good: we know we must have a good healthy, widely spraddled root system. And it should be recalled that an abundance of roots is always closely correlated with abundance of foliage. Many tree lovers fail to realize how completely the roots are governed by the amount of foliage; modern orchard practice takes this into account in the pruning program, and the result is the surprising uniformity of trees in an orchard. Though the trees may vary greatly as to vigor and original habit, when they are raised together and all pruned and shaped to a common standard they soon look almost as though they had been turned out of a mill. If you want to build and perpetuate a fine, branching root system give your tree plenty of foliage through which to feed it.

As to the stem of the tree, this should come up straight as a flagstaff and should branch sturdily, the branches coming out not quite at right angles but turning slightly upward. Branches should not turn down, nor should they be crooked, and great care must be taken to see that they do not grow too long and slender. Brushiness is not only unsightly and inconvenient to the grower, but it is also a pretty good indication of a reversion to an inferior ancestral type and is not unlikely to result in small fruit of poor quality. That is one of the many reasons why I select seedlings with large branches, prominent buds and large, thick leaves.

Given what we conclude is a well-developed tree, we turn to another study of our seedlings, always with the purpose of building a new and improved fruit, and we come to the blossoms. The blossoms should be borne on the larger wood of the tree rather than on the tips. Also, fruit on the extreme ends of the twigs of branches means a heavy weight there as ripening advances, and this means bending the limbs and perhaps breaking them off and mutilating the tree.

The *time* of flowering should be given careful attention in relation to the climate where the orchard is to be located. Many varieties bloom so early that late spring frosts injure them. In addition to missing those possible cold snaps the late-blooming tree has the advantage of a longer springtime in which to prepare itself for the arduous task of making blossoms, buds, fruits, and pits. And we do not need to fear that, no matter how late the blooming season is, the harvest will be thrown dangerously late. Nature takes care of that by enabling the late-bloomer to finish off the development of its fruit quickly--in plenty of time, usually, to be well ahead of Winter's coming.

The length of the bearing season of our seedling must next be studied, and here we must predetermine what purpose we intend for the new fruit. That which is to be harvested wholesale for quick, seasonal marketing must have a short bearing season and get it over with; that fruit which is intended for home or local consumption should ripen over as long a period as possible each year.

Then we consider dependability of bearing. A tree that bears annually and without great variation (except such as is due to unusual weather conditions), and does not have what we call "off years" is the tree we are looking for. Moreover, a tree that balks after starting out with a great load of fruit, and, because of weather or moisture conditions or some "finicky notion" of its own, drops the load is not the kind the fruit-grower will want in his orchard. Perhaps you may have encountered just such trees, or perhaps shrubs or even garden perennials--as temperamental as prima donnas--and just about as useful around the place!

Now we begin to examine, in the course of our experiment, the fruits of our seedlings. First we observe their size, probably preferring a large fruit because there are already plenty of first-rate small plums on the market; next we examine the shape, and here the practical requirements of the packer and shipper and canner may persuade us in favor of the globular fruit; third, we look at the color, deciding that green is not attractive, and preferring red, yellow or blue. The skin of our plum should be thick and firm, especially for a shipping fruit, but it must not be so tough as to take all the fun out of eating it. Now we take cognizance of the flesh, and a sharp knife will be our means of making this test. Unquestionably the plum should be firm, but also juicy; here again we make a distinction depending on the purpose for which we intend our finished product. For home consumption plums may be very juicy--and I have one that, in the family, I call "the Bathtub Plum" because that is about the only place where one can eat it without tucking in a big napkin! For shipping and canning, on the other hand, the fruit must be more or less firm, though never "dry."

What shall we say about the color of the flesh of our fruit? I find many people dislike the purple and purplish-red of the Japanese plums; doubtless we can agree that white or yellow is preferable, or perhaps we can accept a tendency toward pink. Whatever we decide, we are not scientific and finished experimenters if we stop short of our mental specifications, no matter how much longer it takes to complete the "building" according to the predetermined "blue-print."

Next, and, in the case of the plum particularly, we come to flavor. Plums show almost every possible variety here. Certainly every taste can be accommodated: there are sweet and sour plums, sharp and dry ones, bitter and flat, high and insipid flavors. And, as in all fruits, the bouquet or aroma must be considered, since aroma is a complement of flavor and the two should combine to offer us the perfect delight of a truly distinguished fruit. And, to be entirely practical, we who are seeking to develop a new plum must remember that shrewd market buyers and many customers often judge the result as much by smell as by taste.

Finally, there is the matter of the stone. In the case of the very soft plum, the stone may serve a useful function by giving support to the flesh. But the stone can be considerably smaller than it usually is and still be adequate. Certainly it must not be large, for the pit or stone weighs measurably and is practically a waste, certainly to the fresh-fruit consumer. Also, the plum must have the characteristic we call "freestone," and most of my successful plums have been so developed that the stone becomes practically detached from the flesh on ripening.

If to these qualities of root and branch, leaf and blossom, fruit and stone we add a power of resistance to disease, we have come somewhere near perfection. I have pictured here the ideal, and the ideal no man has yet attained in any form of activity. But in any event we have aimed high, and if our arrows fall short we have at least bent the bow to the best of our ability, and have made the great endeavor, so that a bull's-eye is not absolutely essential to our self-esteem. In my own case I do not claim to have reached perfection in a plum, but the Wickson, Formosa, Santa Rosa and one or two others make a fair approximation of what can, I think in all modesty, be called the ideal standard.

CHAPTER XIV
More About Plums

ON one occasion a well-known nurseryman, who had bought many fruit varieties from me for propagation and distribution, stopped before a tree in my orchard and sampled a plum with the air of the expert he undoubtedly was.

"That is the best plum I ever tasted," he said. "At last you have a perfect fruit. Sell me that variety and I'll make a fortune!"

"It is not for sale," I said.

My friend thought that, contrary to my usual practice, I was jockeying for a big price and he began to figure how high he could go with an offer. So I had to interrupt him.

"I don't want to sell that variety," I said, "because it is not at all the fruit that it seems. In the first place, this particular season has been a very favorable one for heavy production and this tree has far exceeded its usual load of fruit. In the second place, the fruit will not stand shipping. Thirdly, the tree requires the most ideal orchard conditions to thrive. In short, this plum can't stand adversity. And you know that I never introduce a variety that cannot prove its willingness to take bad years with good and imperfect soil and culture conditions with perfect. You see now why I said that you can't buy the plum you like so much."

I knew my customer was not convinced. He was relying on the evidence given him by eye, nose, and palate, all of which told him I was mistaken. When he left me I had a strong feeling that he would return the next year--and he did.

I am afraid I had a little twinkle in my eye as I led him straight to the plum tree he had so much admired before; one look at it was all he needed. For three days it happened that we had had unusually warm weather, and that tree which could not stand adversity was wilted, its branches were almost destitute of fruit, and such as it bore was insipid, of poor color and inferior in every particular. He turned away sadly.

"Burbank," he said, "I will never again be guilty of pitting the evidence of my senses against your knowledge. This has been a lesson to me!"

I relate that little anecdote to impress on the reader the need of the greatest caution in testing a new fruit variety. It is all too easy to be deceived by first appearances, by the evidence of one season's bearing, and by one's own enthusiasm. For remember that the work of the plant experimenter is not over when the plant comes to its first flower or the tree to its first fruit. Both must be tested and observed over a period of seasons under varying conditions, and with different soils and climates.

But this procedure only involves time and patience; the real work of the experimenter is in the nursery row.

As we have seen seedlings, especially from cultivated and improved fruits and plants, vary widely, because of the mixed heredity behind them. Therefore our first beginning is with seeds of the best varieties obtainable; these are propagated, selection is made, promising seedlings are saved till they fruit, and from thousands thus handled perhaps there may come one or two fruits worthy of further development.

An extension of this program is cross-fertilization of the seedlings, either on one or both parents, or on other varieties, each experiment being performed in an effort to add to the individual some quality in which it is deficient. Finally the method may be so elaborated that several of the best varieties of different species are intercrossed to form new varieties. My plum "Combination" is an instance: it *combines* the characteristics of three widely varying species and of numerous varieties within these species. In fact most of my plums carry the strains of many diverse species.

Plums in my fruit colony are of every imaginable color, size and quality, and ripen at all seasons from the very earliest in late May or June to the latest in September or even October. (This is in the California experiment gardens, of course; in a less mild climate very early or very late fruits of any sort, except the seed-fruits such as apples and pears, are impractical.) The trees, also, vary greatly, some having green and some purple leaves, some being more hardy than others; some require much moisture, while some will thrive in semi-arid land. The best of them, from the viewpoint of the nurseryman, of course, are those, like the Burbank, that may, be and are grown practically throughout all the plum-growing regions of the whole world.

And here it may be well to emphasize again the reason for the adaptability of such plants as the Burbank plum tree--the same that explains all adaptability, whether in plants or man, in bear or cat, in fish or bird, that is, *diversity in ancestry.* Europe, Asia, and America have furnished the foundation materials upon which have been built the seventy or more varieties of plums, prunes, and plumcots that have already been sent out from my experiment grounds since the first importation of Japanese plums in 1885.

In practically all my plum experiments I used one or another of the numerous American wild plums; this was because, of all plums, our own indigenous varieties are most hardy. Their fruit is usually of good flavor, but small and inclined to acidity. But their ability to stand any climate and to live through drought or flood, under most unfavorable conditions of soil and surroundings, commends them to the experimenter. For that hardiness of theirs, being one of their oldest hereditary traits, is strongest, and least likely to be lost in the process of hybridization with other varieties. So tender plums, easily discouraged by adverse conditions, yet producing splendid fruits, may to advantage be crossed with the American plum, yielding an almost certain result in increased adaptability.

Six important American species have been used in my experiments: American, Wild Goose, Chickasaw, western Sand Cherry, Beach, and the California. These vary widely in quality of fruit, but all have attractive flavors to commend them in addition to their unique characteristic of hardiness, and those flavors I have seized upon and contrived to inject into no fewer than fourteen new varieties I have found worthy of introduction.

Perhaps the most astonishing result produced by cross-pollination with American varieties (native) was with the little Beach plum (*P. maritima*), and one of my hybrid Japanese plums. (Note use of the adjective "hybrid." Whatever the history of the hybrid I selected, it had size of fruit, good color, productiveness and a splendid habit of tree growth--these qualities acquired through the mingling of several Japanese strains over a period of years in my experimental orchard.) A hybrid individual from this Beach x Japanese hybrid, in 1895 bore a fruit *many* times larger than its parent, *P. maritima;* in 1896 the fruit was even larger, and by 1899, as the tree gained in age and strength, the size was still further increased. One of these fruits, measured, was found to be eight and a quarter inches in diameter!

Here is a striking illustration of the power that lies at the very hand of the plant-experimenter, and it is amazing to me that more men and women do not study the fundamentals of the business, art, or science, as you prefer, and reach out for this sort of power. In *one generation* this change was brought about, and this not by chance or guess but by deliberate planning and a practically certain assurance of results.

The trouble has been heretofore, perhaps, that plant-breeding has been a hit-or-miss sort of thing and not reduced to laws. And to point this observation let me add that, in the case of the cross I am writing of, it had been generally supposed that the Beach plum could not be pollinated from, primarily because it blooms very late, after most cultivated plums have passed that stage. But I was not to be thwarted by this obstacle, and used here a device I often used both before and since. What I did was to search out the latest bloomers among my cultivated Japanese hybrids and determine ahead of time that their blossoms would still be capable of fertilization when the very earliest Beach blooms were opened. By cross-pollinating between the latest of the one and the earliest of the others I effected a union that many horticulturists had given up as hopeless. What I mean to impress on the interested reader is that there is almost always a way around difficulties, if he will search for it diligently enough.

Meantime, to go back to the Beach: I had been growing seedlings of the variety by the hundred thousand. Here I did not employ cross-fertilization, but planted the little wild-plum pits as they came to my hand. Instead of pollination I now turned to selection, and by this method had soon developed varieties bearing fruits nearly an inch in diameter, of a pleasing form and color and a most delicious flavor. The trees, moreover, had an almost unbelievable productiveness, together with increased size and vigor. Although the most enthusiastic friends often poked fun at what they called my "huckleberry plums," and fruit-growers scoffed at the insignificant fruit, I saw in the Beach seedlings so many good qualities that I was not to be dissuaded from pursuing the experiment. I finally brought them to the stage where I knew them well enough to make crosses with American and Japanese varieties and hybrids and, although I was usually disappointed in the first-generation results, some excellent varieties, both in productiveness and quality, were brought forth in the second or later generations. The total number of these seedling x hybrid plums was greatly reduced as time went on, but at this writing I have probably a thousand that will be preserved and worked with, with good promise of results useful to the world.*

*After Mr. Burbank's passing, at least three of these *P. maritima* hybrids and descendants thereof were tested and found worthy of preservation and introduction, thus bearing out the prediction above.--Ed.

Another very hardy and promising wild plum of America is commonly called Sand Cherry (*P. Besseyi*). While it has somewhat the appearance of a cherry it is, in fact, a plum. It is thoroughly hardy in the central and northern states, being most commonly found in Minnesota and the Dakotas. From a Sand Cherry cross I produced in 1911 one new plum worthy of introduction--the Epoch. The catalogue description, which sums up its virtues, reads as follows:

> The tree is a compact grower, dwarf, with dark brown wood which always, without fail, produces ropes of fruit, each fruit one and a half inch in diameter, beautiful crimson, with shades and dots of yellow. Flesh pure deep yellow, firm, with a rich cranberry flavor, but sweeter, and when ripe very good. Ripens August 15th. The youngest as well as the oldest trees literally cover themselves with fruit, which keeps remarkably well. Probably the most productive and best of all extremely hardy dwarf plums.

In the California wild plums (*P. subcordata*) is to be found almost every imaginable flavor. The fruit is small and round, but of brilliant color. What recommended the variety to me in my extensive work with plums was the fact that the best fruit is produced abundantly where the trees are growing on poor, almost desert, soil. Under cultivation this wild plum was greatly improved, and some seedlings produced fruit of a superior quality, especially valuable for cooking. When crossed with cultivated plums a large, handsome fruit was developed, and some of my plums that proved the most attractive to canners have been built on the California wild plum.

Thus have the native plums of the North American continent been used in producing new varieties. Turning to the European varieties or those that have sprung from them, we find an interesting history. The earliest settlers brought fruit trees with them, of course, from England, Ireland, and the Continent, particularly from France, where the plum was a favorite. These plums, like the settlers who brought them, found America a land of opportunity, and many of these importations, when acclimated, produced better fruit than any ever known from them in their native soils. While there was no deliberate plant improvement carried on, seeds fell in fence corners and gardens and yards, sprouted and grew, and the seedlings thus accidentally produced often proved valuable and even sensational additions to the list. Every one knows how eager a plant lover is to pass something new and good on to his friends, and those early settlers were not different from us to-day. The result is that those improved varieties of the importations from Europe spread widely in this new land.

It appears that some, at least, of the European plums originated in southwestern Asia, and a wild plum that is thought to represent the original plum variety of the world has been found growing in the region about the Caucasus Mountains and the Caspian Sea. It is known that the plum was one of the fruits, and the dried plum (i.e. prune) a staple food, of the Huns, Turks, Mongols, and Tartars, who practised a rude horticulture from a very early period. The spread of these fruits westward through the Continent and England, and eastward into Japan and China tells the story we have encountered before, namely, that fruits take on the characteristics their growers most desire, so that the plums that traveled *west* became sweeter and sweeter, more juicy, and more delightful to the eye; while those that traveled *east* became acid, drier and generally less attractive and colorful.

The European plums developed good qualities of tree-growth, too, which I found of the greatest aid in my experiments. Strong, vigorous, productive, hardy and upright, these plum-trees put out branches capable of carrying heavy loads and withstanding the strain and stress of storms. Furthermore they proved more disease-resistant than certain Oriental and American Plums.

Another point in favor of these varieties is that they produce new forms readily from seed, so that it is scarcely necessary to cross them with other species to obtain seedlings with varied and new characters. Oddly enough, European plums do not cross easily or to advantage with the Asiatics nor very readily with American natives. On the other hand they intercross among themselves admirably, and especially has the French *P. cerasifera,* or myrobalan, been useful to me. This French plum is a small, slender tree, quite productive. No seedlings of superior quality ever appeared from it, but it lends many valuable qualities to hybrids produced on it from crosses of European plums. Finally, certain of these European varieties, and particularly the French *Prunus Pissardi,* with purple leaves, formed the basis for the production of a new race of plum trees that are highly ornamental. The purple- or red-leafed plum yields inferior fruit, but its beauty is sensational. My experiments produced several excellent fruit bearers with purple leaves, such as Vesuvius (of which hundreds of thousands of specimens now decorate grounds and parks throughout America to-day), the Othello and the Thundercloud.

Asiatic plums are responsible for the unique form of my Apple plum, the delightful pear flavor of the Bartlett plum, the appetizing color of the Santa Rosa and the large size and remarkable shipping qualities of the Wickson. Indeed the Japanese plum *P. triflora* stands as part contributor to forty-three varieties added to American horticulture from my farms, and scores more will doubtless go out from here in time with the same ancestry on one side. China furnished material for the evelopment of other plums, the well-known varieties Maynard, Chalco, Climax, Santa Rosa and Formosa having in their make-up the blood of *P. Simonii,* the "apricot-plum" of China. While it does not give us an attractive fruit, its small stone, delightful aroma and desirable tree characteristics have been imparted to a new race of plums that, without its contributions, would have lacked something they now have that makes them desirable and worthy additions to the catalogue of plums.

Such, then, are the materials that have been utilized in the development of the newer plums. The native plums of the Middle West, the worthless ones from the bleak coast of Labrador, those from the Pacific Coast, those which our forefathers brought from Europe, an unpromising, wild, half-stoneless plum from the Dakotas, Japanese and Korean varieties with large fruits and delightful aromas, the apricot-plum from China, the purple-leafed plum from France and (one of the most useful contributors of them all, though in the humblest capacity!) *P. cerasifera,* which has been grown mostly for stocks into which to graft new, varieties in the nursery--all these and scores more have been freely used, and to great advantage. Although some of the species are in themselves insignificant and unimportant, their characters in combination, through judicious mingling and by careful selection later, have had a share in making fruits of the rarest and most desirable qualities.

And this work, notwithstanding notable results already achieved, is only at its beginning. I venture the assertion that within a hundred years plums will be known on this earth that are as far superior to anything we now have as the Wickson is superior to the wild Sand Cherry plum. For all Nature asks of us is that we determine what we want and with patience and industry we may get it from her. We can go on to now undreamed-of miracles in "training plants to work for man."

CHAPTER XV
The Plumcot

WHEN, for the first time in history, as far as we know, the apricot and the plum were crossed on my farms, the accomplishment was thought by some botanists and horticulturists to be a plain violation of the laws of Nature.

We have already said that man makes many generalizations to which custom and habit give the validity of *laws,* but we have also seen that, when we are dealing with Nature herself, it is not safe to jump at any conclusions without a complete and scientific proof that we *know* what we are talking about. One of the generalizations of plant specialists has been that species will not interbreed, and that they cannot, therefore, be artificially crossed by man. This generalization, when we examine it, has a rather slender and dubious basis. Notwithstanding the almost universal acceptance of the theory of the gradual evolution of all life our friends the botanists clung to the notion that *now* a cross-between-species (that is, one process, certainly, by which a *new* species *must* have been evolved in the past!) was against the rules! I was still quite a young man when I discovered this inconsistency in the books, and I made up my mind then that some day I should put it to the test.

Of course, there are wide gulfs between different species of plants: if, as we now believe, all our present diversified plant life originated in some simple, single form it is obvious that all trees and flowers, ferns and shrubs, mosses and lichens must have a common heritage--be related enough so that some of the narrower gulfs could be bridged by cross-pollination. If hundreds of thousands or perhaps millions of years have passed since the redwood tree and the fern parted company we may pretty well make up our minds that they can not be wedded; if, on the other hand, it has been only a comparatively short time since the apple and the pear, or the apricot and plum reached the fork in their road, we can not, without definite and decisive proof, accept as an axiom that species can not be crossbred.

It was, in fact, in the case of the apricot and the plum that I made my most interesting demonstration that species *can* be interbred, and I did not begin the experiment primarily to justify my theory but for a purely practical reason. This reason was that, in most parts of the world, the apricot can not be successfully cultivated, whereas the plum can. Since there is no fruit more delicious than the apricot, and since the plum has many apricot characteristics, such as attractive flavor and bouquet, juiciness, and appetizing color, it seemed to me that a cross between them might result in a fruit of enormous possibilities. I set to work.

Had I known how much labor, time, patience, and expense would be required I might not have been quite so enterprising. But, no! On second thought I believe I would have gone right ahead; there is something about a tough problem that makes it appeal to the inquisitive and searching mind, and the chances are that nothing could have dissuaded me, even a full foreknowledge of the difficulties and penalties. Plant improvement of any kind tests both purse and patience, and you have seen enough in earlier chapters to know that improvement of fruit trees strains both to the breaking point. Yet, if new ground is broken, a new country of horticulture explored and a new course is charted, all the pains and pangs and penalties are forgotten.

Of course, you now know how my experiment was initiated, if you have read preceding pages with any profit at all. I dusted apricot blossoms with plum pollen and plum flowers with apricot pollen. Being a "wholesaler" by habit I did not confine myself to a dozen or twenty efforts, but to thousands. However, for a long time the experiment failed.

Finally, when I was about to despair or thought I was, several crossbred seedlings were found in a row grown from the seeds of a Japanese plum that had been pollenized with various apricot pollens. These seedlings could be easily distinguished from others by differences in bark, foliage, and general appearance, these being noticeable (at least to me), while the seedling whips were less than a foot high. Examination showed a combination of apricot and plum characteristics, even to the roots of the young saplings, which were varying shades of red, like the apricot root, whereas the plum root is yellowish or almost white.

Now began the interesting work of selection, and here, even though this was an entirely new cross, we worked by rules laid down from past experience for such an operation, since they are universal in all plant experiments. There are certain indications in the youngest of plants as to which way they will go, and as to vigor of growth, root and branch habits, healthiness and general characteristics these apricot-plum crosses had to measure up, or out they went.

But the conflict of hereditary tendencies was at once apparent. Hybrids appeared that departed widely from the traditions of either parent. Of course, there was the expected tendency to sterility that threatens the offspring of every wide cross. One of the first plum-apricot hybrids produced did not have a stamen in one of its blossoms! Many of them scarcely blossomed at all, others showed flowers but could not bring them to maturity. But from the whole number eventually propagated there were enough that blossomed and produced fruit to prove that the unconventional cross was possible and that we were on the right track.

A moment ago I said that I was a "wholesaler" as regards the extent of my experiments; here I used the second device that I had long since adopted and always followed: that is, the process of taking short cuts and tricking old Father Time. Instead of waiting for my plum-apricot seedlings to mature and bear fruit on their own roots I grafted and budded from them into sturdy stock, choosing plum because it is hardiest and most hospitable to scions. The result was that within two years I had the hybrids actually bearing and maturing fruit, and one day for the first time in history a human being tasted a "plumcot"and that human was Luther Burbank.

Thereafter a score of years of further development and experimentation followed, until to-day there are at least a dozen very fine plumcot varieties definitely fixed, with many more in the experiment orchard waiting final approval. The plumcot, which was generally pronounced an impossible dream, had become a fact and one more fruit was added to the world's catalogue.

The new fruits are generally similar to the plum parent in firmness and color; as to form the tendency is toward the plum also, but many show the rotundity of the apricot and the depth of the cleft of that fruit. The stones vary widely: some inherit the plum and some the apricot stone, while a few resemble the peach "pit," especially in the corrugated appearance and in thickness of shell. There is no uniformity in the color of the stones and the sharp, knifelike projection from one edge, a characteristic of the apricot, is found in many varieties. Some stones are attached to the flesh and some are absolutely freestone.

Well, this is the story of the beginning of the plumcot--the first production of the new fruit, in several varieties, a few of which had many virtues. I had proof positive and indubitable that it could be "created," which threw a monkey-wrench, as the boys say, into the theory that separate species can not be interbred. Finally, I had worked long enough to *fix* the new and hybrid characteristics in the new product so that it would come "true to *type"* from seed.

This last is worthy a moment's discussion. We have already seen that the plant developer's task is not completed until his variety or species has been taught the lesson of its purpose, which is done by repetition, repetition, repetition. It is one thing to produce, by accident or design, a daisy or an apple or a lily with new size, flavor, or color, for example; it is quite another to impress on the plant your purpose to keep that quality or kind of size, color, or flavor in the strain. And so, when the plumcot first appeared, years of persistent and skilful work were necessary to fix it as a new species. It might reasonably be supposed that seedlings from the plumcot would revert to the type of plum, or the type of apricot, and at first this was the natural inclination. But that had to be bred out of the tree and fixed characteristics to be bred in. This was accomplished and now the combination was complete and permanent. The new fruit *was fixed as a species.*

Of course, this must not be taken to mean that plumcot seedlings will not vary; you must have learned by now that all seedlings vary, as between themselves. But seeds from one pine-cone or from the cones of any given pine tree will all be pines of the variety of the parent tree; their variations will be wide as to ease of germination, speed of growth, spread of limbs, height, root system and even exact color and character of "needles"--but none of the seedlings will prove to be oaks nor pussy-willows. In the same way, you will find wide variations in plumcot seedlings--wider than in pine seedlings, too, because the pines constitute a very old and proud family fixed through thousands of years of existence and habit. But the new plumcot seeds will all produce, not *apricot* nor *plum,* but plumcot seedlings.

There is one more qualification of my use of the expressions "fixed" and "true to type," and this may be as good a time as any to enter into it. We have already seen that the *older* a characteristic is in any plant the more difficult to overcome or train it; the newer it is, the easier. The plumcot tree has from both ancestors the characteristics of growing a tough bark, blossoming annually, producing a fruit with a pit or stone, covering that pit with a maximum of delicious fruit, and so on. But its new characteristic of combining the apricot and plum flavors and colors, and its new characteristics of combining the hardihood of the plum with the delicacy of the apricot, are all so young in the species that they are not altogether mingled. The tendency to segregation of plum factors and apricot factors in the second and succeeding generations is variously manifested. And here is an interesting fact: At its present stage of development it would be quite easy to find plumcot specimens that, by inbreeding and selection thereafter, could be made to develop races fairly duplicating apricot or plum trees, though never quite becoming either. Just so a "mongrel"--(that is, hybrid)--dog might be so. skilfully bred and inbred with his like that succeeding generations would develop dogs closely approximating one or the other of the breeds which first brought about the mongrel. Nevertheless it would never be possible to produce a "thoroughbred," nor any dog with all a thoroughbred's characteristics, from such a strain. Because, even if the original cross was between a thoroughbred fox and a thoroughbred black-and-tan, let us say, the mongrelization disturbed the line of heredity and brought to life dormant traces of all the breeds of dogs, clear back to the first wolf or fox or jackal from which our breeds of dogs all sprang, that had been submerged and apparently "bred out" of the fox terrier, on the one hand, and out of the black-and-tan on the other.

At this writing, though I have introduced several varieties of plumcots, the species leaves something to be desired. With one or two exceptions it is not yet a heavy bearer; large size in the fruits has yet to be achieved in most of the varieties; only a few have the perfection of flavor and bouquet that I hope eventually to give them. But these are qualities that further years of experimentation, selection, training, and development must give them; I am happy to have made the progress I have in this effort which most of the pomologists and botanists of the earth thought was a fantastic dream!

As a matter of fact the reader must remember that all man's valuable plants of to-day were once wild, bidden by Nature only to reproduce themselves to keep their several species alive. It has taken anywhere from fifty years to hundreds of thousands to give your flowers, vegetables, cereals, shade, and fruit trees, shrubs, and vines the qualities that make them so useful to you or so beautiful in your eyes. By conscious or by unconscious selection they have been improved, man contributing the benefits of his tastes or needs and Nature furnishing the marvelous adaptability and the power to vary which has been so often our theme herein. So the new fruit, whether a natural product of generations or epochs, or one artificially planned and in part of one man's lifetime produced and established, must be worked with patiently and long before it is brought to the stage even approaching perfection.

The best of the plumcots so far produced is the Apex, a final selection of the year 1911 . It ripens with the very earliest of the early plums, about June 10th in my Sebastopol orchard. Inland in California it would be earlier; in less favored climes, later. The tree is a strong, upright grower, and has never failed to bear a good to full crop, even where apricots were failures--precisely one of the first objects of the whole experiment! In some cases the Apex has borne a full crop of fruit even when the local plums were short on account of unusual weather conditions. This fruiting capacity is unusual in the plumcot, as I have said above, but it shows that the new species has latent in it somewhere the capacity, and only time and further development are necessary to bring it out in other varieties.

The fruit of the Apex is extremely handsome, and very large for so early a bearer, being 5½ to 6 inches in circumference. It is globular, and light pink or light crimson in color. The flesh is honey yellow, firm, rich and aromatic, resembling the apricot, and sweet and delicious to the taste. The fruit resembles the apricot very decidedly in form, size and quality, while the tree is more like the plum in foliage, upright growth, productiveness, and the smooth skin of the fruit. It thus illustrates the tendency to segregation of unit characters to which reference has already been made.

This particular plumcot is the only one developed at this time that promises to become a standard market variety, but there are others to follow it that are its equal and, I think, will prove to be vastly its superior. The Apex has an ability to withstand long shipping; it is certainly not a fruit to be lightly passed by, and if my standards were not pretty high I might even be satisfied with it as an achievement.

But one doesn't do that after he has worked at plant-breeding long enough to realize its wonderful possibilities--or, to put it another and probably a more true way: long enough to realize that its possibilities are almost limitless. That is what Nature has done for us: she has given us a few simple laws, the whole wide world to range for raw materials, and, in the plants, adaptability and the power to vary. All that remains is to learn the fundamentals of the work, apply them patiently, intelligently, faithfully, and persistently, and so we can make flowers and trees, fruits, and vegetables, orchard and garden plants and ornamentals just about whatever we choose. If this seems an extravagant statement look back in your own lives and remember changes you have yourself seen and new varieties you have yourself encountered in your own gardens, fields, and orchards.

When we live in a time when one man can have seen the potato developed from a small, warty, watery, tasteless vegetable to the rich, full-bodied, flavorsome, big, smooth tubers of to-day, we can be surprised at nothing. "Old-fashioned flowers." How often we use that expression! What does it mean? Why, simply that most of the flowers even our own grandmothers knew are so quaint and out of style now that we have to characterize them in some simple, distinctive way, and we dub them "old-fashioned," in contrast with the flowers we have to-day. Fruits, vegetables, garden, and field plants of all kinds, have been definitely improved in the last one hundred years almost beyond belief. And this has been either the work of gifted amateurs, the work of accident, the results of specialized experimentation, or the deliberate and conscious effort of a comparatively few men.

When able young people realize the extent of the field, the pleasure and satisfaction of the employment, and the certainty of getting results that plant-breeding offers, perhaps more of them will take it up. And when enough of them demand it, not only the schools but the governments of the world will begin to take an interest more than surface-deep and we will have many more real and breath-taking advances made.

CHAPTER XVI
The Berry Patch

There was a man in our town,
And he was wondrous wise;
He jumped into a bramble bush
And scratched out both his eyes.

THAT nursery rhyme will probably have little meaning for our grandchildren. For the "brambles" of their day will have no thorns, and the berry patch will not be a place of unhappy memories for them.

The thornless blackberry is an accomplished fact, and the value of thornlessness in a berry-producing vine is so obvious that the new product can not fail to supplant the old type. The story of its development is interesting to any one curious about plant-breeding, not only because of the additional light it throws on the general subject but because it demonstrates once more that man has only to consider what he wants plants to do for him and, within reason, the plant will respond. Larger, more juicy, better flavored blackberries, and bushes bearing more prolifically, or earlier, or later--yes; that is reasonable and we have had experiences of that sort of improvement before in these pages. But to shear the vine of its irritating and bothersome thorns--well, that is a new adventure in plant-breeding!

Of course we have only to give the subject a moment's thought to be convinced that the blackberry would be ready to coöperate with our project. Why thorns in the first place? Because for centuries the vine had to protect itself against marauding deer and sheep; the evolutionary process resulted in this defense, through the marvelous mechanism of natural selection. But man took the blackberry out of the woods and dells and put it into protected gardens and fenced patches--and the need for thorns passed. We have seen that all plants should be relieved of unnecessary and obsolete functions, since the energy required to take care of them might better be directed to the production of improved fruit or more beautiful flowers or more succulent vegetables. Blackberry thorns, no longer useful or necessary, but, on the contrary, a distinct detriment, had to go!

As long ago as 1880, while I was still dividing my attention between the nursery that paid the bills and the plantbreeding experiments that were my real interest, I made many trials at producing a thornless blackberry, but without success. The plant with which I first worked was known as the Wachusett Thornless, introduced at about that time and mistakenly denominated, since it definitely had thorns and often plenty of them. It was not a developed plant, but had been found by chance, and its *comparative* freedom from brambles indicated that Nature had actually begun the process, hinted at above, of doing away with a defense that later generations of vines had begun to find unnecessary.

The partly thornless state of the Wachusett was, however, its single recommendation, for its berries were small, flavorless and seedy, and the vine had the pestiferous habit of "suckering" from the roots. I proposed to take advantage of the tendency toward thornlessness and, with that inclination already indicated in this variety, to build up a vine capable of producing really good berries. Unfortunately the difficulties encountered were made worse for me by lack of funds; neither I nor any one else ever went far with the Wachusett, and presently it dropped from view.

Then it chanced (in the year 1902), that Mr. David G. Fairchild, of the United States Department of Agriculture, found in North Carolina a few plants of a wild dewberry that were nearly thornless. Another piece of evidence, discovered many hundred miles from Wachusett, of Nature's intention of dispensing with an organism the function of which had become obsolete!

Mr. Fairchild and myself had frequently exchanged specimens of one sort and another, and he now very kindly sent me a few ripe berries from the partially thornless dewberry. The seeds were planted in my greenhouse; to my great delight, of the several hundred seedlings that resulted, about two in each hundred were nearly or quite destitute of thorns. The others were all destroyed and the selected ones cultivated and brought to fruiting. From the seeds of these berries a second generation (third, counting the Fairchild gifts) was raised, from among which it was possible to select a number that were not only absolutely free from thorns but that showed no signs of any spicules on either stems or leaves.

More than fifteen thousand seedlings were raised from the fruit of the best of these thornless plants and out of that large number not a single specimen showed any tendency toward thorns; on the contrary the canes were as smooth as the branch of an apple tree. My experimental bed of 15,000 thornless dewberry seedlings was far away from any other patch, and the friendly bees and insects had *inbred* the vines, by pollinating from one to the other of these later-generation plants instead of retarding the experiment by bringing back in the undesired thorny trait.

But while the production of a thornless race of dewberries was thus accomplished with ease and celerity, you will have guessed already from your earlier lessons in plant-breeding as here recorded that this was only the beginning of the task. For the berries borne by the new vines were of no value. They were small and of indifferent flavor; we had made one step only, and that in the foundation work under the machinery, but not in the quality of the manufactured goods. And to this matter attention was now directed.

Of course, by selection I could eventually show some results, and perhaps even reach my goal, and still run no risk of having my thornless vines backslide and take unto themselves thorns again. But this was too slow and arduous a means. It was also uncertain, since there was no way of telling surely that the dewberries from which my plants came had had, at any point in their history, the blood of a vine bearing large, luscious, and flavorsome berries. So such "blood" must be brought into the new variety by cross-breeding.

Now the dewberry is merely a trailing variety of the blackberry and it crosses readily with all the varieties of that well-known plant. I had at hand any number of blackberries bearing fruit of the finest quality, but, warned by my experience in the case of the Wachusett "thornless," I knew that these crosses would result in immediate reappearance of thorns on the vines, and also I knew that this tendency to thorns would be prepotent and therefore set me back on my road. However, in the meantime, I had learned that in the *second* generation the recessive quality of thornlessness would break through and a certain proportion of the seedlings would have both the thornless quality of the new dewberry and the delicious fruit of the blackberry-parent. This was, of course, what eventuated.

TOP: Thornless blackberries produced by careful selection through many generations. BOTTOM: Profuse crop of Luther Burbank's thornless blackberry on the Sebastopol Farm.

The experiment now went forward in an orderly manner, and in that regular order of advancement which all my experiments had led me to anticipate. Selection was made of the one specimen in each generation that inherited the best combination of desired qualities, and this was hybridized, in successive generations, with the Lawton, my own giant Himalaya, and various others, to gain size of berry, earliness of bearing, toothsome flavor, an acid tang and the minimum of seeds. Of course, each crossing with a bearer of good fruit meant the introduction of thorns in the next generation, but in the next thereafter the predictable number of seedlings appeared thornless every time. And so, see-sawing back and forth, we made progress, coming at last to a blackberry of very nearly perfect qualities, growing on large, well-shaped, spreading bushes, absolutely without thorns, and the fruit itself large, handsome, glossy, of excellent flavor, and profusely clustered.

Meantime, between the early experiments with the Wachusett and the introduction in about 1907 of the thornless, I had been actively at work with other berries, including the improvement of a blackberry sent me from India. This visitor showed almost at once on its arrival the stimulating effect of the change of soil and climate that I had noticed, for example, in the case of the Japanese plum and of the New Zealand rhubarb. For there appeared among seedlings of the second generation an individual vine that was a very marked improvement on its parents. It proved to have so many fine qualities that it was introduced, in 1885, and widely sold. I called it the

Himalaya. Its berry was and is large, glossy, and sweet, but the outstanding characteristic of the variety is its prodigious power of bearing.

Altogether I have worked with more than forty species of "bramble" fruit, and some random notes on success with the raspberry seem pertinent here. The raspberry and the blackberry are plainly related, though they are not first-cousins, as we might say. The most obvious difference between them is that the raspberry, when ripe, separates from the receptacle, whereas the blackberry is permanently attached thereto. The blackberry was not favorably looked on until comparatively recent years, probably mainly because of its tartness and the vicious aggressiveness of its formidable armament of thorns. The raspberry, on the other hand, has been cultivated in Europe from an early period, the red variety growing wild all over that continent, from Greece and Spain to the Scandinavian lands. By selection many varieties had been improved and had come into general use; in England, a century and a quarter ago, there were said to be twenty named raspberry bushes.

Naturally enough our forefathers brought this favorite and delightful berry with them to America, but the long cold winters of the North and the dry heat of summer in the South were inhospitable and it was not until the colonists turned to the native wild raspberry they found here that they were successful in propagating their own fruit. The earliest variety I find that was extensively cultivated for the New York and Washington markets was known as the English Red; the name would indicate a British origin but I think it much more likely that this was an improved wild berry. Then, in the early forties Nicholas Longworth, of Ohio, introduced an entirely new sport or selection--I do not know which it was, as the records are vague--which he called the Blackcap Raspberry. It was a large and deliciously flavored fruit and sprang into immediate favor.

The autograph foot-prints of various pests were left on this pile of sand in the Burbank gardens and Mr. Burbank had this photograph made as significant of the constant warfare that must be carried on by gardeners and growers against insects and rodents.

From these two and from two native wild vines, *Rubus strigosus* and *R. leucodermis,* have been derived all the raspberries known to-day in this country and, generally, in the continent of North America. Some names, familiar to you, perhaps, are the Purple-cane types, the Reliance, Shaffer, Gladstone, Philadelphia and, since 1860, Allen's Antwerp and Allen's Red Prolific.

For several years preceding 1880 I had been experimenting as largely as my means permitted with all kinds of berries; I must say that I found the raspberry a rather independent and erratic fellow just as likely to come out worthless as not, difficult to predict about and with a mind of his own about which of his family relations he would consent to combine with and which he would not. But it was while working with these and other experiments that I slowly came to a realization of the fact, often referred to before in this volume, that all the best variations and recombinations in a hybrid stock, obtained by crossing, appear in the second and a few subsequent succeeding generations--almost never in the first. This was, of course, Mendel's Law, that I had observed in many experiments long before Dr. de Vries and others unearthed the Mendel reports and made them belatedly public.

Of course, as usual, I conducted the raspberry experiments on a large scale and it was not long before several varieties of value were developed-varieties superior in size, quality, and productiveness to any raspberries theretofore known. The first one of these that I introduced was named the Eureka (1893) ; it was described as "larger than any raspberry in cultivation; bright, red, firm, very productive and similar to Shaffer's Colossal in piquant acid flavor. The bushes are compact in growth and almost free of prickles."

That last phrase is important. The truth is, that raspberries, perhaps because being so much longer in cultivation, showed a tendency before my time of dispensing with their wholly useless thorns; by pressing on this tendency I succeeded in fixing several new types with practically smooth vines. A cross of Gregg and Colossal brought me the Dictator, having the acidity of the first modified by the sweetness and delicate aroma of the second. Another cross of the Gregg, this time with the Souhegan, produced a prodigious bearer; marrying the Souliegan to the Shaffer brought about a berry wondrously sweet which I named, without much originality, perhaps, the Sugar.

Out of all this experimentation, sometimes by design and sometimes by chance, came scores of interesting and a few very valuable new *hybrid* berries, the first of which to be introduced being the Primus berry. This highly interesting fruit, probably the first plant of any kind that could properly be termed a new species developed under the direct guidance of the hand of the experimenter, was the progeny of a hardy little Siberian raspberry and the California dewberry.

The former was remarkable for its sturdy growth; the latter bore rather soft berries, but of a superior quality and flavor. Out of the great number of seedlings propagated from this cross came one that was almost a perfect hybrid. The fruit, larger than that of either parent, resembled the blackberry in form but was of a dark mulberry color and of a delicious flavor; it had the merit of coming free of the core when ripe, like the raspberry; it grew on a plant neither trailing nor upright, but midway between, rendering harvesting of the fruit easy. Finally, this seedling, from the first, had its new qualities fixed and permanent. There was some satisfaction in welcoming that particular baby to the family, I can tell you!

And here is an interesting fact in connection with the successful termination of this experiment that will carry you back in thought, perhaps, to earlier statements made about dogs, for example: that out of a litter of crossbreds there will occasionally come one dog superior in intelligence and perhaps even in nobility of appearance, splendor of body and high qualities of character to those of either parent, while all the rest of the batch are utterly worthless. In the case of the Primus berry it would seem that the two parent species were separated almost to the limits of affinity. The fact that the other seedlings of the same generation were feeble and degenerate plants corroborates this theory. There must have been just the elements in the two types of germ plasm necessary to the production of this one remarkable offspring: favoring chance did the rest!

The promise given by the above experiments resulted in my doing a great deal of work with the dewberry as one parent; from all this resulted a berry that has become widely cultivated and promises to become more popular in time. It came to light by a slight variation of the method used above: after hybridization between the dewberry and several red and yellow raspberries had brought nothing worthy, the seeds of the *seedlings* were planted. It was from these that there came a mammoth berry, measuring up to an inch and a half in length and an inch in diameter; the fruits were of a dark crimson color, slightly downy but glossy; in flavor they combined the qualities of raspberry and blackberry, both flavors seeming to be intensified. It was, in fact, not unlike the accidental hybrid discovered some years ago by Judge J. H. Logan on his place near Santa Cruz, California. But the berry I write of, which I originally called the Humboldt, but which was named Phenomenal by the purchaser, is far superior in size, quality, color, and productivity, and it is gradually displacing the loganberry. I may add that the two are sometimes confounded and unscrupulous dealers have been known to sell the loganberry under the name of Phenomenal.

Before I close this brief summary of the work with these berries and go on to other subjects let me emphasize the importance of what seems to me a very significant scientific fact brought out in connection with these experiments. This is that what I did in producing really new species of berries, by crossing, Nature does frequently in her own Experimental Grounds--woods and plains and jungles and deserts. I have seen with my own eyes entirely separate, different, and new species growing as seedlings where two recognized species lived together closely enough and in numbers large enough to make crossing inevitable. I have elsewhere observed, and I emphatically repeat, that any theory of the origin of species that does not recognize this natural cross-hybridization among the methods employed by nature for the production of new species is altogether inadequate.

CHAPTER XVII
The Most Wonderful Thing in the World

WHEN a man is fool enough to use a superlative he is pretty certain to start an argument, and very often he gets the worst of it.

So I will begin by saying that my choice as the most wonderful thing in the world is my own selection and you are free to disagree if you want to. Most of you will have your favorite candidate for this unique distinction: some will say it is love; some, a baby or a baby's first smile; chemists may assert that it is carbon; engineers, the force of expanding matter; physiologists, the human thumb; physicists, cosmic rays; from these on unendingly. But I am satisfied with my choice and I think you will be interested in the nominee, whether you agree with me or not.

The most wonderful thing in the world to me, then, is this: the leaf of a growing plant.

Why do I say that? For a simple reason.

The leaf of a growing plant is the chemical laboratory or, perhaps better, the manufacturing establishment, where the plant turns earth's beneficent elements into the living substance that is the foundation and basis of *all the life* on our globe!

Does it seem to you that, as the boys say, I am taking in too much territory with that statement?

Not at all. Oxygen, nitrogen, carbon, hydrogen, and the other constituent elements of organic matter are not living things; they are the ingredients which sustain life. But they can not be metamorphosed or absorbed into living cells directly. If you take a slice of bread or a piece of beeksteak or a glass of milk to a chemist he will break your food down into definite elemental units, telling you just how much hydrogen, nitrogen, phosphorus, and so on, there is in each. But if you ask him to take exactly those same elements, in exactly those same proportions, and mix them together in a test-tube the result he gets will not be a slice of bread, a bit of meat or a glass of milk. Between his test-tube of component elements and your bread or meat or milk is a process of absorption and transmutation, almost miraculous in character.

And that process is made first of all for all living things in the plant's laboratory or factory, the leaf--*and only there!*

That leaf-factory makes possible the food of all living things. On an apple tree it furnishes the nourishment to develop blossoms and buds and from them delicious fruit; on a wheat stalk it brings to harvest the grain that is "the staff of life"; in meadow clover it feeds the cow and the deer that, in turn, supply milk and meat for humans and a robust diet for panthers and wolves; in corn it supplies your children with breakfast food and your chickens with a "scratch food" that eventually turns into toothsome broilers or into eggs. In brief, as I have said, every living thing, if you go back far enough, depends for existence, growth, and development, on plants. The birds of the air, the fish of rivers and seas, the smallest insect, the greatest genius among men, the animal world from mouse to elephant--all of these live on plants or their products or on other organisms that subsist on plants, or on other organisms that subsist on organisms that subsist on plants, and so on. All--*all* turn, in the end, to the factory that is the plant leaf!

What is this factory and what is the process that goes on in it?

Well, to begin with, you know that the leaves of plants are green, in whole or in part; you probably also know that plants that are stripped of their leaves during the growing season will die. This green color in the leaves, then, plainly has something to do with the process we are talking about. That, in fact, is true. The green color in leaves comes from the massed effect of little structures called *chlorophyl* granules that nestle in the individual cells. And these chlorophyl atoms, worked on by the action of light from the sun, have the power to and do transform inorganic into organic substances--lifeless matter into life-giving and life-sustaining matter.

We do not yet know why these chlorophyl granules adopted their green uniform, though we suspect that the color has something--perhaps everything--to do with their magic powers. It is enough for us here to know that chlorophyl is green. It is true that there are plants with leaves that seem white or yellowish or even red, but under the microscope you will find that green is really there; also you will find that plants with what we call variegated leaves are either short-lived or die when the varicolored leaves too greatly outnumber the green ones on the plant.

We do not know how it is possible for the chlorophyl to combine inorganic elements into nutritious food. The process is called *photosynthesis*--"a combining through the agency of light"--but we have got only so far as naming it. So, leaving out the *why* and the *how,* we find our feet on firm ground only with the fact that what I have described above is what happens. Let us consider the happening more in detail.

Just as in other factories, the leaf must have raw materials and here we get "down to earth" in a very real sense, for the raw materials for the leaf-factory must be supplied by the gardener--by the person who sows the seed or plants the shrub or sets the tree.

If you were to put a seed into an empty box and lay it away in a cool, dark place, or even set it on a sunny window ledge, the seed would remain a seed till it disintegrated from age. If you dropped it into a jar of absolutely sterile water it might sprout because of the plant-food stored within, but it could not grow much. If you put the seed into dry earth and kept all moisture away from it, it would die. If you put the seed into fertile soil and watered it but placed the pot in a vacuum-tube and drew all the air out, it would never survive. Generally speaking it would not grow, either, if you kept it in complete darkness, even though it might put forth a shoot or two and live for a time in a sickly, pale fashion.

In other words you, the amateur gardener, must supply your plant-factory with a proper site and with *all* the four necessary raw materials--earth, water, sun, and air. As a matter of fact the earth is not, in itself, an essential element: certain essential elements are *in* the earth, in greater or smaller quantities and in right or wrong proportions. Looked at thus we see the earth more exactly as a warehouse where certain raw materials are kept for the factory manager to draw from as he needs them.

A good many of us, too, have a slightly mistaken notion of the real function of water in the garden. We think (and sometimes speak), of our flowers and shrubs and trees as being "dry" or "thirsty"--of their "needing a drink." It is natural to suppose that the water is "drunk up" by the plant just as, when hot and thirsty, we crave and take a glass of water to quench our thirst. The truth is that the primary purpose of water, as far as a plant is concerned, is to dissolve those elements in the soil which it must have for its leaf-factory so that the solution can be drawn up through its roots. Every essential constitutent of plant food might be present in correct proportions, in soil packed with just the right degree of firmness about the roots, yet without water to dissolve those elements the plant would soon die, once it exhausted its stored supplies--used up all its reserves. We drink water that may go almost directly into an element of life in our bodies; we also have marvelous glands that supply our machinery with juices and extracts vital to life. But the plant's water is part of its sap, which contains also its food. And so, when we learn, through study and experience, what amount of water suffices to dissolve the root-foods so they can be absorbed we will have learned how much water to give them. More will drown them out; less will cause them to starve.

Now, what takes place within the structure of the leaf that transmutes the inorganic elements drawn up in the sap into life-giving matter? The answer is that those green-uniformed workmen take a certain number of molecules of water from the sap and compound those with a certain number of molecules of carbon, that has been extracted from the air brought into the leaf-factory through its tiny mouths, called *stomata.* These elements are hydrogen and oxygen and carbon, you see, but they are now miraculously put together to become *sugar.*

But sugar-making is an intermediate step. The factory now goes on to change some of that sugar into starch, which is stored in the plant for emergencies--for a reserve such as we have referred to above. The rest of the sugar is now taken in hand by the green chlorophyl workmen and combined with other elements that have come up in the sap and this combination is that most wonderful and amazing of all substances on earth--the life-making and life-giving and life-sustaining principle called *protoplasm.* Those other elements, by the way, are nitrogen (which must be changed in the earth into nitrates by being dissolved in water), and small quantities of compounds of potash, phosphorus, lime and of six or eight others in infinitesimal amounts.

Now the factory product is ready at last to be assimilated by the plant--to furnish it with continued life, the power to grow, the material from which to build new shoots and leaves and to extend its root system, the substances needed for the development of buds and their expansion into blossoms and their colorings, their reproductive organs, their little nests in which seeds form and the final step--the ripening of those seeds, that, when they fall to earth again, have stored in them the germs from which the life of the parent plant will be renewed and the incredible cycle begun once more!

Meantime let us glance again at the importance of the leaf-factory in the economy of all life. Nature is so bountiful in her generosity that it is possible for the cycle in the life of each individual species to go on even though a large proportion of the successive generations is destroyed. The leaf-factory is not always permitted to finish its work before it is, as we may say, closed down. This happens, of course, with the grasses that, before they have time to make seed, are eaten by animals, to sustain *their* lives. The flower in your garden may get as far as finishing a beautiful blossom, with all the expensive work entailed by that job, when along you come and cut it to put in a vase in the house. The grain and nut leaf-factories are allowed to go farther: they complete the seed-making process, at great cost again to the plant, then we harvest wheat or corn, the walnut or the pecan, and gobble them down to build up our bodies. Fruits ripen, not to make food for us, but to encase and protect the seeds inside--pips or pits or kernels. But we pay no attention to Nature's purpose and revel in the delicate flavors and delicious flesh of apples, pears, peaches, tomatoes, melons and all and throw aside carelessly the seeds that the plant went to so much trouble to build and in which it stored the life-giving germ and a reserve of starch to help it start in life again as a baby plant.

Yet there are always enough grasses left so that they can finish out their task of developing blossoms and seed; trees go on growing and a sufficient number of their seeds find the earth so that saplings spring up to take the places of parent trees chopped down for firewood or dead of old age; the seedsman refuses to sell his lettuce or peas or sweet corn in the market but lets them ripen and fill out their days so that he can supply gardeners with seeds for the spring planting. The point is that the leaf-factory, all along the line, has been running three shifts turning out protoplasm, making life possible to the plant, and so providing all living things with means to survive, grow, reproduce and enjoy their little place in the scheme of things, whether that place be to cluster with trillions of others and form a coral island, or to rise three or four hundred feet as a redwood tree, or to run a mile in less than two minutes as a race-horse or to take a quill pen and, as Shakespeare, write such a drama as *Hamlet!*

Do you think that I am so far wrong, now, in saying that the most wonderful thing on this round globe is the leaf of a plant?

There is one very fascinating subject we should refer to here, before we go on. It is a question that comes to mind when we study the operation of the plant-factory, namely, how does the plant lift its dissolved food up to the leaves from the root system. The tiniest creeping ground covering and the loftiest monarch of the forest uses the same system. What is it: a pumping plant, a pressure system, some sort of elevator? Plainly the plant has no heart, to send its lifestream coursing through its veins. And stop to think that the larger species of plants must lift a tremendous amount of water. For example, consider the orange tree. An average orange contains four or five ounces of water, in juice and the cells of the "peel." All the leaves and twigs are full of moisture. The tree "breathes off" a great deal of water every hour, through its leaves. Give it, say, a thousand oranges and you will see that the fruits alone have to contain thirty to forty gallons of liquid. And this must be drawn up from the roots. How?

Alas, we do not know.

Here is one of the gaps science has yet to fill in our knowledge of the how and why of the fascinating universe about us. Some day, when that gap is closed, I imagine that we will look at one another and say: "How simple! Why didn't we think of that before?" But at the present moment the complete explanation escapes us.

It has been reasoned that the law of capillary attraction may operate here to some extent. That is the pull one molecule exerts on those that touch it so that, in extremely tiny, hairlike tubes, they will pull one another along, like children paying "Crack-the-whip."

But the Dutch physicist, Vant Hoff, partly in answer to questions from Dr. Hugo Vries the great naturalist and botantist, gives us the clue that is most widely accepted now. He thought that the sap is elevated by *osmosis*--that is, the passage of water through a membrane from a weaker to a stronger solution. This passage is due to the push of the molecules on the "strong" side against a cell wall until there is an equalization of pressure on the "weak" side. And since we know that the sap of plants does not rise in continuous tubes or veins, like our blood-vessels or like a waterpipe, but step-by-step from one cell in the sapwood to another, we are inclined to think Dr. Vant Hoff is on the right track.

The process, you see, is not altogether unlike the activities of a "bucket-brigade" at a country fire, where pails of water are passed from one hand to another, instead of like those of a city fire department, where a hose is connected to a main and the water is pumped through by the fire-engine.

Strangely enough, plants have an amazing power to lift overloads of sap that, considering they do not have a pump, increases our wonder and awe before this problem. If you wound almost any plant it will "bleed" --that is, its sap will be exuded where the cut or break occurs. This is noticeable in the cases of spruce trees that are found with blotches of solidifying gum in seams of the bark of the trunk; peach trees, if hurt, will cover the whole wound with a thick coating of a gummy material. And in one case, at least, this phenomenon has been taken advantage of by man who, tapping the maple tree, draws off quantities of sweet sap every year without seriously damaging the tree. How much more work the maple has to do to transform the elements into sugary sap for us to take from it, without return, is cause for new wonder!

Yes, we owe more debt to the plants than we usually stop to reckon. Beauty and fragrance we take for granted. Delightful flavors and appetizing nourishment we get from them with every strawberry we pluck or every bowl of porridge we eat. Our hunger is sharpened by their zestful spices and aromas. Our clothes are made from their bolls or the fibers of their leaves. Our houses are framed and finished from their timbers. Our animals are fed from their leaves or their grains of seed. Look where we please we find them serving us--in the paper of this book, in the rugs or matting on our floors, in the coal that burns on the hearth and in the gasoline that drives our automobiles and flying machines--for buried plantlife, deposited deep in the earth, has been transformed into carboniferous deposits there. In truth, there is almost nowhere we can look *without* finding our debt to plant-life increased.

And now we discover that the very stuff of life itself originates in that marvelous factory--the leaf!

CHAPTER XVIII
In the Vegetable Garden

YOU may wonder why we got switched off, in that last chapter, from the study of plant development to the theory or science of plant growth. The reason is not far to seek.

I want to take you now into the vegetable garden, and in the vegetable garden we find treasure houses of the sugar and starch that are made in the leaf-factory--find them stored there, ready for our use in delicious and easily assimilable forms.

Those stores are mostly of what we call carbohydrates; with the notable exception of peas and beans the vegetables bring us very little nitrogen, which we get instead after it has gone into the animal-factory, the cow, the sheep, the fish, the chicken or the oyster, and been further transmuted before it reaches us on the table. But those carbohydrates are most important food materials, and the vegetables also bring us certain vitamins, minerals and other elements essential to our health and growth. We could not live without vegetables, grains, nuts, and fruits.

Leaving out wheat, our most important vegetable product is the potato. The potato is nothing but an enlarged portion of the root, called a tuber. And its content is not manufactured in the ground where we find it, but is created in the leaf and sent down for storage in the safest place the plant knows of--underground. Similar store-houses, though not tubers, are such root-vegetables as the radish, carrot, parsnip, and turnip. Such plants are usually biennials, storing a reserve of starch and sugar one year and concentrating in the second season on flowering and the manufacture of seed.

Notwithstanding the large number of garden vegetables, all the common forms fall into a few general groups.

There is the great family of melons and squashes, known as the gourd family, which includes all our delicious melons and useful squashes and pumpkins and that also includes the cucumber.

Then there are the cabbages (with which the turnip is connected botanically), the root vegetables above referred to, the peas and beans, such vegetables as the artichoke and the lettuce that are related to daisies and sunflowers and other members of the family of Composites, the onion and its cousins, more valued for their flavor and pungency than for nutrition, and a great collection of herbs. Artichokes and lettuce are really flowers, tomatoes and egg-plant are fruits, asparagus is a tender stem topped with tiny leaves, just as celery is, and rhubarb. In fact, our term "vegetable," meaning a food-plant, usually cooked, that has less sugar than what we call fruit contains, is very elastic. And if I had two lives, instead of one, I think that I could develop to good use ten thousand plants, including many weeds and wild things, that are not even thought of as foods now. Just for example, I mean the common wild thistle--at present a noxious weed that every farmer hates and tries to destroy! We are steadily increasing our catalogue of "vegetables" as it is; just remember that it was in our own parents' time that tomatoes were considered poisonous and were avoided and banned by cooks. Remember also that tender bamboo shoots are a delicacy to the Chinese and that Caucasians who once learn to eat them agree with our Oriental cousins.

It was with the purpose in mind of increasing the productiveness of vegetables, giving them better size, texture, or flavor and generally expanding their usefulness that I devoted a great deal of my active life to work with them. And in this chapter I propose to sketch briefly some of the experiences of that work.

Cucumbers and melons interested me, but I soon found that there was no use crossing them, not because that was difficult-it was, in fact, altogether too easy!but because the results were mongrel types inferior to the parents used. And so I confined myself to selection entirely and by careful work succeeded in fixing some improved variations in both cucumbers and melons. The ease with which this family of vegetables is crosspollinated, referred to above, is a real detriment to the grower. Unless he is scrupulously careful and keeps away from inferior members of the clan, and even

away from such first-cousins as squashes, he will find his melons deteriorating, becoming less and less flavorsome and more and more like gourds or squashes, because the insects have done a little experimenting for a him-and haven't succeeded in bettering his variety!

It is supposed that all of the near relatives of the cabbage are modified descendants of a single species that grows wild along the Mediterranean and Atlantic coasts of Europe. Turnips are descended from another closely related species from the same neighborhoods, and radishes, the horse-radish, water-cress and mustard are, surprisingly enough, other members of the family, though not so close in relationship. From the standpoint of the student of plants the members of the cabbage clan are interesting because of the widely diverse fashion in which they have developed, considering they go back somewhere to a single species--to the same ancestor, as it were. There are the diverse varieties outlined above; also, while the cabbage itself is merely a monstrous flower bud, the edible parts of the cauliflower and of broccoli are really thickened and consolidated parts of the flower and the edible part of kale consists of expanded but tender leaves. Brussels sprouts, on the other hand, are thickened buds developed, not on stems, as we would expect, but in the axils of the leaves, whereas in the kohlrabi it is the short and few-leaved stems that, becoming thick and bulbous, are splendid eating!

Here, then, is a plant in the different related offshoots of which every different part except the root becomes an inviting vegetable for man's use! If some one will develop one of the tribe with a succulent root the family will just about take the prize for wide variations of usefulness!

And here we stumble on a new bit of knowledge of value to the plant-breeder. Because, through centuries of selection, the different members of this assorted tribe have taken each its own path in specialization, with each one developing its own peculiar form of usefulness, it is practically useless to intercross them in the hope of developing new or better forms. They have, in short, attended to that themselves. And so, at least in my experiments, I got little but worthless mongrels when I performed the very easy feat of crossing between them. The only success I did have was in improving a purple-leaved cabbage by crossing it with other varieties of cabbage, working for a larger head and a somewhat less dark color. But when I hybridized sprouts with broccoli or cabbage with kale I got results that would make a man laugh!

After one corn experiment in the Santa Rosa grounds, this plant grew from kernels that fell to the ground in a pathway. By this accident there was brought to maturity a marvelously productive corn variety for the making of ensilage, requiring more stalk and leaf-more bulk.

Turning to the root-plants, including the radish, carrot, parsnip, "oyster plant" and so on, we find them very set in their ways but not beyond improvement, especially as to delicacy of flavor. I spent some time in company with several varieties of radish, hoping to get improved form, color and a sweeter pungency of the meat. But my principal success, because I could not go as far as I would like to have done with the experiments, came from selection rather than crossing. I am sure that definite improvements could be brought about in all these root vegetables, not only as to that delicacy of flavor I speak of but also in the matter of uniformity and smoothness of the root. And it would be advantageous, also, to work toward the minimum development of foliage consonant with full maturity in the root. Here is a field the amateur plant-breeder will find interesting, since he is bound to get variations in any sowing and can increase those variations markedly by doing some cross-pollinating of varieties.

Among the peas and beans there is a great field for the plant-developer, even though, especially as regards the beans, there are already a great number of sorts grown and marketed. The process of selection offers the easiest course, but hybridization, while a rather neat task, might give amazing results.

It was by selection that I early produced a pea according to the specifications of a large canner of vegetables--another illustration of the truth that plant-development can be almost as exact a business as building a house designed by an architect. My client wanted a heavy producer of smaller, sweeter peas than any variety then available; the fact that he sent me *one pod* that he had happened on in a field that was close to his ideal indicated at once that there were variations in the pea that the smart plant-breeder should take advantage of. Since it was possible, in my California gardens, to mature two crops a year I was able, in three years, to select and reselect from six generations of peas and to get a pea at the end that not only met specifications but that contained smaller and sweeter peas than Mr. Empson had hoped for. Of course, more time was required to propagate that prize-winning pea until there was sufficient seed for extensive planting, but presently we had enough to sow hundreds of acres, the harvest from which kept the canneries busy.

You will realize, of course, that, in growing tens of thousands of plants through six generations, we were getting just as many variations away from our goal as toward it. Seeking a small, very sweet pea that would bear prodigally we got large, sweet peas, large, flavorless peas, small, tasteless peas, worthless peas that were fairly groaning with pods, splendid peas that bore only a handful to the plant, and so on. I kept an eye open, therefore, for improvements other than the ones Mr. Empson had ordered and, as it happened, developed four strains of different varieties from the one he had specified, all four of which the canners were glad to buy. Because each of them fulfilled some other need--and did so better than any pea then on the market.

It was with the pea that the great Austrian monk, Gregor Mendel, performed the prodigious series of experiments from which he was able to formulate his laws governing the inheritance of characteristics from generation to generation. Perhaps because the pea has, for centuries, been cultivated under widely differing conditions and pretty well all over the world, the plant shows a marked tendency to vary and is satisfactory to work with, but by selection and-in a less degree--by cross-pollination.

TOP: Wild potatoes from Peru, the original potato of the world. CENTER: Wild potatoes after four generations of experimentation in Luther Burbank's gardens. BOTTOM: The Early Rose potato (left) and the final development of the Burbank potato. These two pictures were made by Mr. Burbank about, 1899.

Tomatoes and potatoes are cousins, even though there is so little "family resemblance" between them, and I have performed some interesting experiments with them, separately and by crossing them. The story of the Burbank potato is known; some of you may be acquainted, too, with one or more of the "Burbank" tomatoes, several varieties of which have been produced in my gardens and are now on the market and widely grown. But here I will relate briefly one astonishing and amusing experience that followed a cross between the two.

This was not a cross by pollination, but by grafting. I was curious as to what would happen if I joined the two plants. In one case I grafted the tops of young tomato plants on the main stalks of potato plants; also amputated potato tops were grafted on shoots of tomato. The first marriage resulted in a bush that looked like a tomato, though with some faint resemblance in the leaves to those of the other parents. The tomato fruit was normal in every way but flavor, which was inferior.

But meantime the potato roots, that had been sending up potato sap to its odd mate above and, in turn, had been receiving starch manufactured in the tomato-leaf factory, insisted on making tubers below-ground. The result was not very successful, the potatoes proving small and badly shaped and bitter in flavor. Some sense the potato roots had that things were all wrong stirred them, too, to a remarkable response. For, almost as soon as the underground tubers were formed, they began *sprouting*--a thing unheard of, at least by me! Usually potatoes keep for weeks or even months after being dug before they start sending out sprouts. The only explanation that occurred to me was that the potato root, supplied with strange food from above, reacted by trying to hurry the process of reproduction before things went all to smash in the upper stories and the factory was closed by the management!

Fully as amusing were the results of the opposite implantation--the potato top grafted on the stem of the tomato. Perhaps you would like to put this page aside and try to guess, with the above story in mind, what happened. You would see at once that the tomato root could not produce its normal fruit on a potato plant; equally the potato plant could not very well force its unwanted partner belowground to form tubers. From there on, what?

Well, here is what happened. The tomato roots sent up their regular supply of elements for the making of tomatoes, and the potato leaves sent back in return the juices, loaded with starch, for the filling out of tubers. But the tomato roots put up an embargo--stopped the shipment at the border! In this dilemma the potato compromised and began growing tubers at the point where potato and tomato met. In other words, it developed something entirely new under the sun--aerial potatoes! These were small, ill-formed, and immediately took to sprouting tender, pale green leaves. But, alas for the tomato roots, the upper half of the partnership was so busy getting at its potato-producing that it had no time to make tomatoes, even if it had the machinery and the hereditary impulse, which, of course, it did not have. Equally, the tomato roots, having known nothing through the ages about producing tubers, were unable to grow underground tomatoes.

There were clues here to one of the important problems of plant-breeding, aside from the comical horticultural freaks developed. That problem is too complex to go into deeply here, but it concerns the question of how far we may go in *sap-*

hybridization. In other words, when the orchardist grafts on to a plum sapling of one variety a plum of another variety, to what extent does the root make over into its own kind of sap the supplies sent down to it that are of another kind? And when we graft several or many varieties, to what extent is the supply that is sent up from the roots to the whole tree modified or blended? On one occasion, for example, a scion of a purple-leafed and red-fruiting plum was grafted on to a green-leaved and yellowish-green-fruited Kelsey tree in my orchard. Presently I observed, on a neighboring, ungrafted Kelsey twig, the development of purple leaves and, eventually, the appearance of a small crimson plum or two. Apparently the purple-leafed-plum-graft's factory had sent down to the roots a food-supply that rose again to that neighboring twig and influenced its leaves and fruit.

Such a striking instance of evident "sap hybridism" is exceedingly rare, but can we be sure that influences of scions from many sources on one another when they are placed together on a single tree may not be considerable? If this be our premise it would seem that such fruit "populations" may exercise something of the influence on individual members of the group that community life in human society exerts on the several individuals that go to make it up. But of this we know, in fact, very little, though coming plant-breeders may astonish themselves and the world by revelations along this line that will prove of vast importance to the whole subject and in the whole field.

That there is such a thing as being too popular, many plants (as well as animals) have learned to their sorrow. For popularity with the plant implies that it is attractive to some hungry beast and its mission in life--to reproduce its kind--is suddenly ended.

The only recourse of the plant is either to develop an extraordinary capacity for thriving under difficulties, as, for example, some lawn grasses do, or to develop weapons of defense. These defensive measures may take the form of a tough and indigestible fiber, a protective coating of thick bark or a coat studded with spines or prickles, the development of a power to sting the enemy (the nettle) or other systems, including that of secreting offensive odors or a bitter, acrid, or peppery taste.

Many of our vegetables originally followed this last plan, but, unfortunately for them, the flavors they developed had an appeal for the human palate. And so several members of the lily family, including the onion and the garlic, and many others such as the mustard, pepper, mints, and the like, were taken in hand by gardeners, their pungencies or strong flavors curbed and modified through selection and their plants put to work for man. When my turn came I, of course, tried my hand at improving these flavorsome garden plants; I proved again and again that onions, chives, and garlic, for instance, were willing to coöperate and furnish our tables with more tender and less odorous bulbs and shoots than the known varieties. But I never was able to fill the order I had from one woman in the east who wrote that she liked the flavor of garlic but could not abide its smell, so would I please produce a garlic with a lively seasoning power but no odor? Of course, what my correspondent didn't know was that most of the spicy flavor of the garlic or the onion is really a smell, caught by the sensitive nerves of tongue and mouth-roof and not a taste in the sense, say, that saltiness or sweetness is. But I did develop a garlic bulb considerably less pugnacious than older varieties and there is more of this sort of work still to be done by plant-breeders in this field.

I also worked with mints, pepper-grasses, peppers like those usually called "bell" (from their shape) and the other vegetables and herbs that are chosen for their appetizing qualities--their spicy and unique flavors. Those sweet peppers were very amenable to development and many years ago I introduced and sold to a seedsman a large, sweet, heavy-bearing pepper that he called for a long time "the Burbank" but which has since, I believe, lost the name. More can be done with all these vegetables than has been done, except in rare cases. With many, as I have suggested, selection is the route to take in seeking improved varieties; in other instances much may be done, and probably will be, by crossing. But, no matter what program is followed, the introduction of new and superior forms of vegetables for the tables of the world is certainly a fine, high goal for the plant-breeder. For so can he benefit the largest number of people in the most direct and practical fashion.

CHAPTER XIX
Hand-Made Flowers

PERHAPS we have gone far enough in our exposition of the principles and practices of plant-breeding now so that at this stage we can give you some hints as to how you, in your own garden, may perform experiments and develop flowers that, in greater or less degree, are actually "new creations." This is meant precisely as it is set down. If you care to give the time and if you have patience you can not fail, within the space of a very few years, to have in your plots somewhere a flower that is definitely new--a handmade flower different from any you or your neighbors have had before.

To begin the lesson, let us take an experiment performed in my grounds looking toward the development of a plant with a new sort of *leaf.* I choose this account because the leaves of plants have pretty generally fixed habits of growth, form, color, shape, texture, and so on and, though they vary, do not vary as much, in ordinary cultivation, as do the flowers of the plant. And the plant here involved is the wild geranium (*Heuchera micrantha*) which is a native of the western coast.

Several years ago I found one of these common little wild plants on a dry, rocky ledge in the hills not far from Santa Rosa, that attracted my attention because its leaves were slightly crinkled at the edges. As this is unusual in the wild geranium, I lifted the plant carefully and took it home with me for some further study.

Let me say right here that this tendency of my new-found friend to produce crinkled leaves caused me to take particular note of its surroundings, because I knew that the time would come when I would want some explanation of the strange quality in the leaf and then it would be important to know what its environment had been. What I saw was that there were other wild geraniums growing in the vicinity, but some of them were in sheltered, shady spots, some in damp places, some in full sun but where there was moisture, and some, like the one with the crinkly leaves, in the barest and driest and hottest possible spot. All of these plants had adapted themselves to their different environments; this meant that they had in them different qualities and powers---in short, plants produced from the seeds of these different individuals would not only differ in themselves but would have increased *power* to differ--a subject into which we looked pretty carefully in earlier chapters.

But of all the plants I saw only the one had put forth those crinkled leaves. So it could not be that I had come on a community of crinkled-leaved geraniums; only that I had found a spot where enforced variations had, in one case, resulted in this phenomenon. And enforced variations, whether due to environment or cross-breeding, are bound to create in the plant a tendency toward, and a capacity for, variation in its children. That, of course, would help me, because what I was always after was a range of variations from which to select all the individuals that I found were "going my way."

Well, in due time I gathered from my little *Heuchera* a tiny harvest of exceedingly small black seeds, which were planted. When the little plants were only a few inches above ground I found some with leaves more crenated and crinkled than others and a few more so than those of the original plant. Ruthlessly I destroyed at once all the individuals with smooth-edged or only slightly crinkle-edged leaves, to save time and space; a little later I repeated this process; then again and yet again until, in the fall, I had *one single* wild geranium with most interesting crinkled leaves, superior in every way, and showing a slight tingle of a reddish color.

From this single plant I got, of course, hundreds of third-generation seedlings; again I reduced them all to one. And this might have been difficult for a less experienced experimenter than I was, because, in this planting, the tendency toward crinkled leaves was almost universal. But I was not to be led astray by plants that had gone part of the way and stopped short of perfection. I repeated my planting of the seeds of the single survivor and now I was able to keep many of the seedlings, instead of just one, for many of them had reached the high standard I had set.

And so, in four years, I had a fixed, definite, attractive, *new species,* which I named *H. cristata* and which is growing in thousands of gardens throughout the country to-day. It had a leaf just about as different as is possible from the old wild geranium leaf, the plant is sturdy and willing to grow in almost any soil and climate, its blossoms are bright and gay and it presents a light and almost lacy appearance, with a distinct reddish color in leaves and stems.

Now, what had I done to effect this "miracle"?

First, as you note, I had relied on the simple method of patient and rigorous selection. But, more than that, I had taken advantage of the second formula for developing new varieties in plants-pollination.

"Wait a minute!" you say. "You have said nothing about pollination in your story. You have only told of *selecting* from the successive generations of seedlings!"

True; I have only mentioned selection. But I took pains in the beginning to describe the surroundings of my little guest and to stress the importance of the variations I found in wild geraniums in the vicinity. My *heuchera* started its partnership with me hiding in its cells both an inclination and a power to vary.

More, the geranium, while subject to cross-pollination with others of its kind, is also a self-pollinator; each of its tiny flowers has the power to fertilize itself, if no passing insect brings pollen from a neighboring plant or, more frequently, from a flower on another stem of the same plant. If you will recall, I dealt through four generations with only one single plant, having destroyed all the others. And so I had, in effect, concentrated every bit of tendency my *heuchera* had toward bearing crinkled leaves instead of bringing in all sorts of other tendencies, from other geraniums, such as a tendency toward red flowers, or toward fragrant leaves, or toward a dwarf bush or toward long stems, or any other form that variations in plants may take.

And so, not only had I selected with care and a ruthless hand, but I had taken advantage of that *inbreeding* process that is an intense and rapid means of increasing a particular tendency or trend in the plant. I might have hand-pollenized--crossbred--the geranium by mechanical means; that is an ordinary and, in many cases, a necessary method with the plant-breeder. But here I had the work done for me and done better than I could do it.

If you propose to practise plant-breeding in your own garden, you will be helped by the lessons to be drawn from this experiment with the wild geranium. It teaches that, when we wish to modify a plant as to some particular feature, we should (1) select an individual that shows the most marked departure from the normal in the direction we propose to take; (2) isolate this plant so that its flowers shall be self-fertilized, if they have that power, supplementing the natural method by hand-pollenizing if necessary; and then (3) follow out a patient but inexorable course of selection of the best individual and repeat through successive generations until the maximum amount of variation in the desired direction has been produced. I should add that it sometimes helps to combine two or more of the best plants, as the experiment gets along, especially if each, while going the way we hope to have them, offers some helpful character that is missing or recessive in the others. For instance, a plant with a perfectly crinkled leaf might show a weak stem or a stem too long or short to please you, while its neighbor, with a less perfect leaf might be perfect in the structure. But do not seek too many points of attack, when you are beginning your experiments. Better at first to finish one drive, then start over again to attack some other problem, even in the same plant.

I think perhaps I was the first person to make the unreserved statement that, given time and patience and a knowledge of Nature's laws, man can modify, change, improve, add to or take away from any plant he chooses, causing it, to greater or less degree, to come closer to his ideal for it. And I still make that statement, after fifty years of proving the assertion in my own gardens. Let us take a few scattered examples.

One of my most consistent lines of endeavor has been toward increasing *fragrance* in flowers--adding it to the other charms of some that lacked it or that, in a few cases, had a disagreeable odor. You will find this flower characteristic is sometimes neglected by plant-originators. I recall the case of one of the biggest seedsmen in the world who long specialized in sweet peas. This flower started with a delicate fragrance countless years ago; it is natural to it. But my seedsman friend became so excited in a search for new color shades and striking flower-forms in his sweet peas that when I visited his farms once I was dismayed to discover that some of his finest new types were completely without odor. He admitted that he had not even thought of that. Even to-day you will find some splendid varieties of new sweet peas that lack the fragrance they should have and that is an unfailing characteristic of the older varieties.

In my gardens a great deal of work has been done on this matter of fragrance in flowers: a pleasing scent was added to the calla lily, which most plant-growers said could not be done; it was developed in the verbena, the cosmos, the coreopsis (which was given a honey-like perfume utterly foreign to its habit), and in many other plants; it was increased in many of our roses and bestowed on some that lacked it, and so on. All these experiments were perfected through long months, sometimes years, of patient effort. With the annuals and certain lilies and bulbous plants it was begun by the selective process after chancing on *one blossom* that carried a faint perfume.

Thenceforward the process was like that employed with the wild geranium. With the rose, on the other hand, there was another door open. For it is the habit and nature of the rose to be fragrant, as the oldest of roses--the brier--tells you in sensational fashion. In centuries of cultivation some of the roses lost that characteristic because they were being led along other channels--toward new colors, forms, sizes, and so on. Here, then, we could go to some fragrant cousin and borrow a little of her perfume by crossbreeding. With that process the selective method followed, of course, as in all plant-breeding work.

Let us take the matter of color. I am disposed to think that all shades of all colors can be produced in our flowers if the work is gone at systematically and persisted in long enough. This may seem extravagant to you, who see certain genera producing only red flowers, or blue or yellow; it may be difficult to imagine a yellow delphinium, for instance, or a blue marigold. But these are flowers that have been carefully bred to retain and deepen their accepted color; when you turn to flowers on the other hand that men have patiently sought to change, results have almost always been obtained. The rose, for example--one of our first intensively cultivated treasures--has been led to darken its reds to a deep purple that often becomes tinged with real blue, which is certainly not a color we would look for in that flower. You will remember hearing about the efforts made in Holland a century or more ago to develop a black tulip and how close the Dutch breeders came to success can be seen in some of the deep-colored tulips of to-day. On the other hand the pansy, which was an inconspicuous and pale member of the wild violet family originally, has, through crossbreeding with the help of the insects and the wind as well as through hybridization by man, clothed itself in sensational colors that run the whole length of the spectrum and that very successfully wear particolored dresses also. These are examples of what has happened, on both sides of the question.

Nature painted our flowers originally, not to gladden our eyes, but to advertise to busy bees, butterflies, moths, and other insects the stores of nectar kept on hand; thus she contrived to make the unconscious customer an errand-boy to carry parcels of pollen from one store to another, in an organized system of special delivery. We have already seen that the bright flowers-reds, oranges, and blues-flourish in the daytime and seek association with the bees, while the evening flowers, seeking to attract night-fliers, wear white or pale yellow-easiest colors to be seen in the darkness or twilight. If we let Nature take her course, or follow her in that course, in plant-breeding, we will get the results she gets--that is, we will continue to clothe our flowers in the colors they have always worn. But our purpose being to modify or change those colors, we must face right-about and depart from the natural method.

Here, then, is a brief summary of the process by which a new color was produced in a well-known flower--the poppy.

As early as 1887 I became interested in a variety of this lovely family that had been produced, through selection, by an English minister, Reverend Mr. W. Wilks. He called it the Shirley. It had been perfected, after some years of patient work, as the result of the finding of a single individual in a field of the scarlet "corn poppy"; this individual plant, alone of all those in the field, had a very narrow edge of white. Building from this Mr. Wilks not only produced a delicate and gracious white poppy but he succeeded in changing the usual black central portion of the poppy to yellow or white.

This Shirley poppy was so striking that I procured some seed and began experiments looking toward strengthening the stalk of the Shirley (then pretty pliant and tender), hoping at the same time, to give the petals more toughness, as they were then easily bruised and fragile. After some seasons of careful selection from large plants of Reverend Mr. Wilks' Shirleys I was rewarded by discovery of an increasing tendency of the flower to go in the directions I had aimed toward; shortly thereafter I discovered in a few flowers a very faint smudge in the color of the petals that I believed had a slight blue pigmentation. You may believe that I pounced on this find! And, to make the story brief, I eventually succeeded, by selection which was aided by the poppy's own habit of crossing with its neighbors, in developing and later fixing a Shirley poppy, with fine, crinkled leaves and strong stems and a bronze-colored center, that was a definite and lovely blue. True, almost a score of years were required for this work, but I considered the achievement worth it.

As a final example of the possibilities in this field of plant experimentation, from which you may learn something of how to go about it in your own garden, let us take the development of a new rose.

In the 'eighties and 'nineties I was giving a good deal of attention to roses, in addition to thousands of other experiments that were always going forward at that period, and I determined to produce, if possible, an ideal bedding rose. When I was beginning this project I found half a dozen seed-pips on a bush of a Hermosa in my home grounds; as this rose had several of the characteristics I would require in my contemplated new variety I jealously guarded those seed-pods and, in due time, planted them. The seedlings produced formed a remarkable family; eventually it was from their number that I was able to develop several entirely new roses, including one now known as the Santa Rosa.

But in pursuit of the bedding rose I was most immediately concerned with I could not afford to wait on Nature to produce more and more variations, through successive generations of seedlings. In fact, it is likely that those variations would not be as great in later plantings-the first break might be the greatest. Therefore, selecting carefully the Hermosa seedlings that seemed inclined to go in the general direction of bedding types, I began to hybridize--to build a handmade rose.

Now I could pick and choose the individuals I wanted to use as parents in the production of a perfect bedding rose, just exactly as the breeder of racehorses can pick and choose, in order to add to his line stamina, deep-chestedness, good temper, strength of limb, or any of the other characteristics of the thoroughbred that he seeks. I desired to give my new rose sturdiness, a power to produce beautiful blooms in very large quantities over a long blooming period, a glossy and brilliant foliage, an ability to adapt itself to a wide variety of soil conditions and climates and, finally and most important perhaps, of all, as well as most difficult, to make it resistant to disease and insect enemies. I had everything in my favor, to begin with, because the Hermosa seedlings I had selected tended in the direction I was going, even where they did not reach perfection in all or even in any of these qualities. And, with the hundreds of varieties of established roses on my grounds, each with a known history, heredity and set of characteristics, I could hybridize inside a pretty wide range.

The result, after about twelve years, was the rose a nurseryman later named the Burbank, which was awarded a gold medal at the St. Louis Exposition in 1904 as "the best bedding rose" of all those shown! It has all the characteristics I have indicated above, with a delicate deep pink color all its own, and a delightful fragrance; it offers a wealth of bloom almost perpetually and it is growing to this day from northern Canada to the Gulf of Mexico and from New England gardens to the patios of southern California.

You will get improvements in flowers in your own garden by mere chance, often. Nature's marvelous law compelling variation from seed will insure this. But to hold that improvement or, on the other hand, to initiate and perpetuate it, you must be ready to give time, patience, study, and perception to the task.

There is, as I must say again, no short and easy way to successful plant-breeding; the process is not one for a "wizard," but for one of those "geniuses" who, somebody has said, possesses "an infinite capacity for taking pains."

CHAPTER XX
Flower Family-Trees

JUST as the biography of a man fails to tell the whole story unless it goes back to his ancestry and presents a sketch of his family tree, so the really complete and fascinating stories of our plants will only be told when we delve into the heredities behind them. And this is particularly important to the reader who is concerned for any reason with plant-breeding and plant-improvement. This book has failed of its purpose if it has not already convinced you that heredity is the principal factor in plant variations, on which, in the final analysis, the whole of plant-breeding rests.

We do not know where plant life first appeared on this globe of ours, though we can see that the spread of vegetable life from places of origin to new ground, new regions, new continents, must have been much more rapid than was the dispersion of the land-animals.

Sea-life, perhaps, went everywhere and every which way from the beginning, within the limits fixed by the adaptability of the individuals. Birds undoubtedly tried their wings with longer and longer flights and even crossed seas in time. Land-animals moved slowly.

Plants very soon must have begun to vary and to adapt themselves to environmental conditions so that, among other things, they could get themselves moved about by other agencies, such as insects, birds, the stomachs and eliminative systems of animals, by the winds and by water. Their seeds acquired wings, or became "gliders," or put out burrs and hooks so they would be caught in the fleeces of animals, or they made themselves attractive to birds but, slyly enough, developed shells so tough that the bird's machinery couldn't grind them up and destroy them and therefore dropped them, still intact, perhaps scores or even hundreds of miles away. We haven't time here to discuss the infinite recourses of the plants in this respect; if I have not said it before, let me say here that there is no more interesting collection for young people to make than one of seed-containers. And from such a collection a perfect library of amazing and interesting stories can be gathered--and a considerable amount of information will be thrown in for nothing on the way!

We have no means of knowing when man first began to cultivate flowers; it was, of course, some time after he had been experimenting with the wild vegetables that he found about him by moving them from forest or plain or hill or meadow or marsh to a plot of ground near his home, or by gathering the seeds of wild plants that he had learned would furnish him with food, and planting them in crudely prepared beds, that he soon had to protect from neighbors and prowling animals with what must have been the first walls and brush fences ever laid out by human hand. Quite a little absorbing speculation could be indulged in on that subject, too: the influence of gardening and planting on the practices, habits, and lives of humans. But we must pass that, also, if we are to stick to our subject at all!

It may be more to the point if we glance here for a few pages at the long-time history of garden flowers. They all came, of course, from a wild condition; they all began as what we call, very loosely and sometimes wrongly, "weeds." But the graceful forms and bright colors the plants had chosen as advertising to attract insects and birds so they would drop in for a sip of nectar and, inadvertently, carry off with them a load of pollen for the fertilization of the next blossom of the same variety or species they visited, also caught the eyes of men--or, more probably, of women. Soon the garden was born. And what a thrill it must have given the woman who first made one. How her immediate neighbors must have stared and gossiped and been envious! And how they must have begun pestering their own menfolks "to get out of the cave, for pity's sake, and help make a posy bed like Mrs. Stonehatchet's!"

Centuries may have passed thereafter before any improvement was made in the flowers except such as Nature was always making, according to the laws of variation and heredity that she laid down for all living things in the beginning. If a few men or women rooted out plants that produced flowers inferior to those of others about them in the "garden" and so began what we call selection, there was certainly no organization to the work and the progress must have been slow. But we have reason to believe that, fairly early in what are known as "historic times," the selective process must have been discovered by the agriculturists of their time. For it is plain that grapes, wheat, cotton, flax, and other staples were enormously improved then as compared to products of the several plants in their wild state.

As soon as man realized that he could, by study and deliberate selection, speed up the natural processes, some one must have applied the principle to the growing of flowers. It is likely that lilies, roses, bulbous flowers, and others were worked on with the intent of improving their beauty, fragrance, size, and adaptability to new soil and climate conditions, as far back as Bible times. And we can be sure that, once man found what could be done and learned how to do it, plant improvement of a very definite and successful sort began and spread, even though no living being understood the precise reason for the results attained.

Plant-breeding, meaning the planned improvement of plants by hybridization and cross-fertilization, was a later development, though that was done early enough to be surprising. It followed on the discovery, first as a suspicion, then as a vague notion, then as a theory, that the laws governing all life on this planet were one and the same. Application of that law awakened thoughtful men to the logical assumption that, if horses became swifter, or stronger or more spirited and beautiful through selective breeding, then cows and sheep might be so improved; the inevitable next step was that plants should be amenable to the same practice. You may be sure that it wasn't more than a week after that news got around till some old flower-lover was hard at work trying to figure out a way to cross a red pea and a white one in the hope of producing from the resultant seed a lovely pink one. He had a lot to learn in *that* regard, of course, but you may be sure that he learned rapidly.

Coming down to comparatively recent times, let us look at a typical story of what happens to a common flower in its development from the wild state to its present-day perfection.

The gladiolus probably first came from South Africa, though it was found pretty well all over the civilized world as a popular garden ornament by the beginning of the nineteenth century. At that time, however, it had long, weak stems and short spikes of flowers, of an off-white or red color and of un-uniform size. As early as about 1810-20 the Dean of Manchester, England, the Reverend Dr. William Herbert, a tireless and able gardener, tried some crosses between the *Gladiolus cardinalis,* bearing showy red flowers, and the smaller but free-flowering *G. blandus.* He had considerable success and went on bringing into his new hybrid strains the bloods of other species until his gladiolus were of great beauty and fertility.

A Chelsea garden-lover, a Mr. Colville, heard of the Dean's success and, in 1823, crossed *G. cardinalis* with a hardy species called *G. cristus,* getting an entirely new race of gladiolus having more flowers to the spike than had ever been seen before and being acclaimed as sensational by every one, including the generous minister from Manchester.

It was probably with varieties resulting from the early work of these two English gentlemen that a gardener of Ghent, on the Continent, began his work twelve years later that resulted in the development of gladiolus hybrids that went all over the world and that became the parents from which most of our modern varieties derive. This man, M. Bodinghaus, used the *G. cardinalis* hybrids of his predecessors but his cross was from *G. psittacinus,* widely different in history and character from *G. cardinalis* or any others used by the Englishmen. His gladiolus was of such striking appearance, improved flowering and ease of cultivation that it was soon accepted as a definite type form all its own and was given a species name: *G. gandavensis,* or the "glad" that was originated in Ghent.

Have you been with us long enough now to be able to put down this book and, for yourself, reason out why, with such a foundation, our modern gladiolus varieties cover such a wide range and offer such a great many colors and types to the garden-lovers? Well, at any rate you will only have to be reminded that in this flower from Ghent there were undoubtedly many divergent strains, since at least four we know of have been named and there were probably others; also that the somewhat earlier experiments of Herbert and Colville and probably others like them had already stirred up old characteristics and tendencies in the heredities of the gladiolus and had put them into the proper condition to show off as ancient habits, trends, influences, inclinations were awakened and given a chance to assert themselves. In short, here is again the lesson that when you stir up the heredity of a plant by any means or method you are bound to start it off on new tracks. And some of those tracks are bound to lead sooner or later, straight or deviously, to new form, color, qualities, and characteristics.

The Watsonia, of which Mr. Burbank was very fond, produced, as a result of twenty years of experimentation, some of the loveliest possible new varieties of the flower, all in charming pastel, shades or pure white--the only "absolute white", he said, ever produced in a flower.

My own work with the gladiolus (interrupted for quite a few years once by the gophers, who seemed to like gladiolus even better than I did and to whom I yielded the field for a time, having other things to do) was toward two definite ends. The first was to strengthen and stiffen the stalks on which the spikes of flowers grow; the second was to find blossoms that would open more flatly on the spike, would grow all around it instead of on two (or at most three) sides and that would be more uniform in size. I succeeded in these aims; in the end, and after I had imported scores of gladiolus seeds and bulbs from Europe, England, and Africa to bring in still newer blood, I had the satisfaction also of adding other desirable qualities to this pleasant and dramatic flower. These included some entirely new colors and color effects, including the first true blue gladiolus ever seen, as far as I know.

There is another flower that, in times past, engirdled the globe--the verbena. There are some eighty species, beginning with wild forms found in Africa and Europe, in the temperate parts of Asia and in the Americas, mostly pretty ragged and weedy in appearance and pale rose-colored or in lilac of a dingy white. The cultivated "old-fashioned" verbena produced a small flower, though in all its forms it had been taught to grow a crown of blooms instead of straggling up and down a spike.

The verbena plant has the habit of growing in masses, and as it is low and sufficiently attractive to insects it has from the beginning of its history been freely cross-pollenized and, therefore, tends to wide variations. In fact it is now such a complicated hybrid that the plant-breeder finds it easy to get a new strain but difficult to fix that strain. My own experience was that I produced a lovely and showy verbena I named the Mayflower and sold it to a prominent seedsman, but when, a few years later, I sent to him for a packet of the seed I found that it grew plants that had very few of the qualities of my perfected variety. He had failed to weed out poor plants; also he had doubtless grown other verbenas close at hand. The result was that he had permitted the Mayflower to become contaminated and to slip back into its old habit of marrying into most any verbena family that came along. And that is the sort of thing that can happen with your experiments if you do not remember the rule of repetition,

repetition, repetition, in impressing on the plant what characteristics you want it to have.

There is another common garden flower that offers us almost a unique problem in plant-breeding. It is the fouro'clock (*Mirabilis*), and the trick it can perform that very few other flowers do is to stripe its flower-petals with varying colors. We have seen plenty of flowers which will vary in color, decking themselves out in red, pink, white, yellow, and perhaps a pale blue all in the same garden bed and from the same seed packet. But the four-o'clock, while varying in this way, too, is not content with that sort of toilette, but proceeds to paint some of its blossoms in stripes, as well as in solid colors of two shades on one plant.

It is obvious that a plant showing such wide variation as this one does not need hybridization to stimulate variation as regards color, at any rate. The mingling of hereditary strains is already so complex that you will have your hands full getting, by selection, anything like true-to-type plants in your four-o'clock seedling beds. And any work you do with them will give you a good deal of insight into the mysterious workings of heredity, if you will go to the pains of keeping notes on your plantings and the flowers that result, in successive generations.

I do not know why the *Mirabilis* tends to this unusual variation, with clean-cut stripes, usually of solid color, or to offering us, on one plant, flowers of two different colors. It is a native of the warmer climates of America, though it has near relatives in other continents. One of its names, by the way, is "marvel-of-Peru," because some of the first plants cultivated in this country came from our cousins in South America. All we know about its peculiarity is that some limitation in its chromosomes forbids it to blend and mix colors; as it is extensively cross-pollenized by insects and humming-birds it has many colors to work with and it compromises by making its dress of different pieces of cloth.

If you can, by experimentation, throw any light on this subject you will perform a service to the science of plant-breeding and will also, probably, get your name in the papers. But you will have to observe and set down accurately what particular combination of hereditary factors give what results in color-use by the flower. The entire problem of the heredity of color in plants still bristles with unanswered questions. Your experiments could conceivably shed light on, if they did not serve to answer, some of those riddles.

A most interesting flower-family history would be that of the larkspur, if we could know exactly what it has been. All we have are clues enough so that we can reconstruct part of the story.

A genus of the order *Ranunculaceæ,* the larkspur is native to north temperate zones pretty well around the world, coming from parts as far away as Siberia (*Delphinium elatum*), from Middle Europe (*D. Ajacis* and *D. Consolida*) , and from most parts of the United States, with some Oriental species. As a cultivated plant it reached its highest development in England where it is very popular, and deservedly so, for its graceful form, its jolly, nodding heads and its very wide range of most attractive colors. In truth I do not know of any flower that surpasses it in beauty for use in vases in the house, if the flowers are cut with long stems and some of the leaves removed to give the whole bouquet a lacy and fernlike appearance. [Of course I except the rose. I always do that when talking or writing of flowers that are favorites with `me, and you must read that in where I forget to mention it expressly!] But note that when we get larkspurs now most of them are sold as hybrids. This means, of course, that they cross-pollinate so freely and have such mixed ancestries that such a thing as a pure strain is hard to get at. In my own gardens I worked first with the lovely and highly varied larkspurs of California, which grow in many different sorts of locations and under many kinds of conditions of soil, moisture, and climate. They vary, indeed, from small, scrubby valley flowers to very tall cañon varieties; those last, reaching upwards for light and sun and to attract the bees, gave me the long and strong stalks I desired in order to work toward a more showy plant. And the colors would please a painter! They run from whites and pale yellows and blues to bright orange red, in *D. naudicaule,* and very bright reds and yellows, in *D. cardinals.* Then there is *D. Californica,* of towering height but inferior flowers, small and of poor form and a purplish blue or dingy white in color.

Every inch of space was used by Luther Burbank in his experimental gardens. Note the bifurcated stake-supporters for his water sprinklers, the small beds surrounded by "headers" for seedlings and bedding plants, and the variety of plants here-a small corner of the Santa Rosa gardens, that comprised more than four acres in all.

All this tells us something of the past of the larkspur. Its first task was to adapt itself to widely divergent environments and that is one reason for its variations. Then it had to go into business for itself in competition with flowers that, in some parts, were quite showy or very fragrant and that, in others, were large and more inviting to the insects. I suppose that, in the darker cañons, the larkspur succeeded in attracting attention to itself by putting on orange and red dresses that glowed like lanterns in the shadows. In the valleys it was more easily seen, but it had to reach up the flowers of its stems so as not to be missed among grasses and weeds.

At any rate, when I crossed our native California larkspurs with the mixed-blood hybrids I imported I got immediate and interesting results. I found the larkspur susceptible to attack from pests and disease, however, and part of my work was to make them more resistant. I found, too, that that tall-growing tendency was too easy for the plant; by careful breeding and selection I had to strive to make the tall stems sturdy and to cut them down when they got too ambitious in height.

From the larkspur comes the sensationally beautiful delphinium, very properly the absorbing study of several fine breeders now and some day, I am sure, to be one of the most sought after and highly prized of flowers. But behind it will always be the history of its kind, which at once explains its habits and tendencies and is a guide and help to us in further work with it. This last is the real purpose of examining into flower histories; without it most of our work at plant improvement would be haphazard at best and certainly rendered more difficult and tedious than it is.

CHAPTER XXI
Our Biggest Plants

LIKE to sit or lie on the grass in a forest on a sunny, warm day and search in the tangled sward for the tiniest plant I can find, to study its minute perfection--its stems no bigger than a fine needle, its leaves smaller than the wings of gnats, its precious flowers, perhaps, so small that their infinitesimal parts can not be seen as units except with a magnifying glass.

Then I like to lift my eyes to the bole of some forest giant close by, to let my glance follow the trunk up-up-up until the branches begin to spread their mighty hands, and so on up, perhaps two or three or four hundred feet to the topmost branch where I may see a bird perched, so high that he is scarcely to be made out there, mocking me and my earthbound body and trilling out over the region his song of triumph and joy.

I like to look from a single spot and viewpoint from the tiniest to the greatest of plants and to remember that, in the essentials of structure and in their obedience to the laws of Nature, they are precisely the same thing. Just as the most minute and even microscopic insect and the elephant are members of the same animal kingdom, and as the tiniest grain of sand and a mountain as high as Everest are akin, so the bit of plant life you can not even discover unless you will peer very closely is related throughout to the spreading oak or elm that will shade a house and barn or to the redwood that is the oldest of living things and the largest. And it is even more wonderful to ponder the fact that the germ inside the seed from which grow both the greatest and the least of plants (or animals either, for that matter!) is much the same in size and in appearance. By what alchemy of Nature the microscopic life-germ of the one is made to contain all the heredity of enormous size, lofty height, spreading limbs, an infinite multiplication of branches and twigs and an enormous load of leaves, with provisions made for supplying heart-wood, sap-wood, cambium arterial system, prodigious roots, bark, blossoms, seeds, and the renewed germ of life, while the other is charged only with building a plant so small a baby could crush a score of them between diminutive thumb and feeble finger--ah, that we know but vaguely and imperfectly, as yet--may never know to the last secret! For there are some enigmas Nature does not appear to want man to solve, perhaps lest he become so proud that. he will bring about his own destruction!

But we are allowed to know, for a certainty, that the same rules and ordinances govern the growth of a tree and a rose, of a vine and the blades of grass in our lawn, of a pansy and a sunflower, of some minute plant multiplying by billions in a bit of scum and a forest that may cover half a state. And our biggest plants, the trees, are limited by the same rules, also, and are as little able to vote in a new by-law or ignore an old statute as the Sweet William or the hairlike stems that will grow in mold.

There is nothing new about the principles of tree-growing, then, that can be said in this place. We use heavier tools, we work in fewer numbers, we get our results more slowly with trees, to be sure, but we do not in any sense depart from the practices that have been described throughout this book as governing all plant-breeding and plant-improvement. You have learned already that the *seeds* of trees vary just as the seeds from zinnias do, or from sweet peas, and therefore you know that, if you plant the seeds from a winesap apple or the nuts from an almond or the acorns from an oak, the seedlings that spring from them will vary definitely and as widely as does the heredity of the tree that produced them.

But you will remember, if it is not part of your regular stock of knowledge, that we have seen orchard trees largely propagated by "division"--that is, by taking a part of the tree and "planting" it, not in a garden bed but in a living tree of its own kind or of a closely related kind. As I think I have said, my success in producing and perfecting an almost endless catalogue of genuinely and entirely *new* fruits, nuts, and berries has been due to the fact that I used tree-stock exactly as I did a garden-bed--as the "soil" in which to plant, not one or two grafts but tens, scores and even hundreds, in order to speed up the work and in order to be able to engage in plant-breeding on a wholesale basis. Instead of grafting or budding two or three cions of one variety under experimentation, I used many times that number; in a cherry tree behind the little house at Sebastopol I had growing at one time over a hundred entirely different varieties of cherry.

Now, let no one be confused by this outline of my method. All that the bud or graft drew from the stock tree in which it was put was nourishment, not blood, if I may use that expression. If I wanted to mingle two strains of cherries in one fruit (in order to test the result and get seeds for planting, you see) I would have to do it by crossing the pollen from one variety of cherry blossom on the pistil of another variety. Here, by Nature's own process, the two strains would be more or less intermingled in the seed that would result. That seed, planted in the *ground,* would grow into a seedling with some of the characteristics of each parent cherry in its make-up.

But, as you know, most trees require several years and some many years to grow enough to begin bearing. Until my cross-bred cherry blossomed and bore fruit I could not tell precisely what sort of fruit I would get. I wanted to speed up this process of maturing and bearing fruit.

And the way to do it was, of course, to take a bud or a graft from the seedling and "plant" it in a good, strong, healthy older tree of the same species. There it would become, in a year, an absolutely integral part of the old tree, just like the tree's own branches, except that it would have in its make-up the characteristics of its own parent trees, rather than those of the tree which was, we might say, running the boarding-house for it. With strong streams of life-giving sap manufactured in the leaf-system and root-system of the mature tree my engrafted scion would fairly jump forward and, in the second year or, at most, the third, it would be bearing fruit. And so I could save anywhere from two to seven or eight years. Time was always a valuable commodity to me; I could never get enough of it, and I worked out ways of speeding up natural processes for that reason.

Let us glance now at some of the work that has been done with other trees than those designed for fruit-bearing. I have already mentioned work with the walnut, which resulted in the production of Paradox and Royal. I had known native black walnuts in my New England home and was led to begin experimenting with them soon after my removal to California. Another tree that I knew well from my boyhood days was the chestnut. I had been struck, when gathering the nuts in the region around my Lancaster home, with the great variation in the nuts, some being large and with sweet and tender meats, some large and bitter, some small and good and some small and absolutely worthless. Here was something to pique my curiosity and arouse my interest, so when I was established in California I was presently experimenting with chestnuts.

The wide variance in the sizes and qualities of the nuts of this tree, of course, goes to indicate a wide dispersion throughout the world, which is precisely the history of the tree. I had chestnuts from Europe, from the eastern United States, I had the wild nut called the "chinquapin" that grows wild in parts of California and finally I imported nuts from China and Japan. I crossed these as early as 1880, at random, in the beginning, but later with a definite plan for combining desirable characteristics. I, had astonishing success and some almost unbelievable results.

One of the oddest of the latter was the production of a dwarf chestnut tree, that stopped growing at a height of five or six feet but that matured into a perfectly formed and very sturdy tree and that bore full crops of nuts. Another was a tree-prodigy that bore full-sized and edible nuts at the amazing age of six months--that was bearing almost all the nuts it could well support at eighteen. After years of hybridizing and selection I was able to introduce two or three varieties of very superior chestnuts, showing fine form, growth to great size, an impenetrable roof of beautiful leaves and nuts of the first grade for eating. .

Meantime, however, in 1904, appalling news came from New York State where a fungus, thereto unknown, was blighting chestnut trees and rapidly spreading. No remedy was discovered; in a few years tens of thousands of beautiful, full-bearing chestnuts were dead, all over the East and Middle West. I had not planned my trees to withstand this new scourge, except as I always worked to perfect sturdy, healthy plant growths, vigorous enough to hold their own wherever they went. But what was my delight to discover that the Burbank chestnuts, planted in the blight areas, were immune to the universally fatal blight that struck older varieties! Here was another illustration of the value to the world of plant-experimentation and plant-breeding! Not only is it possible for man to train plants to produce more abundantly a more valuable or beautiful harvest but to withstand attacks from without of pestilences of all kinds. Wheat that will fight off rust, snap-dragons immune to its own enemy of the same sort, garden plants that can live under attacks from aphis, roses that will not mildew--the list is long and, luckily for our gardens, orchards, fields, and parks, is growing every day, thanks to the tireless and intelligent efforts of the new race of plant-investigators and plant-breeders!

In the short span of life vouchsafed me I was not able to work as much as I should like to have done with our biggest plants, the trees. But I was continually stealing a few minutes in which to make some sort of try at them. Once friends sent me cuttings from an elm under which I had played as a boy and I straightway grafted scions from those cuttings into elm saplings I was able to get hold of. I saved only one of these grafted elms, but it rewarded me with a prodigious growth--so great a growth, in fact, that after a score of years it was monopolizing a valuable part of my Santa Rosa experiment gardens and I had to have it chopped down. I also did some work with native California trees of great beauty, among them the so-called Catalina cherry, which proved amenable and from which I was able to produce several new and interesting ornamental and shade trees for my own use and to give to friends. And so it went.

But my time was increasingly taken up with other plant experiments and I had to leave ornamental, shade, and useful trees pretty much for others. I should like here, however, to call attention to some of the possibilities that I plainly see in our trees.

If you will think for a moment about the vast usefulness of trees of the forest to man you will realize the importance of any study or experimentation calculated to improve them. In spite of the increasing use of cement in building we will always, I think, rely on trees for our lumber, both for building mighty structures and small homes, for making ships and wharves and furniture and for the construction of models from which many metal objects are now fabricated. Trees furnish us with firewood. Their leaves, berries, and nuts provide us with drugs, with food, with spices, and so on. And their saps provide us with an amazing variety of indispensable things, none of which will ever be made so satisfactorily by any synthetic or artificial process. I think offhand of rubber, of the chicle in chewing-gum, or maple sugar, of turpentines and resins, of drugs and scents, and there are thousands more.

Here is an isolated instance of a tree that offers possibilities that might be worth looking into. The wild shrub known in eastern states as the waxberry, or bayberry, bears an abundance of small berries from which may be extracted a quantity of hard, greenish, fragrant wax, once used in candle-making but having other possible uses. After a very little (and stolen) time given to this shrub that, in California, grows also in a species that is a tree sometimes reaching sixty feet in height, I was able to increase the wax-content of the berries, from which I pressed a very superior wax which I found of value. Candle-making is coming back now; perhaps commerce could find other uses also for the waxberry wax. And the certainty has been proven by me that the shrub-tree will respond to hybridizing and might well eventuate in something important to the world.

A better race of maple trees might be developed; I am convinced that the maple could be induced to change its habits enough so that it would flourish in parts of the country where it does not now produce sugar. There is "latex"--the natural basis of rubber--in many trees and shrubs, and also in some plants now despised as weeds, including the one we know as the milkweed. Who is to enter the field to delve into that possibility? Of late years chemists, physiologists, and physicians, among others, have become greatly interested in "alkaloids" and are beginning to find new uses for them. I know that there are bitter compounds in the barks of trees that are made up of or contain these alkaloids; I am certain that a plant-breeder, working with a chemist in the tropics, could uncover many interesting and valuable facts and might furnish man with a whole new list of now unknown aids to health and a longer active life-span.

I have said before in this book that there remain to be discovered and developed for man's profitable use many nuts, fruits and vegetables that are at present passed by. As we are here considering trees, I may suggest, as one possibility, the proper training of the "buckeye" or "horse-chestnut," that grows so widely in the world and almost everywhere bears so heavy a load of now worthless nuts.* But those solid, thinly-encased buckeyes were once used by Indians, who ground the meats into flour; I myself demonstrated that they vary widely as to quality, starch and sugar content and also as to the amount of the bitter property in the nuts which, if concentrated, is poisonous. And if they vary they could be improved--that is one of the first things we learned here and it is one of the last things I want to leave with you.

* After this was written by Mr. Burbank, but before it was published; chemists in England produced a synthetic *acetone,* in commercial quantities, for munition-making, from this very tree.--*Ed*.

CHAPTER XXII
Practical Pollenization

ONCE upon a time--it may have been a matter of several million years ago--a plant imbued with wisdom made a friendly compact with a fellow creature that was fraught with strange and fateful meanings for races of beings yet unborn. The fellow creature in question was at that time probably the most highly developed citizen of the world, although he was only what we now call an insect.

The compact the plant made with him was that the former would manufacture sweet nectar as food if the latter would carry from plant to plant fructifying pollen germs.

No more important compact was ever made in the history of life on this earth. For out of it grew the rivalry that stimulated variation and made possible the development and evolution of the whole race of plants that bear beautiful flowers, produce life-giving grains, furnish us with vegetables, garnish our fare with fruits, provide natural perfumes, and perform for man an endless series of services vital to his life. And this arrangement, mutually made, not only applied to plants living close together but to those scattered over great distances. This bringing together of germ plasms habited to very diverse environments insured variant and virile strains and determined in large measure the amount and direction of the evolution of the highest order of plants.

But it should be noted in passing that large numbers of plants of a lower order refused to enter into this coalition with the insects: examples are the mosses and lichens and ferns that have to this day retained, the primitive habit of propagating their kind with the aid of self-moving germ-cells. These motile cells, of microscopic size, find their way through the water (or are carried for land plants by films of rain or dew), and effect cross-fertilization without calling for help from insects. Since they do not deal with butterflies or moths or winged beetles they do not need to advertise with showy blossoms; since they have no need for the help of ants or crawlers they can dispense with cups or flasks of nectar, and they do.

But if they are independent these lower orders are also unprogressive: since they cross only with their immediate neighbors they reproduce their own like, with little diversity of form and small capacity for adaptation. The result is that our present-day ferns bear a striking resemblance to plants of the remote Carboniferous Era, traces of which are preserved in the coal beds of earth. In short, these plants that refused to join the union are conservatives and like all conservatives they change but little, relying on the validity of the law of the status quo.

There are other plants that we have reason to believe originally joined this union of ours but that later withdrew from it. There are evidences that many of our mightiest and stateliest trees, now independent of insects, but scattering their pollen on the wind, began in prehistoric times by collaborating with the insect world. But for some reason they later abandoned this practice: whether they grew large because of this abandonment of the alliance, or abandoned the alliance because they grew large and no longer needed it, it would be hard to say. We know that, in the main, insects tend to keep near the surface of the earth, and it is possible that, when the trees began to reach great heights, the insects ceased to work with them and compelled their hosts to resort to the new scheme of bearing enormous loads of pollen and broadcasting it, though with an appalling waste. In any event the great trees exert no energy now producing flowers to draw the insects, but are compelled instead to put valuable energy into the production of enough pollen so that, though clouds of its grains may be wasted, the essential few find lodgment and insure propagation.

There is another class of plants that has back-slidden from the insect alliance--those that depend only on self-fertilization, such as wheat, peas and beans, certain species of violet, the jewel-weed, fennel, rue, and the nettle. There can be no doubt that these plants are descended from tribes that at one time belonged to the plant-insect union. One evidence is that most of them retain more or less conspicuous flowers; why any of them resigned from the alliance would be difficult to say. We may suggest that wheat, for instance, has been so long grown thickly in fields carefully prepared for the purpose that pollination was almost inevitable and therefore the need for pollen-carriers ceased to exist.

You have noted above, doubtless, the inclusion of the violet in this list, and you will observe, acutely, that the violet certainly produces flowers and that it is famous for their perfume. The only answer we have to that poser is that the violet must cling more tenaciously than some of the others to its old heredity of flower-bearing; it may seem to you remarkable that, when the violet is transplanted to a sunny spot, it begins to attract insects and may actually resume the custom of growing seeds pollinated by its visitors.

One of the most fascinating of studies is that of the methods employed by various plants to insure fertilization, and perhaps we had better pause for a moment here and mention a few of them.

The common barberry, for example, opens and exposes its pollen-bearers only during the bright hours of a cloudless day. But in case an insect fails to visit it "during office hours" provision is made for the stamens to dart forward periodically and sprinkle their pollen over the pistil.

In the case of a certain fennel flower in France, which does not open at all, the pistils bend forward when they are ripened and, after taking the pollen from the stamens, straighten up again.

With the rue, the arrangement is curiously complex and almost machinelike. Of the several stamens, each in turn bestows its pollen on the common center--the pistil, advancing for this purpose alternately--numbers one, three, and five in turn; numbers two, four, and six in succession; as if the entire mechanism were actuated by clockwork.

Such accounts could be multiplied almost indefinitely, but the truth taught is that, in all Nature, preservation of the species is jealously sought. Self-pollination is a risky device, and we know that many species so limited have become extinct in the ages past. It may well be doubted whether the existing varieties of wheat could perpetuate their kind, if put on their own in competition with wild plants, for a dozen or a score of years. At best such plants, if left to their own devices, will stand still or, as is the rule of life, will retrograde. In short, the plant that depends on self-pollination is in a sense retracing its steps down the ladder of evolution by which its ancestors have made ascent.

It is flowers of the great brotherhood of insect-loving (entomophilous) plants, naturally, that chiefly claim the attention of the plant experimenter, because these, making up the largest census in orchard and garden, are easily acceptable of hand-pollenization and are most tractable. As for the amateur, he is little inclined to work with the other kinds, since only the insect-lovers are in the display-advertising business with their blossoms. Let us look a little at the mechanics of pollination, then, concerning ourselves here only with these varieties.

Wisest of all the flowers are those that contain within themselves both pollen-bearing and pollen-receiving parts which render self-pollination certain in case the insects chance to fail and cross-fertilization does not take place. This is the perfect flower mechanically, and in this class are the major part of our most familiar cultivated plants. It is these, at once the most common, the most attractive and the easiest to work with, that we will consider in this chapter.

A plant-breeder working in Luther Burbank's gardens hand-pollinating a Burbank poppy. At the left, Mr. Neil is using Luther Burbank's own set of instruments, the box of which stands in the foreground. The first step of hand-pollination, removing the stamens from a blossom to be pollinated, is .shown in the center. At the right is the second step, dusting pollen from poppy (in left hand) on the naked pistil of a prepared blossom.

The pollen-bearing organs are the stamens; the pollen-receiver is the pistil. About them, rising from the outer shield we call the calyx, is the conspicuous insect-signal or "advertisement" known as the corolla--what is ordinarily spoken of as "the flower." The botanist is very particular: he thinks of the calyx and of the petals of the corolla both as "modified leaves"; of the stamens and pistil as "modified petals"; but it is not necessary for us to make these fine distinctions: If you are interested you may make a little side-trip for yourself, leaving the main party of us, and go into your own garden to discover a flower in which the stamens and pistil have practically become petals and are no longer seed-producers. The very double roses, the chrysanthemum and the dahlia are examples; they have advertised to such an extent that, alas, they now have nothing to sell, and you may smile a little to see the bees and butterflies wing up to these flowers, puzzle a little, look inside to see the stock on the shelves, and go away quite indignant, perhaps saying to themselves: "What a fraudulent piece of advertising! There's a big sign over the door and not a thing inside to eat!"

Now we return to the main line, as it were, and, with any normal flower before us, such as a honeysuckle blossom, a poppy, or a single rose, examine the central and all-essential organ--the *pistil.* It is the female part of the flower, tipped with a more or less protuberant style which is the *stigma* and running down into the *ovary,* which contains the *ovules* or embryo seeds. In most flowers this ovary is within the well-protected *calyx;* in all it is so designed as to be subject to the fewest risks of destruction or injury.

ABOVE: Everywhere in Luther Burbank's gardens and farms the visitor came on these bagged blossoms--covered to prevent accidental cross-pollinating by insects or the wind. BELOW: Looking south along an experimental bed of crinums on the Sebastopol Farm. Part of the test orchard can be seen on the crest of the hill.

The *stamens,* which are the male organs, normally grow in a circle about the central pistil; these develop at their outer ends *anthers* that produce *pollen* grains of exceedingly minute size. Each pollen grain contains all the hereditary potentialities of the entire plant; the same is true of the ovules; neither is capable of reproduction alone, but when the two, by Nature's marvelous process, are brought together the result is a *seed*--the most awe-inspiring wonder of the universe, and so filled with mystery and magic that thousands of scientists, in history, have spent their whole lives studying it, without yet being able to tell us anything like all there is to know about it. Perhaps, indeed, we will never fully understand the mystery of the seed and its jealously guarded life-germ. Doubtless it is just as well, for if we understood it we might learn how to manufacture it and I, for one, am content to let Nature attend to that business, for man has a great faculty for making a mess of things when he gets too ingenious!

From our immediate human standpoint--getting back again!--the chief interest for us is in the corolla, with its petals of varied hues. It is not our desire to improve on the seed-bearing capacities of the plant, even if we could, but it is our purpose to improve and glorify the advertising sign we call the flower, and some knowledge of the machinery is necessary. What we propose to do is to induce the flower to change or beautify its dress; we do this by employing the mechanical parts studied above and taking advantage of our sure knowledge that the latter will perform their miracle to aid us.

The essence of pollenizing is merely the transfer of pollen from the stamens of one flower to the stigmatic surface of the pistil of another of the same species or, more likely, the same variety. To begin with, then, we must secure a certain amount of pollen, usually by shaking it from the stamens on to a watch crystal or butter-pat; we transfer the precious germ-bearing specks of this pollen to the receptive pistil of the other flower, either with a clean fingertip or with a fine camel's-hair brush.

It is wise to remove the stamens of the flower we propose to pollinate, using a pair of manicure scissors or forceps, before our transfer of pollen is made; after the transfer it is best also to cover the flower, perhaps with waxed paper or a little paper bag, to keep the insects from volunteering their services and "throwing a monkey-wrench into the gears." Now we have only to let Nature take her course, to mark the pollinated flower stem carefully, to gather the ripened seed, to plant it in its season, and then to watch, with I-cannot-tell-you-what excited interest, until the blossoms come forth again to tell us what we have achieved by our experiment.

I have here outlined the procedure in the cases of the simple flowers. So-called composite flowers, such as the daisy and sunflower and all their numerous relatives, require special treatment. Here the true flowers are very small, and grouped in masses. Individual treatment is out of the question: the best way is to wash away the pollen with the hose, then rub the head of the pollenizing flower against the one selected, thus effecting pollination by job-lot.

In the case of flowers that have very short pistils--the blossoms of fruit trees are good examples--their removal, as referred to above, is almost impossible. Here I have found that by attending to them just before the bud opens I can cut around it at about the middle with a thin-bladed knife, thus excising the anthers with one operation.

As a matter of fact all we have room for here is to impress you with the principle involved--with the mechanics of the method in its simplest form. You will find every flower a different problem. There are some so complex in their structural form that your ingenuity will be taxed. You will discover that there are flowers that close at night and others that open only toward evening, such as the "four-o'clock." You will learn that certain flowers bear their pollen before the specimens you want to pollenize are open to receive it, and you will have to gather and preserve the precious germs until your time comes. You will become more proficient and successful as you go on, however, and you will, I guarantee, enjoy your flowers more and spend more time in your garden, so that the net result will be all on the right side of the ledger, no matter what ultimate results you achieve.

As a matter of fact you can hardly fail to accomplish something. You may be amazed at the heterogeneous assortment of blossoms that appear on the progeny of your artificially crossed plants. As I have said before, all that the plant-breeder can do is upset the heredity of his plants, bringing new strains and influences into the life-stream; after that Nature will do the work and the experimenter's next step is to select from her offerings those flowers that seem to him to go in the general direction he wants them to go. But surprising combinations often appear. The plants seem to be so disturbed by crossing that they scarcely know what they are about. The wide variations in form, color, size, and petal-growth that ensued, for example, on my experiments with the zinnia were almost incredible. And this is only one instance.

Remember that Nature's dependence, for the perpetuation of species, on *two* parents brings in two different blood-lines in the second generation, four in the third, eight in the fourth, sixteen in the fifth, thirty-two in the sixth and so on.

We humans, like the other animals and most plants, are the products of an almost infinitely extended system and succession of ancestors widely diversified in character, powers, tastes, weaknesses, and strengths; do not be surprised at your children when they develop a sudden and (at first glance) unaccountable ability or grace, weakness, or deformity. They are of "mixed blood" no matter what is shown in the family tree you have so proudly framed: it would be surprising if they were not occasionally unusual, since it would be surprising if your properly projected family tree did not show somewhere in it a genius and a scamp, a poet and a horse-thief, a man with red hair or a woman with a fiery temper! And, in your experimental flower bed, look for the unexpected--it is the only thing you can with confidence expect!

CHAPTER XXIII
Ingenious Coöperators

AS the last chapter may have made hard sledding for the reader, it may be agreeable if we take a few pages here for odd tales concerning the ingenuity exercised by flowers in insuring the success of that coöperation with insects which we discussed. And so, at random, we will glance at some interesting examples.

Out in the desert regions of the southwestern United States there grows a very remarkable plant called the yucca, or Spanish bayonet. It is familiar to all desert men, and will be recalled by those who, from a transcontinental car-window, have seen the tall white, slender cones rising on the straight stalks in the midst of sand and rock and sage. The story of the alliance between the yucca and its insect-friend is one of the most fascinating in the whole range of plant-and-insect compacts.

The insect is a small, yellowish-white moth, so unfamiliar to most people that it has no nickname; entomologists know it as *Pronuba yuccasella.* If you observed closely you might see this pale, tiny moth fluttering about, but only the most tireless scrutiny by trained scientists has revealed the whole story of what occurs when the moth visits the yucca blossom. It appears that the female moth has developed a long ovipositor, with which she pierces the tissues of the ovary of the blossom to deposit her eggs there. On the face of the matter you would say that she was doing the blossom no favor and that it was a very one-sided sort of bargain between the two.

The surprise comes when we learn of certain maneuvers preliminary to the deposit of the eggs. If you could watch the moth on her visit to the yucca flower you would see her at once begin to gather the adhesive golden pollen grains with the aid of a pair of curious tentacles growing about her mouth--tentacles unlike those of any other moth known. As the pollen grains are gathered they are rolled into a small pellet, and this she carries to another yucca blossom. It is now that she pierces the ovary of the flower and lays her eggs within. Thereafter she takes her gathered ball of pollen up and, poising at the tip of the style, pushes her burden down into the cavity of the stigma.

No plant experimenter, whatever his skill, could do the thing better. But you are still in the dark. Why this deliberate and skilful cross-pollenization--which, of course, it is?

Perfectly simple! If, in that arid region of baking sun and hot, fierce winds, pollination failed to take place, the blossom would dry up and die, the sterile "eggs" of the plant inside the ovary would wither, and the young of the mother moth would starve. With pollination insured the plant-eggs develop, swell, and become delicious and nourishing food for the larvae of the moth. And--as a final instance of the ingenious device of Nature in the case of this flower-insect alliance--the yucca's ovules, or "eggs" grow into an abundant food supply, greater than the larvae need., So not all the seeds are eaten but some are left to ripen and fall to earth, there to germinate and, in due course, grow into flowering yuccas once more!

How did so remarkable a coalition between insect and plant develop and come to perfection? It is impossible to conceive that any sudden mutation of form on the part of the plant or of habit on the part of the moth could have brought it about. Rather we are compelled to believe that this extraordinary relationship now manifested is the result of a long series of slight adaptations through which plant and insect were mutually specialized in such a way as to conform to each other's needs. The change must have been slow and gradual. We may suppose, in the beginning, a condition in which the ancestors of the yucca were sometimes visited by the ancestors of the moth, but were not dependent on them for cross-pollination insurance. Then we imagine successive ages in which the moth gradually developed its special pair of pollen-gathering jaws, while the yucca blossom correspondingly shortened its pistil and became more and more dependent upon the special process of fertilization to which the moth was becoming adapted. Of course, if you like, you may reverse the order and conceive that, for some reason, the yucca, through generations, shortened its pistil and compelled the moth to its slow development, by natural selective processes, to develop her egg-depositing device.

The marvel of this partnership is emphasized by the fact that the pollen is not of *direct* use, either to the moth, to her eggs and their protection, or to her larvae, but is of *indirect* importance because it makes certain the development of food for the brood. At first glance, then, one can scarcely escape the conclusion that the insect is endowed with a form of intelligence. We are not ready to argue that such "intelligence" is the precise word, but the farther we go in the study of Nature's ways the more we are forced to acknowledge the existence, through the whole natural world, of an ordered scheme of forethought, comparable, in its entire range, to the thinking and planning capacity of human beings.

Consider, for example, the way in which lilies project the receptive stigmas far beyond the stamens, so that no insect can get in to the nectar cup below and out again without transferring at least a few grains of pollen where they are needed. The amaryllis, the carnation, the balloon flower, the geranium, and numerous others evidently desire cross-pollination as between blossom and blossom, in preference to self-pollination; to effect this they bring stamens and pistils to maturity at different times, so that the pollen *must* come from some neighbor and, of course, it must come by aid of bees or bugs or moths.

Then there are plants like the sage, the stamens of which seem to lie in wait for the visiting insect, bending over quickly, under the stimulus of contact, and rubbing their pollen on either side of the caller's back. Again there is the milkweed, which stores its pollen in tiers of handbags connected with a strap that entangles the feet of the bee to be sure that he does not leave empty-handed--or, hadn't I better say, empty-footed. Alas, the milkweed sometimes overdoes the business, for I have myself seen the insects so overloaded that they could not rise, and died at the foot of the plant!

There is a little water plant called *Villarsia nymphoid* that sends out its flowers from its submerged haunts in the form of detached balloons that float to the surface of the water and there burst open, attracting the attention of the waterbugs and winged creatures, and being pollinated in this state. The eelgrass projects its pistillate, or female, flower up to the surface of the water on a long spiral stem grown solely for that purpose; its staminate flowers strain at the short stalks on which they grow until they break away and come to the surface. The insects do their work, the floating staminate flowers drift away and die, and the pistillate flower, pollinated and ready to develop its seeds in their season, is drawn again beneath the surface by the recoiling stem, never to reappear.

Not the least sensational stories of this sort concern the orchids, the extraordinary pollinating devices of which were first made generally known through the studies of Darwin himself. A familiar illustration to plant students is furnished by *Orchis Mascula* which bears its pollen in small bundles at the end of a slender stalk, at the other end of which is a disk covered with a sticky solution. Insects visiting the flower are compelled by the structure to pass beneath these bundles and they can not avoid the sticky disks that adhere to their heads and so insure their carrying away a load. But the most remarkable part of this flower is that the pollen stalk begins to curl at once and becomes a sort of horn on the bee's head, occupying such a position that it is certain to strike the pistil of the next orchid the carrier visits.

Another species of orchid, *Orcbis pyromidalis,* has two pistils; to insure each of the pair being pollinated the flower produces its pollen bundles joined together somewhat like an ox-yoke. The visiting butterfly is almost certain to leave the flower with one of these yokes attached to its proboscis, and the next flower entered is thus fairly sure of receiving a little of the fructifying powder on each pistil.

I have referred above to flowers that provide against self-pollination, citing the geranium as an example. The mechanics of this provision in one of our most common flowers is interesting. When the geranium flower first opens a little cluster of anthers may be seen on the tip of the erect filament in the center of the bright, showy flower. At this stage the undeveloped stigma lies closely folded up and wholly unreceptive among the stamens. But soon after the pollen has been shed or gathered the anthers drop off; then the stigma spreads out its five receptive lobes from the tips of the connecting filaments, and is ready to receive pollen brought to it from another flower.

In the snapdragon the anthers lie along the roof of the corolla tube, where they are brushed by insects that pass down the tube in search of nectar. The stigma holds a similar position, but is farther out toward the mouth of the tube. This stigma is composed of two flattened lips, which respond to the slightest touch. Now when a bee, after visits to other snapdragons, enters the tube, the hairlike appendages on her back brush against the lower lip of the stigma and the irritation causes the lips to close quickly and tightly together, coming thus in contact with and scraping the pollen-dusted back of the bee. Whether or not the receptive lips have secured any pollen, they remain closed for four or five minutes, so that there is no danger that they will encounter the bee as it leaves laden with a fresh supply of pollen from the companion anthers--the flower's own pollen, which it does not desire to use, but manufactures for consumption by a neighbor. After the bee is gone, however, the stigma opens again, like a trap set for the next caller.

There are flowers with pollen loads too bulky for the smaller insects to bear, and when we examine these and study their devices we soon find that they make the necessary arrangements to attract the large insects or the birds. In that connection there are flowers with long nectar tubes that can be reached only by the coiled proboscis of a moth or the slender bill of a humming-bird, and you will find that the pistils and stamen of the honeysuckle, the passion-flower, certain squash blossoms and the like are cleverly designed to give the visitor an errand to perform at the flower where he next stops. There are even certain flowers that exclude small insects from the nectar chambers, so that the little rascals won't be traipsing in and out and wasting pollen, without contributing anything in return.

But generally speaking, particularly of plants of the temperate zone, with no special problems to face, growing things are content to make alliance with any of the small insects, and the majority of the flowers of orchard and garden are most cordial to and most visited and aided by the bees.

This familiar insect, the one member of the tribe that is directly helpful to man as a producer of food, is at his work of coöperating with flowers, morning, noon, and night. Although he takes his stores of honey and wax from widely divergent blossoms, from the desert sage to the onion, and from the apple blossom to the lowliest clover, you will learn by watching him and studying his ways that here, more than anywhere else, is a striking proof that I am correct in calling flowers the advertisement of the plants.

There are entomologists who have questioned whether insects really have the sense of smell or a vision for color, but if you will watch bees in your own garden you will see plenty of evidence of both. You will see, for instance, that many bees will go unerringly from one red flower to another, or from white to white, which seems to me to show not only that they have color sense but preferences as well. As to the sense of smell in insects, if further evidence than that supplied by everyday observation were required, it is furnished by an interesting experiment made with butterflies by Professor Jacques Loeb.

Professor Loeb placed a female butterfly in a cigar box, closed the box tightly, except for some small air holes, suspended this darkened cell and its prisoner midway between ceiling and floor of his room, and opened a window. "At first," says Professor Loeb, "no butterfly of this species was visible far or near. In less than an hour a male appeared on the street. When it reached the window it flew in and presently perched on the cigar box. During the afternoon two other males of the same species came to the box, in the same way."

Another experimenter has shown that ants will follow a trail that has been made by other ants bearing sugar or honey. The inference seems obvious that the ants are following a very delicate trail by the sense of smell alone. But perhaps it is as well, considering the unrevealed nature of the stimulus associated with odors, to adopt Professor Jacques Loeb's cautious phrasing and speak of the sense as "chemical irritability." After all, a gardener who lays no claims to being an entomologist and thinks it wise to stay in his own backyard of science will be satisfied to observe that bees and butterflies *do* visit flowers that give off perfume.

I happen to have a very special proof of this, and incidentally a circumstance in which the bees were of inestimable help to me as a plant experimenter. I was working patiently to produce a fragrant petunia, which is not a flower, in its odorless form, that bees care much about. One dull morning when there was a thick dew on the gardens and odors were intensified by hanging close to the ground, I thought I detected in my big experimental petunia bed a new fragrance. I had been working toward this end so long and hoping for it so earnestly that I thought I might be deceiving myself, but at last I observed that several sluggish bees, not yet warmed up to their work, were flying heavily about the flowers. By watching them closely I discovered that they concentrated their attention on one particular plant, and on it, sure enough, I found my new fragrant petunia! As I say, I intend to stay in my own scientific yard, but I do ask the entomologists how they can deny bees a sense of smell and still account for that circumstance!

The fact that a bee is able to travel in a straight line back and forth between the garden and its distant hive, even though the distance be a matter of miles, suggests the possession of organs of a far more delicate character than man's olfactory nerves. It seems unlikely that vision is an important aid in these long-distance flights, for Professor Loeb's experiments, among others, lead us to infer that the dioptric apparatus of insects is inferior to the human eye. And again I, from the viewpoint of a garden lover, observe that the flowers would scarcely need to put out expensive corollas and deck themselves in gaudy colors if sight played no part. In point of fact, the complex multiple eye of the insect, which lacks the adaptive apparatus for focusing that we have, probably has a capacity for seeing large masses of color but does not have acuteness of vision.

If you have a taste for this sort of study you can add greatly to your enjoyment of your garden by observing the habits of insects and birds in their performance of the obligations of their compact with the plants. And, understanding the principles involved, you can learn a great deal that is absorbingly interesting and very much worth while of the ingenious methods by which the various flowers, each in his own different way, make it easy for their visitors to perform the exact service required and hard for them to do it any other way or to offer some gratuitous service that the flower does not want done. And every moment spent in such research will open your eyes wider to the marvelous provisions Nature has made to preserve the species and make improvement possible through variation.

CHAPTER XXIV
Seedling Propagation

THE word "evolution" chances to have nine letters. Suppose that these letters were printed each on a block of wood, and the nine blocks were put in a bag and mixed together. Suppose then that you were asked to put your hand into the bag and bring forth one block after another, placing them in sequence on the table before you just as you fished them out.

What probability is there, do you think, that your blindfold selection of the blocks would result in bringing them out, in one try at it, in such sequence as to spell the word "evolution"?

Our friends, the mathematicians, tell us that the chance of such a happening is one in 362,881, and no matter how patient and speedy you were, the task might consume a considerable length of time.

If no other factors entered into the problem than this simple mathematical one--though there would be many others--you can see something of the difficulties that confront the plant developer who expects to find, let us say, nine particular. qualities combined in just the desired proportion in any seedling flower, fruit, or vegetable selected at random in the course of his experiment.

But if, in making your experiment of choosing the lettered blocks, you were permitted to retain the "E" when you drew it, and if then you were allowed to put the "V" next it when it came out first in a drawing, and so with "O" and "L" and the rest, it is obvious that each new test would find you with a smaller number of letters from which to select, and hence with an increasing probability of successful selection. When, finally, there remained only two letters in the bag, your chance of securing the right one at the first draw would obviously be even; and when only the final "N" remained, you could not be wrong.

This illustration is used because I think it has peculiar application to the case of the plant-breeder. His method is actually not unlike that suggested. As the result of his first hybridizations, he does not dare to hope that he will secure the exact combination of qualities he would like to see brought together in his ideal fruit or flower. But by having a large number of seedlings from which to select he may reasonably hope to secure one that will present at least one of the desired qualities in superlative degree. This selected seedling is retained, with its desired quality, as you retain the letter "E" in our game, as marking the beginning of your success in spelling the word "evolution."

And as he continues his experiment with successive crossings and successive selections, he will be able in later generations to find individual seedlings that combine successively more and more of the qualities he is seeking. When, finally, he reaches the stage where the parent forms have between them all the desired qualities in a superlative degree, he is somewhat in the position you were when only two of your lettered blocks remained in the bag. There is at least an even chance that he will find among the seedlings of his next generation one that will approximate his ideal, even though the number from which he selects is far smaller than in the earlier groups.

Thus by advancing step by step and using the ground gained as a new starting point, the experimenter attains his end with comparative celerity, even though there would have been scarcely more chance of attaining that end with a single experiment than you would have had of fetching out the nine letters of the word "evolution" in the correct order, by that first blind chance.

But it must be clearly remembered that the probability of success for the plant-breeder or experimenter is enormously enhanced by working with large groups--what we may call a wholesale or "quantity production" method. I suppose that I have gone as far in this direction as any one in my line; I have never hampered myself with stingy experiments with a few plants, for this increases my difficulties and reduces my chances of success, not in arithmetic but in geometric ratio.

In practice we do not expect to secure ideal results, even the simplest, by a single crossing or combination; we seek to group desired qualities together through successive experiments. Keeping one supreme quality in mind and perhaps two or three others in the immediate background we make sure of first one and then another of the qualities we are building toward and thus, although seeming to advance but slowly, and as it were by indirection, we ultimately work with increasing certainty and, as we approach our goal, sometimes progress with more and more celerity and ease.

For example, our first cross, say in the case of a fruit, may be made between two varieties both of which show a fair quality of fruit. Careful attention to the result will guide us in the matter of the next experimental crossing. We soon discover which qualities are prepotent, and which tend to remain latent, and, by selecting only individuals that show a tendency to *vary in the desired direction,* we introduce an element of order into the experiment.

I am accustomed to speak of this as "the momentum of variation." We do not always know why a plant tends to vary in a given direction, but we may observe the fact and take advantage of it. Technical workers sometimes call this trend "orthogenesis," but we will get along without the hard words where we can, and this seems to be one of the places.

But even with the advantage of the momentum of variation, the course of our advance is often devious. It may be somewhat compared to the progress of a sailing ship which tacks this way and that, even seeming to be going in the wrong direction at times, but eventually winding up in its home harbor.

Take by way of illustration the stoneless plum. We may take for granted, in the beginning, that the habit of bearing a stone will be dominant in the plum, and the stoneless quality be so latent as to be almost nonexistent. So we must be prepared to find that the progeny of our first generation of hybrids all produce common stony fruit. But a knowledge of the tendency of latent or recessive characters to appear in successive generations encourages us to go on with the experiment with full confidence, even though it may be some time before results appear.

In due course the second generation of plums appears with a number of specimens in which the stones are small, or partly absorbed; meanwhile, however, the qualities of the fruit we desire have probably suffered, and in order to bring these back we must make a new cross, again with a fruit bearing full-sized pits. In three generations, then, we find ourselves, as regards the essential quality of stonelessnes, further back than we were before.

On the other hand, our third generation fruit has qualities of flesh that its stoneless ancestor altogether lacked; and in later generations we may be prepared to find individual seedlings that bear stoneless fruit possessing many of the qualities we desire to put into the finished product.

But we are running counter to the trend of heredity, because a vastly greater proportion of the ancestors of our plum were stone-bearers than otherwise. And so we must continue reshuffling and repealing, as it were, and watching results. We may lose in one generation what we gained in the one before, but we are making progress at all times, no matter what seem to be the facts.

Because each individual seedling of a hybrid strain represents a unique combination of ancestral traits, and constitutes in itself a new and unique experiment, equivalent to a "new deal of the cards." So the probability of securing what we seek will be somewhat proportionate to the number of seedlings.

This is particularly true in the case of such variable plants as the fruit trees of our orchards, with the possible exception of the apple. The case is far simpler when we are dealing with plants that vary little in their qualities, or where we are breeding with only a single pair, or two pairs, of unit qualities in mindsay hardness of kernel and immunity to rust, as in Professor Biffin's experiments with wheat; or good flavor and whiteness, as in the white blackberry.

But where the varied traits sought to be combined are numerous, as in the Shasta daisy experiments, or in work with a commercial cherry or prune, the case assumes new complexities. Hence it is that my records show tests applied to about a half million seedlings of the daisy, seven and a half million seedlings of various plums, and so on.

Let us turn back the pages of my experience a little, now, and glean some information about the care of seeds and the culture of seedlings, as a practical help to you.

To begin at the beginning, let us note that the preservation of tree and fruit seeds calls for careful attention. All fruit seeds, except those of the apricot and the almond, when removed from the fruit are at once placed in slightly moist, coarse sand, or fine gravel or in sterilized sawdust. In warm climates the boxes containing the seeds are then buried on the shady side of a building where they will become neither too dry nor too wet. The object is to keep the kernels as nearly as possible in their natural condition. If tree seeds, especially those of the cherry, pear, or plum, once become thoroughly dry, it is difficult to induce them to germinate. An important function of the fruit pulp, in the original wild state of the fruit, was to keep the seeds moist until winter's rains set in.

In warm climates fruit seeds may be planted out-of-doors, in January or February. Quince, pear, cherry, apple, and plum seeds are planted at a depth of an inch; peach, nectarine, and apricots a little deeper. Over them is sprinkled a thin layer of fine soil, then the furrow is filled up with sawdust. This regulates the moisture, allows for sufficient aeration, equalizes the temperature and finally arouses the disgust of slugs, thrips, cut-worms and other insect pests. In more rugged climes such work calls for a greenhouse of some sort.

The planting boxes, or "flats," indispensable to the plant experimenter, should be made of redwood or cypress: 18 x 18 x 4½ inches is a good size, and the bottoms, made of "shakes," should have narrow cracks left for drainage. If three narrow strips are nailed on the bottom of the finished box they will insure ventilation through the soil and also add to the strength of the flat and ease of handling it. It is a good plan to dip the joints in linseed oil before nailing, as this tends to prevent the nails from rusting out. These flats may be used for many years, with ordinary care, but remember to sterilize them thoroughly once a year by immersing them for five minutes in boiling water.

A suitable soil is the first requisite and, for all ordinary seeds, does not vary. I use one-half clean, sharp sand, 40 per cent of some good pasture or forest soil, and 10 per cent of finely powdered moss or peat. The addition of 1 or 2 per cent, by volume, of fine ground bone-meal or superphosphate, makes a nursery bed in which almost any seed on earth will germinate, and in which the seedlings will thrive until ready for transplanting. If the seeds of choice plants are to be grown it is a wise additional precaution, by the way, to sterilize the soil by scalding, to destroy any possible fungus or insect pests.

For cuttings, use only common sharp sand, though here, again, you may be well repaid if you will pour boiling water through the sand, which sometimes carries disease or pests.

Now that your planting soil is prepared, cover the bottom of your flat with half an inch of clean sand, fill it up with your soil, as above; mixed (or with straight sand for cuttings) to within an inch of the top or less, and you are ready to plant. I may say now that all ordinary seeds may be sown fairly thickly and covered lightly with the soil-just a dusting for very fine seeds and an eighth to a quarter of an inch for coarser ones. After the seeds are covered press the surface in the whole box down with a piece of flat board until it is smooth, level, and firm.

Now, instead of watering from above by any means, place the planted boxes in a square pan containing sufficient water to rise nearly even with the surface of the soil. In a few minutes the water saturates the whole, without disturbing the seeds or surface, and without causing any risk of packing. Then remove the boxes, give them a very slight tilt to drain them, and you have done all you can for the present. Your own judgment will tell you whether it is necessary to water again, but at no time sprinkle or spray the surface until the seedlings have a good start. Then, particularly if you can sprinkle a thin covering of our western green-tree moss over the surface to prevent washing and also to equalize temperature and prevent too rapid evaporation, you will start watering from a can or hose, with a very fine spray.

When the plants have two to four leaves it is best to transplant, whether you are dealing with large or small individuals, in order to give them more room and to weed out weaklings and misfits and total strangers, which may mysteriously appear in spite of all your care. In each of these second boxes we usually put eight plants each way or not more than ten; then, when the weather is warm enough, they are ready to go out of doors. But they ought to be moved by degrees, so it is a good idea to move them first into some sheltered place--the ideal situation being a lath-house, that tempers both wind and sun. Thereafter they are ready for the field or garden plot. Carry the boxes into the bed, make an incision in the ground with a spade or trowel that is worked back and forth to open a crack, transfer your seedling with its roots still in the flat-box earth, press down the home soil firmly, and your work is done. I never "coddled" my plants, nor bothered them with fussiness or petting. Firm, just treatment seems to please them best; they are Nature's children and, while you are not following Nature's way, you must strive to approach it as nearly as you can if you want healthy, vigorous plants.

Young seedlings in the first flats may be killed by a common fungus which causes what nurserymen call "damping off." This is particularly menacing where plants are grown too thickly in the seed-boxes, or in a close atmosphere. The trouble generally commences in little spots or patches; sometimes your plants may be saved if you apply a light dusting of sulphur, or even by moving to a cool, dry atmosphere. Of course, one is obliged to look out for insect pests--slugs, cutworms, crickets, aphids, and thrip--which may be very destructive and must be continually fought. The appetites of these pests increase faster than the young plants can provide their food, and every attack they make weakens the constitution of the growing thing.

Sometimes slugs may be headed off for a time by sprinkling lime, red pepper, quassia, or tobacco dust in their paths. Thrip and the aphids are best destroyed by fumigating the house once or twice a month with tobacco fumes. There are now commercial insecticides and fungicides that will do the work, but do not put off your battle until it is already lost, as you may well do if you are not always vigilant!

All in all, it is a severe gauntlet that the little seedling is called upon to pass, even under the most favorable conditions. Yet if the methods here described are carefully followed it is possible to grow successfully any seed, from whatever climate or soil or location it came, if it has in it the slightest germ of life.

These last-named considerations were always important to me because I was constantly receiving seeds and cuttings from my friendly collectors in such far-flung lands as Siberia, Brazil, Chile, Argentina, Patagonia, Mexico, Central America, the Philippine Islands, .Alaska, British Columbia, all the widely varying regions of Africa, central and western China, Japan, and Korea, to name those most helpful to me. When you go to the nearest seedsman and buy a ten-cent packet of seeds, your loss of a few or even most of the little plants is not vital. But when your whole supply consists of, perhaps, three or four seeds gathered from a rare plant in the Andes, preserved with infinite care in a handkerchief or pocket-book, packed out, perhaps a thousand miles or more, jealously wrapped in waxed paper in Bogota or Antofagasta, sent express with costly insurance by the first steamer, and received by you in the full knowledge that probably no one else on earth has seeds of the same variety for propagation, your methods must be such as to reduce the risk of loss to the irreducible minimum! In any case, if you are to be successful, even in amateur plant breeding, you can ill afford to employ any technic except the best and safest, if only for the sake of your own satisfaction.

CHAPTER XXV
Grafting and Budding

I HAVE often speculated on the question of how man first discovered that a portion of one plant can be joined with a second and made to grow and thrive as a part of that second. This, in fact, is what occurs when we perform either of the operations known as grafting or budding--essentially the same operation, in principle, and one of the most important in all the practice of horticulture.

Some commentators assume that an astute observer at some time or other saw a vine, the shoots of which had grown along the ground and become partly covered with earth, and had then taken root there and become vines on their own account, even though cut off by a later accident from the parent stock. Seeing this, the astute worthy in question began to study the phenomenon and reached, by inference, the conclusion that, if a vine's trailer could thus make a new start for itself when planted in the earth, a portion could be planted in the body of another individual of the same family, and would there "take root" and thrive. If the astute gentleman in the fable made the observation, reasoned as is suggested, and then tried the experiment he might easily have succeeded, and become the originator of grafting.

From my own observations I am led to suspect that the first discovery of this miracle in nature was accidental and that the conclusions drawn were by inference. Suppose, for the sake of my argument, that our observer found two forest trees, A and B, of the same variety, standing so close together that a branch of A had extended into B, been rubbed against it by the movement from the wind until the bark of both was worn away at the junction point, and that in the end the A branch had been joined with the B trunk and a union formed. If, at a later time, the trunk of A had been broken off or had died, its limb, joined by this amazing natural union into B, would continue to grow and flourish--in short, a *natural graft* would have been made. The observer who saw this wonder and who thought about it might easily have reasoned out something of its possibilities and have been led to experiment, thus giving us this great boon. For I myself have often seen cases similar, both in my orchards and in the forest, and if we had not long since known of the method, I think I might have been tempted to try the experiment of making an artificial graft.

Whatever the facts we owe a great deal to the first discoverer of the secret. By the method he introduced, and with the improvements made on the technic since, we are able to accomplish results of in estimable value to horticulture, to the plant experimenter, the nurseryman, and the world at large. Using it, we are able to graft valuable varieties into strong and quick-growing stocks, to propagate desirable fruits on disease-resistant roots, to grow all sorts of ornamentals, such as the so-called "weeping" trees and shrubs, to produce trees like the "Camperdown elm," and (as far as plant experimenters are concerned), to develop the "mass production" methods of fruit experiments to which I have referred in earlier chapters.

The single requisite that underlies all successful grafting is that the layer of tissue lying just beneath the bark, called the "cambium layer" shall be brought in intimate contact with the corresponding layer of tissue of the stock on which it is grafted. The lifegiving sap flows through this thin layer only; the "heart" of the tree, or branch or twig, is a mere framework of growth, and bears no sap. Under favorable circumstances the wounds made in the implanted twig--what we call the "scion"--and in the bark of the branch into which we are planting the scion--what we refer to as the "stock"--will soon heal, the sap will flow to the "buds" in the scion along those subjoined cambium layer tissues, and soon the scion sprouts, develops limbs, and will eventually bear blossoms and fruit as though it had never been cut from its original parent plant or tree.

Knowing this principle and then adhering to it, even the amateur may become proficient in growing grafts. A few specific hints as to the details of the best methods will, however, be of service.

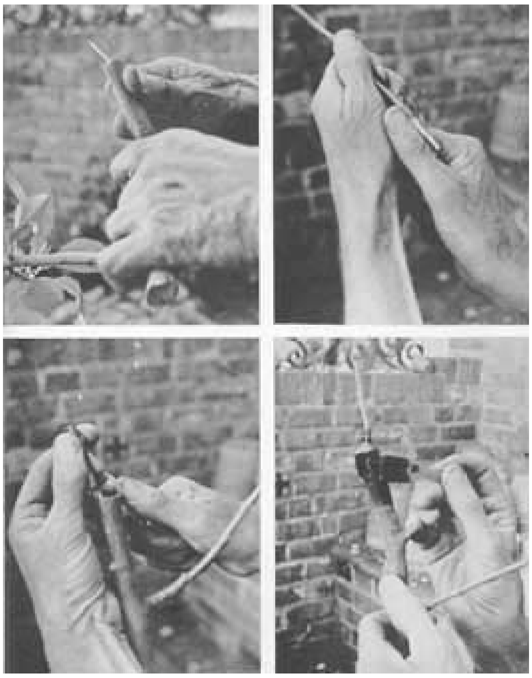
Grafting may be divided under three headings: (1) Grafting proper, in which a scion or small shoot is inserted into or upon the stock; (2) inarching, in which the scion is left attached to its parent stock until union with the new stock is completed (as in the example given above of the two forest trees, A and B, that made a natural union); (3) budding, which consists of the insertion of *a single bud* upon the cambium layer of the stock. There is no fundamental difference between the three processes--they are merely different methods of accomplishing the same purpose, and your choice will be guided by circumstances, to which we will refer later.

The plant experimenter or nurseryman will find the most useful graft-form for grafting young seedlings is "side" grafting. Your graft will be taken from "new wood" (the latest growth), on which are two or three well-formed buds. Cut it between two and three inches long, then slice off the lower end to make a sloping wedge about an inch long, with the edge that is to go toward the inside made as narrow as possible and that which is to go toward the outside slightly wider.

We assume here that you are putting your graft into a small sapling growing in the gound. Bend it aside with your left hand and make a vertical gash in it, near the ground. Then insert your wedge-shaped scion in this gash, gently forcing it in as far as it will go without splitting the stock sapling. Your most particular care must be to see that the cambium layers of scion and stock meet exactly, for it is here that a union must be formed to insure life to the scion. Next, cover the joint with grafting wax, to keep out air, insects, and disease. Finally you may either cut the sapling off just above the scion or, as I often do, you may break it partially off, so that, for a time, sap will continue to flow into it but not the full flow, which might rob the scion.

In grafting the branches or trunks of trees, as in "grafting over" a mature tree, the so-called "cleft graft" is usually employed. In this method the branch to be grafted is cut squarely off with a good sharp saw and the "stub" is split down and the scions pressed or tapped into the clefts. In this case not only the union of graft and branch is waxed, but the raw stub into which the graft was placed. Before applying the wax it is safest, though, to wrap the union with raffia, twine, thin cloth in strips, or tough paper, to reinforce the joint until a union has been made.

The "tongue" or "whip" graft is used in "bench" grafting--that is, of stock that has been dug and brought indoors--and also in what we call "top-grafting" trees which are standing in the orchard or field. Top-grafting consists in placing grafts on the various branches of a tree in order to change it over to a new variety. The tongue graft differs from the cleft graft in that there is a cleft, or wedge, cut in both scion and stock. These interlock when closely pressed together and result in a firmer union pending the healing of the wounds. In top grafting it is well to select branches not bigger than half an inch in diameter; also it is wise to graft only on the strongest branches one season and on smaller ones the next.



Four steps in simple crown or top grafting. Top LEFT: A deep cleft made in stock to be grafted. Top RIGHT: The scion whittled to a wedge-shape for insertion in cleft. BOTTOM LEFT: The wedge-shaped scion inserted in cleft, cambium layers exactly in juxtaposition. BOTTOM RIGHT: The finished graft wrapped and then completely covered with prepared grafting wax.

There are many variations of the grafting methods outlined above, but some of them were invented for use under unusual conditions and some are mere freaks of doubtful value. If you learn to make a simple graft so that it will "take root" and grow, you can add refinements to your practice later. A lively scion, a healthy "stock" tree or branch, a precise juxtaposition of the cambium layers of the two, and proper protection until the scars are healed are your concerns--not fancy or unusual procedure.

The grafting wax referred to above for protection of the cuts is important. There are several good waxes on the market, ready prepared, and you may be well advised to buy them. If, however, you plan considerable work, or prefer to be a real horticulturist, you may make a wax that will give you sure and excellent results and that will cost you less than the manufactured brands. My formula, refined and perfected after years of experimentation, I give here.

Eight pounds of common resin and one pound of beeswax or paraffin (latter will do if no acid or alkali is present, though beeswax is preferable), are mixed with one and a half pounds of *raw* linseed oil. Boiled oils often contain chemicals injurious to plant tissue. If the wax is to be used in cool weather it is better to use only seven and a half pounds of resin and a half pound of beeswax, thus giving the mixture a lighter consistency.

The ingredients should be slowly heated together until resin and wax are melted and thoroughly combined. This composition is poured into pressed tin pans, to make cakes of convenient size for handling. To remove from the pans, turn these upside down and pour boiling water over them till the cakes fall out. In use the wax is carried in any convenient container with a strong, short handle or, in some cases, a bail. In field work, in cold weather, it may be necessary to carry the wax in a frame or tin with a small heater in the bottom, like a coal-oil burner; the wax may be applied when it is much hotter than the touch will stand, but it must never be hot enough to scald the plant tissues. In all the processes with this grafting wax the danger of overheating or perhaps of causing it to catch fire is removed by using a double boiler.

If applied with care with a small paint brush, first around the thick bark of the stock and then, as the wax cools on the brush, on and about the cuts and open wounds, no harm will result. The plan of brushing the hot wax about the graft has almost entirely replaced the tedious old method of laying it on the with the fingers, saves time and does far better work.

If the wax should prove too soft and sticky, as in warm weather, melt it over again, adding the needed amount of resin. If too brittle, add a little more oil. The whole purpose is to get a wax that will spread well and yet will set firmly when cool. Fact is, the best results are obtained when the consistency of your wax is about that of ordinary chewing gum--when the chewing gum is working!

Grafting is much the most common and the most useful method of propagation of this sort, but both "inarching" and budding are important, the latter decidedly so. which leaves the roots both of the stock and the scion growing until a union is formed--has its place in horticultural work. For example, I once had a weakling plant in a pot that I was anxious to put on new roots, as its own were inadequate. So I placed my pot in the ground close to a sturdy field seedling of the same family, made an inarch graft, and was rewarded presently with a fine healthy young tree, its original roots cut away soon, and its parent-stock top soon cut off entirely.

Budding is only a special case or kind of grafting and means simply that one single bud is implanted into the stock. One of the advantages of budding is that each one of the buds on the scion can be given its own chance to grow: instead of a single-shot graft we may implant four or ten or twenty buds, with four or ten or twenty chances of success instead of one. Therefore budding is generally used for the production of nursery stock on a large scale, or for the propagation of rare varieties, grafting material for which is costly or difficult to secure.

The method of budding is closely similar to the method of bark-grafting already described, except as to season--June, July, or August, when the stock tree is in full leaf, instead of early spring, when the sap is just beginning to rise. A piece of bark about an inch and a half long, with a well-ripened bud, is sliced from the scion, the incision being just deep enough to include the cambium layer. The bark of the stock is slit horizontally and then vertically to form a T, the size of the slit being determined by the size of the bud to be inserted. The upper corners of the vertical slit are gently lifted with a knife and turned back to reveal the cambium layer. The bud is slipped into place, the flaps pressed down, and then some tie, such as soft string, raffia, or tape, is used to cover everything but the bud. Waxing is not necessary.

In ten to fourteen days the bud becomes united to the seedling and the binding cord may be loosened or removed. The bud remains dormant, though of a lively color, until the next spring, if your operation has been successful; then, when the leaves begin to start the tops of the seedlings (stock) are cut down to within two or three inches of the bud, all of the natural buds around being cut off to give the implanted youngster the full strength of the tree. By fall, then, we usually have healthy, strong new growth from that single bud.

It is possible to get bud-growth in the same season if you are dealing with a variety that ripens its buds earlier--say in June or even the first part of July. In this case, to force growth that same year the tops of the young tree are broken over (not cut off), at about half their height, as described above. This accomplishes really two purposes: first, keeping up the sap circulation of the stock-sapling, instead of killing it as you might do if you cut it off; second, forcing most of the strength of the tree into the bud.

These are called June buds by nurserymen. When well grown they make excellent trees for replanting, as the whole root system can be lifted, whereas with two- or three-year-old trees some of the roots are necessarily amputated in digging or before transplantation.

Now let us take a brief glance at the practice followed by those eminently practical horticulturists--the nurserymen, who are the greatest propagators of trees and without whom we would have very few orchards in the world to-day.

We are already well-grounded in the knowledge that seedlings vary and that type-true young trees can only be got by budding or grafting the desired variety into stock. This stock, however, is comprised entirely of seedlings, and variation here--which applies only to leaf development and type, color, shape, quality, and so on, of fruit--does not matter. Therefore the first thing the nurseryman does is to plant as many seeds as he is going to want stock-saplings for his next year's business. When these are grown up to sufficient size, almost invariably in one year, he selects the best seedlings, buds into them scions from the varieties he needs, and that fall or winter has ready for sale "grafted nursery stock"--that is, type-true fruit trees on seedling roots. It may be added that, in practice, most nurserymen do not grow their own stock seedlings, but buy them in wholesale quantities from growers who do nothing else. But the method is the same in any case.

We have already observed that many wild varieties furnish sturdier root systems and more disease-resistant trees than the more finely bred and therefore more sensitive orchard varieties; we know that diseases which in the past threatened to wipe out whole fruit industries were only checked by putting the desired varieties on resistant stock, as in the case of the California grape that was menaced by the dread *phylloxera* and only saved by being grown on a root that, for some obscure reason, was obnoxious to the deadly *aphid.*

So much for commercial uses of grafting and budding. As to their employment by plant-experimenters, a knowledge of these arts is indispensable, as several hundred varieties may be tested on a single tree.

View in the experimental orchard at the Sebastopol Farm. Here, so thickly planted that orchardists marvel that they grow at all, are the fruit trees with and from which Luther Burbank developed, hundreds of varieties of orchard fruits, scores of which are now extensively grown throughout the world. Each tree was a "bed" to Mr. Burbank, for in it he would "plant" grafts or buds by the hundred as a part of his "wholesale method" of fruit experimentation.

On my Sebastopol Cold Ridge Farm there are *single acres* on which ripen several thousand distinct varieties' of hybrid seedling fruits that could not be tested each on a separate tree on less than *seven hundred* acres of land! Besides, a seedling grafted into a bearing tree usually produces fruit in two or three years whereas, if the same seedlings were planted as usual and allowed to grow up until they fruited, it might require anywhere from four to fifteen years. There is still another advantage in grafting many seedlings on a single tree: a better opportunity is afforded for *comparative* tests. If the individual stock seedlings were employed some trees might be in better condition than others, or have better roots or grow in better soil, and thus no accurate comparison could be readily made.

In grafting for my purposes the weaker-growing seedling grafts are placed in the strongest-growing branches, while the stronger grafts may be implanted toward the outside, lower down on the tree, or on smaller branches. Pruning is important in this experimental work, too: in wintertime we always take pains to give the weaker growers plenty of space for development, and those that grow too rankly are severely pruned. Here you will need to employ all your skill, for a rule-of-thumb or catch-as-catch-can pruner could nullify a year's work in a few minutes. In fact, pruning everywhere is much more important than most horticulturists realize. I would as soon go to some pruners for the amputation of my right leg as I would for assistance in pruning one of my trees in which are experiments that may be the culmination of ten years' work and that may have cost me thousands of dollars. Hire a barn-painter to re-touch a Velasquez or a Turner in your art gallery, but don't hire a Jack-pruner to put your orchard into shape!

A Word in Closing

AS all books must do, this book comes to an end. In it an attempt has been made to give the reader two things, either of which he may put aside, but one of which, if he has persisted in the reading, must have interested or concerned him.

The first of these two things is a rambling study of the marvelous and yet simple workings of Nature in the plant world, through which, from the very beginnings of time until to-day, she has produced the vegetable life of the planet and has made possible its continuance and its development to fit its own needs; the second is an account of the fashion by which man, coöperating with Nature and using her laws, finds it possible to make that vegetable life more useful to him or more beautiful in his eyes. The first is natural history; the second is plant-breeding. The first is, I hope, of general interest; the second I have earnestly tried to make of practical value.

This treatise can be of little use to the scientist, the trained and experienced nurseryman, the established plant-breeder or the botanist. It is not addressed to such an audience, for they have their own text-books, written for and by them in a language that I can read and speak but that would be more or less unintelligible to the audience I hope to reach. That audience is made up of garden-lovers, of those who love Nature and want to know more of her ways, of those who share with me an insatiable curiosity concerning the world about us and, finally, of any young people who may have thought, or have been led to think through this reading, that they would like to become plant-experimenters.

It is to those last that I particularly address myself. I am growing old; my work is nearly finished. I am more and more impressed with the illimitable field for such labor as mine has been that opens on every hand. Plant-breeding as a career is comparatively new; the number of men and women engaged in it is so small as scarcely to touch the outer rim of possible researches that would lead to definite results. Do not suppose that it is a field in which you will become rich; do not rely on the belief that in it you will attain great honor or fame. What I have had of all three of those objects men seem to strive for--money, fame, honor--has come to me because, in many ways, I was a pioneer--and so got my name in the papers!

But I can promise you this much: if you study earnestly, work diligently and patiently, persist tirelessly and, without fail, listen to what Nature has to tell you and are guided by the laws she enunciates and the experiences she gives you, you are bound and certain to perform a valuable service to your fellowman.

If there is a higher reward than a consciousness that one has done that, I do not know what it is.