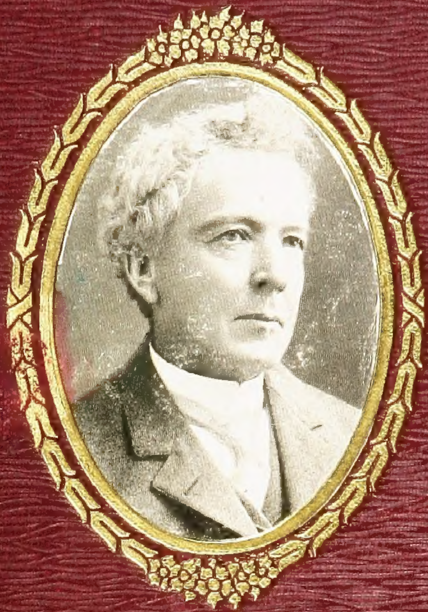

Luther Burbank

Shasta Daisies by Mr. Burbank's Porch

Mr. Burbank took what the farmers of New England had always considered a troublesome weed—the daisy—and transformed it into a flower of wondrous beauty. Every step in this transformation is explained in detail in the opening chapter of this volume. The direct color photograph print above, of Mr. Burbank's door-yard, shows how the Shasta daisy may be employed in lawn beautification.

LUTHER BURBANK

HIS METHODS AND DISCOVERIES AND THEIR PRACTICAL APPLICATION

PREPARED FROM
HIS ORIGINAL FIELD NOTES
COVERING MORE THAN 100,000 EXPERIMENTS
MADE DURING FORTY YEARS DEVOTED
TO PLANT IMPROVEMENT

WITH THE ASSISTANCE OF
The Luther Burbank Society
AND ITS
ENTIRE MEMBERSHIP

UNDER THE EDITORIAL DIRECTION OF
John Whitson and Robert John
AND
Henry Smith Williams, M. D., LL. D.

VOLUME II

ILLUSTRATED WITH
105 DIRECT COLOR PHOTOGRAPH PRINTS PRODUCED BY A
NEW PROCESS DEVISED AND PERFECTED FOR
USE IN THESE VOLUMES

NEW YORK AND LONDON
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Volume II — By Chapters

Foreword to Volume II

Having, now, a broad general understanding of the work—of the underlying principles, of the methods involved, and of the possibilities—let us listen to Mr. Burbank as he tells us just how he produced nine of his most striking transformations.

There are many Burbank productions which may be rated as much more important to the world than those treated in this volume; but these have been selected because they reflect, better than others, the various ways in which his methods have been combined to produce final, fixed results; thus serving to give the reader a complete exposition of working detail in the smallest possible space.

In this volume, then, we have Mr. Burbank's own fascinating story, for the first time told, of the exact steps which he took in producing a number of widely different plant transformations; together with many of his own observations on life—plant, animal and human—from which we gain a new insight into the relation between his viewpoint and those of other workers in the same and parallel lines.

THE EDITORS.

The Shasta Daisy

By comparing this new flower with its parents, shown further on, it will be seen that in size, shape, color, grace, and even leaf and stem, a new race has been created. More than ever will this be appreciated when it is understood that the flowers of the Shasta often attain a diameter of eight inches.

The Shasta Daisy

How a Troublesome Weed Was Re-Made Into a Beautiful Flower

"WHITE is white," said one of my gardeners, "and all these daisies are white. They look just the same color to me." "Yes," I said, "white is white—there is no doubt about that. But these daisies are *not* white—and they do *not* look just alike to me. No one of them is pure white, but there is one that is nearer white than the rest, or else my eyes deceive me."

All the other gardeners agreed with the first one, and it was some time before a visitor came who was not of the same opinion. Person after person was questioned, and each one declared that all the daisies in the row seemed to be pure white in color. No one could discriminate between them.

But one day an artist from San Francisco visited the garden, and when she was shown the row of daisies and asked about their color, she answered instantly that there was one much whiter than all the rest; and to my satisfaction she indicated the one that all along had seemed quite different from the others to my eye. There was no question, then, that this plant bore flowers nearer to purity in whiteness than any others of all the thousands of daisies in my garden.

Needless to say that particular plant was selected for use in future experiments, for the ideal I had in mind was a daisy that would be of the purest imaginable white in color. How the ideal was achieved—after fifteen years of effort—will appear in due course.

The daisies in question, of which the plant bearing the nearly white flowers was the best example, had been produced by several years of experimentation which had commenced with the cultivation of the common roadside weed familiar to every one in the East as the ox-eye daisy, and known to the botanist as *Chrysanthemum leucanthemum*. This plant, which grows in such profusion throughout the East as to be considered a pest by the farmer, was not to be found in California until these experiments were begun.

I brought the plant chiefly as a souvenir of boyhood days. But I soon conceived the idea of bettering it, for it had certain qualities that seemed to suggest undeveloped possibilities.

Original New England Ox-Eyes

The above direct color photograph print shows two New England Ox-Eyes, actual size, such as Mr. Burbank brought from his Massachusetts home when he came to California in 1875. This transported flower or weed formed the basis of the series of experiments which led to the production of the Shasta Daisy.

In its native haunts of New England, the ox-eye, as everyone knows, is a very hardy plant and a persistent bloomer. Its very abundance has denied it general recognition, yet it is not without its claims to beauty. But it did not greatly improve or very notably change its appearance during the first few seasons of its cultivation at Santa Rosa; nor indeed until after I had given it a new impetus by hybridizing it with an allied species.

Mating the Ox-Eyes

The plant with which the cross was made was a much larger and more robust species of daisy which I imported from Europe, where it is known colloquially as the ox-eye daisy, although the botanist gives it a distinct name, in recognition of its dissimilar appearance, calling it *Chrysanthemum maximum.* There is also a Continental daisy, by some botanists considered as a distinct species and named *Chrysanthemum lacustre,* which is closely similar to the British species, and of this seeds were secured from a German firm.

Both these plants have larger flowers than the American daisy, but are inferior to it in grace of form and abundance of bloom. The plants have a coarse, weedy appearance, with numerous unsightly leaves upon their flower stalks, whereas the stalk of the American daisy is usually leafless.

The Shasta Daisy and Two of Its Parents

The upper flower is a form of the Shasta Daisy slightly different from that shown on page six, the curving rays of which give a better realization of the kinship between the daisy and the chrysanthemum. At the bottom are shown a Japanese daisy at the left, and an European daisy at the right, both in proportionate size. The two small flowers at the bottom may truly be called direct ancestors of the larger flower above.

Notwithstanding the rather unsightly appearance of the European ox-eyes, I determined to hybridize them with the American ox-eye, in the hope of producing a plant that would combine the larger flowers of the European with the grace, abundant flowers, and early blooming qualities of the American daisy. The cross was first made with the English daisy *C. maximum,* by taking pollen from this flower to fertilize the best specimens of the American daisy that I had hitherto been able to produce.

When the seeds thus produced were sown next season and the plants came to blooming time, it was at once evident that there was marked improvement. Some of the flowers appeared earlier even than those of the American daisy; they were very numerous, and were larger in size than the flowers of either parent. But all the flowers had a yellowish tinge, unnoticed by the average observer, but visible to a sharp eye on close inspection. And this tendency to dinginess in color was not at all to my liking.

Further improvement was attempted by crossing the hybrid plant with the German daisy just referred to. A slight improvement was noticed, but the changes were not very marked.

By selecting the best specimens of the hybrid, which now had a triple parentage, I had secured, in the course of five or six years, a daisy which was very obviously superior to any one of the original forms as to size and beauty of flower, and fully the equal of any of them in ruggedness and prolific blooming.

But the flowers were still disappointing in that they lacked that quality of crystal whiteness which was to be one of the chief charms of my ideal daisy. So year by year I anxiously inspected the rows of daisies in quest of a plant bearing blooms whiter than the rest; and seeds were selected only from the prize plants.

The daisy spreads constantly, and one root stalk will, if carefully divided, presently supply a garden. But of course each plant grown from the same root stalk is precisely like the parent, and while I thus secured a large bed of daisies that combined approximate whiteness with all the other good qualities I was seeking, yet the purest of them all did not appear to my eye unqualifiedly white.

And when my judgment was confirmed by the decision of the artist, I determined to seek some new method of further improvement that should rid my daisies of their last trace of offending pigment.

In casting about for a means to achieve this end, I learned of an Asiatic daisy known to the botanist as *Chrysanthemum nipponicum;* and presently I obtained the seed of this plant from Japan.

Aid from Japan

This Japanese daisy was in most respects inferior to the original American ox-eye with which these experiments had started. It is a rather coarse plant, with objectionable leafy stalk, and a flower so small and inconspicuous that it would attract little attention and would scarcely be regarded by any one as a desirable acquisition for the garden. But the flower had one quality that appealed to me—it was pure white.

Needless to say no time was lost, once my Japanese plants were in bloom, in crossing the best of my hybrid daisies with pollen from the flowers of their Japanese cousin.

The first results were not 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 the hybrid plants had hitherto produced. Moreover the plant on which this flower grew revealed the gracefulness of the American plant, and in due course was shown to have the hardy vigor of all the species.

From this remarkable plant, with its combined

The Shasta and a Selected European Ox-Eye

The direct color photograph print above gives a good comparative idea of the difference in size between the average Shasta daisy and the largest of its European parents. The European Ox-Eye, at the right above, is perhaps three times as large as the average of its kind, and represents an improvement in size and form brought purely through selection.

heritage of four ancestral strains from three continents, thousands of seedlings were raised each year for five or six ensuing seasons, the best individuals being selected and the others destroyed according to my custom, until at last the really wonderful flower that has since become known to all the world as the Shasta Daisy was produced.

So at last I had the pure white daisy of which I had dreamed.

Moreover I had a flower that excelled my utmost expectations as to size, grace and abundant blooming qualities; a blossom from four to seven inches in diameter, with a greatly increased number of ray flowers of crystal whiteness, and with flower stem tall and devoid of unsightly leaves; a plant at once graceful enough to please the eye and hardy enough to thrive in any soil; a plant moreover of such thrifty growth that it reached its blooming time in its first season, although none of its ancestors bloomed until the second season; and of such quality of prolificness that it continues to bloom almost throughout the year in California, and for a long season even in the colder climates.

Conflicting Tendencies

The Shasta Daisy, sprung thus magically—yet not without years of coaxing—from this curiously mixed ancestry, exceeded my utmost expectations in its combination of desirable qualities. I can hardly say, however, that the result achieved was a surprise; for my experience with hundreds of other species had led me to anticipate, at least in a general way, the transformations that might be effected through such a mingling of different ancestral strains as had been brought about.

There was every reason to expect, while hybridizing the American and European ox-eyes, that a plant could ultimately be produced that would combine in various degrees all the qualities of each parent form. By selecting for preservation only those that combined the desirable qualities, and destroying those that revealed the undesirable ones, a fixed, persistent hybrid race that very obviously excelled either one of its parent forms was produced.

Nor is there, perhaps, anything very mystifying about this result, for the simpler facts of the hereditary transmission of ancestral traits are now matters of common knowledge and of every-day observation.

No one is surprised, for example, to see a child that resembles one parent as to stature, let us say, and the other as to color of hair and eyes.

So a hybrid daisy combining in full measure the best qualities of the European and the

American ox-eyes, as did my first hybrid race, perhaps does not seem an anomalous product, although certainly not without interest, in view of the fact that its parent stocks are regarded by many botanists as constituting at least two distinct species.

But the final cross, in which the Japanese plant with its small flowers, inferior in everything except color, was brought into the coalition, calls for explanation. A general impression has long prevailed that a hybrid race whether of animals or of plants is likely to be more or less intermediate between the parent races; so perhaps the common expectation would have been that the cross between the new hybrid race of daisies and the obscure Japanese plant would result in a hybrid with medium-sized flowers at best, and, except possibly in the matter of whiteness of blossom, an all round inferiority to the best plants that I had developed.

And in reality, there appeared the beautiful mammoth Shasta, superlative in all its qualities, surpassing in every respect each and all of the four parent stocks from which it sprang.

This apparently paradoxical result calls for explanation. The explanation is found, so far as we can explain the mysteries of life processes at all, in the fact that by bringing together racial

Shastas as High as the Fence

Not only is the Shasta daisy mammoth and graceful as to its flower, but also as to its stem. In this picture it will be seen that these stalwart daisies have grown almost as tall as Mr. Burbank's picket fence.

strains differing so widely a result is produced that may be described as a conflict of hereditary tendencies. And out of this conflict comes a tendency to variation.

The reasons for this are relatively simple. Heredity, after all, may be described as the sum of past environments. The traits and tendencies that we transmit to our children are traits and tendencies that have been *built into* the organisms of our ancestors through their age-long contact with *varying environmental conditions.*

The American ox-eye daisy, through long generations of growth under the specific climatic conditions of New England, had developed certain traits that peculiarly adapted it to life in that region.

Similarly the European daisy had developed a different set of traits under the diverse conditions of soil and climate of Europe.

And in the third place, the Japanese daisy had developed yet more divergent traits under the conditions of life in far away Japan, because these conditions were not only more widely different from the conditions of Europe and America than these are from each other, but also because the Japanese plant came of a race that had in all probability separated from the original parent stock of all the daisies at a time much more

A Typical Shasta Daisy Bush

From this direct color photograph print a good idea may be gained of the Shasta Daisy as it grows on the bush. With its long blooming period and its profusion of flowers, a single bush such as this may be used to good decorative effect.

563 Buds and Blossoms

At the time this direct color photograph print was made, a careful count showed that there were 563 buds and blossoms on this single Shasta daisy bush. Although in many respects this flower was wholly transformed, it will be seen from this that it inherits, to the utmost, the stamina and profuse blooming qualities of its New England parent.

remote than the time at which the European and American daisies were separated.

The Plant as a Camera

To make the meaning of this quite clear, we must recall that a given organism—say in this case a given stock of daisies—is at all times subject to the unceasing influence of the conditions of life in the midst of which it exists. The whole series of influences which we describe as the environment is perpetually stamping its imprint on the organism somewhat as the vibrations of light stamp their influence on a photographic plate.

Indeed, as I conceive it, the plant is in effect a photographic plate which is constantly receiving impressions from the environing world.

And the traits and tendencies of the plant that are developed in response to these impinging forces of the environment are further comparable to the image of the photographic plate in that they have a greater or less degree of permanency according to the length of time during which they were exposed to the image-forming conditions.

If you expose a photographic plate in a moderately dim light, let us say, for the thousandth part of a second, you secure only a very thin and vague negative. But if without shifting the scene or the focus of the camera, you repeat the exposure again and again, each time for only the thousandth of a second, you will ultimately pile up on the negative a succession of impressions, each like all the rest, that result in the production of a strong, sharp negative.

But if in making the successive exposures, you were to shift the position of the camera each time, changing the scene, you would build up a negative covered with faint images that overlap in such a way as to make a blurred and unmeaning picture.

And so it is with the plant. Each hour of its life there come to it certain chemicals from the soil, certain influences of heat and moisture from the atmosphere, that are in effect vibrations beating on its protoplasmic life-substance and making infinitesimal but all-important changes in its intimate structure. The amount of change thus produced in a day or a year, or, under natural conditions, perhaps in a century or in a millennium, would be slight, for the lifetime of races and plants is to be measured not in these small units but in geological eras.

Nevertheless the influence of a relatively brief period must make an infinitesimal change, comparable to the thousandth-second exposure of the negative.

And when a plant remains century after century in the same environment, receiving gen-

A Million Shasta Daisies in a Row

This direct color photograph print, snapped on Mr. Burbank's Sebastopol proving grounds, shows an estimated million of daisies which he grew and presented to the National Federation of Women's Clubs at their meeting in San Francisco in 1912.

eration after generation the same influences from the soil and atmosphere, the stamp of these influences on its organic structure becomes more and more fixed and the hereditary influence through which these conditions are transmitted to its descendants becomes more and more notable and pronounced.

So it is that a plant that has lived for countless generations in Japan has acquired a profound heredity tending to transmit a particular set of qualities; and when we hybridize that plant with another plant that has similarly gained its hereditary tendencies through age-long residence in Europe, we bring together two conflicting streams that must fight against each other and strangely disturb the otherwise equable current of hereditary transmission.

Long experience with the hybrids of other species of plants had taught me this, and hence it was that I expected to bring about a notable upheaval in the hereditary traits of my daisies by bringing the pollen of a Japanese plant to the stigmas of my hybrid European and American ox-eyes. That my expectations were realized, and more than realized, is matter of record of which the present Shasta Daisy gives tangible proof.

We shall see the same thing illustrated over and over again in our subsequent studies.

In offering this explanation of the extraordinary conflict of tendencies, with its resulting new and strange combination of qualities that resulted from the mixing of my various strains of daisies, it will be clear that I am assuming that the different ancestral races were all evolutionary products that owed their special traits of stem and leaf and flower to the joint influence of heredity and environment.

I am assuming that there was a time in the remote past when all daisies had a common ancestral stock very different from any existing race of daisies.

Touring the World

The descendants of that ancestral stock spread from the geographical seat of its origin—which may perhaps have been Central Asia—in all directions. In the course of uncounted centuries, and along channels that are no longer traceable, the daughter races ultimately made their way to opposite sides of the world. Some now found themselves in Europe, some in America, some in Japan.

Thousands of years had elapsed since the long migration began; yet so persistent is the power of remote heredity that the daisies of Europe and America and Japan even now show numerous traits of resemblance and proof of their common

More Evidence of Chrysanthemum Cousinship

The flowers shown above, selected from some of Mr. Burbank's Shasta experiments, have more the appearance of the chrysanthemum, almost, than of the daisy. It will be noted that the flower at the lower left gives evidence of doubleness to such an extent that the center has begun to fill up. Mr. Burbank has, in fact, produced some daisies in which the center is completely filled.

origin that lead the botanist to classify them in the same genus. But, on the other hand, these races show differences of detail as to stem and leaf and flower and habit which entitle them to rank as different species.

As the likenesses between the different daisies are the tokens of their remote common origin and evidences of the power of heredity, so their specific differences betoken the influences of the different environment in which they have lived since they took divergent courses.

The Japanese daisy is different from the German daisy because the sum total of environmental influences to which it has been subjected in the past few thousand years is different from the sum total of influences to which the German daisy has been subjected. Not merely differences due to the soil and climate of Japan and Germany today, but cumulative differences due to ancestral environments all along the line of the migration that led one branch of the race of daisies eastward across Asia and the other branch westward across Europe.

Are Acquired Traits Transmitted?

But all this implies that the imprint of the successive environments was in each case an influence transmitted to the offspring; and this is precisely what I mean to imply.

To me it seems quite clear that the observed divergencies between the European and the Japanese daisy are to be explained precisely in this way. I know of no other explanation that has any semblance of plausibility.

It is my personal belief that every trait acquired by any organism through the influence of its environment becomes a part of the condition of the organism that tends to reproduce itself through inheritance.

In other words I entertain no doubt that all acquired traits of every kind are transmissible as more or less infinitesimal tendencies to the offspring of the organism.

But it would not do to dismiss the subject without adverting to the fact that there are many biologists who dispute the possibility of the transmission of acquired traits. Indeed one of the most ardent controversies of recent years has had to do with that point; and doubtless many readers who are not biologists have had their attention called to this controversy and perhaps have received assurance that traits acquired by an individual organism are not transmitted.

I shall not here enter into any details of the controversy, although doubtless we shall have occasion to revert to it. But it is well to clarify the subject in the mind of the reader here at the

Many Steps Toward a Given End

Both of the flowers shown here are Shasta daisies, but the flower at the right, as compared with its mate, gives striking evidence of the improvement which may be wrought through selection — continuous, persistent selection. This flower is a recent Shasta, while the other represents the Shasta of a number of years ago.

outset, by pointing out that this controversy, like a good many others, is concerned with unessential details, sometimes even with the mere juggling of words, rather than with essentials.

As to the broad final analysis of the subject in its remoter bearings, all biologists are agreed.

There is no student of the subject speaking with any authority to-day, who doubts that all animal and vegetable forms have been produced through evolution, and it requires but the slightest consideration of the subject to make it clear that Herbert Spencer was right when he said that no one can be an evolutionist who does not believe that new traits somewhere and somehow acquired can be transmitted.

Otherwise there could be no change whatever in any organism from generation to generation or from age to age: in a word there would be no evolution.

The point in dispute, then, is not whether any trait and modification of structure, due to the influence of environment, is transmissible, but only as to whether environmental influences that affect the body only and not the germ plasm of the individual are transmissible. But when we reflect that the germ plasm is part and parcel of the organism, it seems fairly clear that this is a distinction without a real difference.

As Professor Coulter has recently said, it is largely a matter of definition.

We shall have occasion to discuss this phase of heredity more fully in another connection. In the meantime, for our present purpose, it suffices to recall that biologists of every school will admit the force of the general statement that heredity is the sum of past environments, and—to make the specific application—that our Japanese daisies and our German and American daisies are different because long generations of their ancestors have lived in different geographical territories and therefore have been subject to diverse environing conditions.

In a word, then, the Shasta Daisy which stands today as virtually a new creation, so widely different from any other plant that no botanist would hesitate to describe it as a new species, owes its existence to the bringing together of conflicting hereditary tendencies that epitomize the ancestral experiences gained in widely separated geographical territories.

Without the aid of man, the plants that had found final refuge in Europe and America and Japan respectively, would never have been brought in contact, and so the combination of traits that built up the Shasta Daisy would never have been produced.

In that sense, then, artificial selection created the Shasta Daisy, but the forces evoked were those that nature provided, and the entire course of my experiments might be likened to an abbreviated transcript of the processes of natural selection through which species everywhere have been created, and are to-day still being created, in the world at large.

New Races of Shastas

Once the divergent traits of these various strains had been intermingled, the conflict set up was sure to persist generation after generation.

Each individual hereditary trait, even though suppressed in a single generation by the prepotency of some opposing trait, strives for a hearing and tends to reappear in some subsequent generation.

So the plant developer, by keenly scrutinizing each seedling, will observe that no two plants of his hybrid crop are absolutely identical; and by selecting and cultivating one divergent strain or another, he may bring to the surface and further develop traits that had long been subordinated.

Seizing on these, I was enabled, in the course of ensuing years, to develop various races of the Shasta, some of which were so different that they have been given individual names. The Alaska, for example, has even larger and more numerous

Three Shastas from Different Lots

In this, as in all of Mr. Burbank's experiments, quantity production has been the key note. Of the millions and millions of daisies raised, the few only have been saved, while the many have been discarded; and from this finally selected few, a whole new race has been propagated. The color photograph print here shows three variant daisies, each selected by Mr. Burbank for some individual good quality blossoms than the original Shasta, with longer and stronger stems and more vigorous and hardy growth. The Westralia has blossoms of even greater size, and exceptionally long, strong and graceful stems, and the California has a slightly smaller flower but produced in great profusion; and its blossoms instead of being snowy white like those of the other races, are bright lemon yellow on first opening.

Moreover the enhanced vitality due to cross-breeding and the mingling of different ancestral strains, was evidenced presently in a tendency to the production not merely of larger blossoms, but of blossoms having an increased number of ray flowers.

The daisy is a composite flower, and the petal-like leaves that give it chief beauty are not really petals but are technically spoken of as rays. The flowers proper, individually small and inconspicuous, are grouped at the center of the circling rays.

In all the original species the ray flowers constitute a single row. But the hybrids began almost from the first to show an increased number of longer and wider ray flowers, some of which overlapped their neighbors.

By sowing seed from flowers showing this tendency, I developed after a few generations a strain of plants in which the blossoms were characterized

A Sport Among the Shastas

Among the thousands of aberrant forms which showed themselves during the production of the Shasta daisy, none, perhaps, was more strikingly singular than the sport or freak shown above. In this, as will be seen, the rays, instead of being flat and overlapping, are separate and tubular, flaring out into graceful formations at the ends.

by two rows of ray flowers instead of one. Continuing the selection, flowers were secured in successive generations having still wider and longer rays and increased numbers of rows, until finally a handsome double-flowered variety was produced.

Aberrant forms were also produced showing long tubular ray flowers and others having the rays fimbriated or divided at the tip.

And all these divergent and seemingly different types of flowers, it will be understood, have the same remote ancestry, and represent the bringing to the surface—the segregation and re-combination—of diverse sets of ancestral traits that had long been submerged.

It is certain that no plant precisely like the Shasta Daisy or any one of its varieties ever existed until developed here in my gardens at Santa Rosa. But the *hereditary potentialities* of every trait of the new flower were of course present in one or another strain of that quadruple parentage, else they could never have made appearance in the ranks of the hybrid progeny.

—I entertain no doubt as to the transmissibility of inherited or acquired traits.

The White Blackberry

How a Color Transformation Was Brought About

TO SPEAK of white blackbirds or of white blackberries is to employ an obvious contradiction of terms. Yet we all know that now and again a blackbird does appear that is pure white. And visitors to my experiment gardens during the past twenty years can testify that the white blackberry is something more than an occasional product—that it is, in short, a fully established and highly productive variety of fruit.

I doubt, however, whether there is record of anyone having ever seen a truly *white* blackberry until this anomalous fruit was produced.

Nevertheless it should be explained at the outset that the berry with the aid of which I developed the new fruit was called a white blackberry. It was a berry found growing wild in New Jersey, and introduced as a garden novelty, with no pretense to value as a table fruit, by Mr. T. J. Lovett.

He called the berry "Crystal White," but this was very obviously a misnomer as the fruit itself was never white, but of a dull brownish yellow. It had as little pretension to beauty as to size or excellence of flavor, and was introduced simply as a curiosity.

When a white blackbird appears in a flock, it is usually a pure albino of milky whiteness. It may be regarded as a pathological specimen, in which, for some unknown reason, the pigment that normally colors the feathers of birds is altogether lacking.

It is not unlikely that the original so-called white blackberry was also an albino of this pathological type. But if so, hybridization had produced a mongrel race before the plant was discovered by man, or at least before any record was made of its discovery; for, as just noted, the berry introduced by Mr. Lovett could be termed white only by courtesy.

Nevertheless the berry differed very markedly from the normal blackberry, which, as everyone knows, is of a glossy blackness when ripe. So my interest in the anomalous fruit was at once aroused, and I sent for some specimens for experimental purposes soon after its introduction, believing that it might offer possibilities of improvement.

The "Crystal White," So Called

Mr. Burbank learned that a wild blackberry of New Jersey, pictured above, lighter in color than any other blackberry, had been introduced as a garden novelty under the name "Crystal White." Although lighter than any other blackberry, it was of a muddy brown color, as can be seen from the photograph; and the berries were small and of poor flavor. This wild berry, however, was the first step in the production of Mr. Burbank's perfected white blackberry.

Making use of the principles I have found successful with other plants, my first thought was to hybridize the brownish white berry with some allied species in order to bring out the tendency to variation and thus afford material for selective breeding.

Creating a Really White Blackberry

The first cross effected was with the Lawton blackberry, using pollen from the Lawton berry. The Lawton is known to be very prepotent; it is of a very fixed race and will reproduce itself from seed almost exactly, which is not true of most cultivated fruits. Its seedlings often seem uninfluenced when grown from seed pollenated by other varieties.

It was to be expected, therefore, that the cross between the Lawton and the "white" berry would result in producing all black stock closely resembling the Lawton; and such was indeed the result.

But the Lawton also imparts its good qualities to hybrids when its pollen is used to fertilize the flowers of other varieties. As a general rule it is my experience that it makes no difference which way a cross is effected between two species of plants. The pollen conveys the hereditary tendencies actively, and so-called reciprocal crosses usually produce seedlings of the same character.

That is to say, it usually seems to make no

The Lawton Blackberry

A fine flavored, well fixed race of blackberries is the Lawton, shown above. If the pollen of the wild white berry had been applied to the pistil of the Lawton berry little variation could have been expected, the latter being so prepotent. But, by applying pollen from the Lawton berry to the flower of the so-called "Crystal White," Mr. Burbank produced variations which retained the lightness of color of the wild parent and combined the size, flavor and other good qualities of the well fixed Lawton.

practical difference whether you take pollen from flower A to fertilize flower B, or pollen from flower B to fertilize flower A.

This observation, which was first made by the early hybridizers of plants more than a century ago,—notably by Kölreuter and by Von Gærtner,—is fully confirmed by my observations on many hundreds of species. Nevertheless it occasionally happens that the plant experimenter gains some advantage by using one cross rather than the other. In the present case it seemed that by using the Lawton as the pollenizing flower, and growing berries on the brownish white species, a race was produced with a more pronounced tendency to vary.

Still the plants that grew from seed thus produced bore only black berries in the first generation, just as when the cross was made the other way. It thus appeared that the prepotency of the Lawton manifested itself with full force and certainty whether it was used as the staminate or as the pistillate flower.

When the flowers of this first filial generation were interbred, however, the seed thus produced proved its mixed heritage by growing into some very strange forms of vine. One of these was a blackberry that bloomed and fruited all the year. This individual bush, instead of dying down like others, kept growing at the top like a vine or tree, and when it was two or three years old it was so tall that a step-ladder was required to reach the fruit. Its berries, however, were rather small, soft, and jet black in color.

This plant, then, was an interesting anomaly, but it gave no aid in the quest of a white blackberry.

But there were other vines of this second filial generation—grandchildren of the Lawton and the original "Crystal White"—that showed a tendency to vary in the color of their fruit, this being in some cases yellowish white. Of course these bushes were selected for further experiment. Some were cross-fertilized and the seed preserved.

The vines that grew from this seed in the next season gave early indications of possessing varied qualities. It is often to be observed that a vine which will ultimately produce berries of a light color lacks pigment in its stem, and is greenish or amber in color, whereas the stem of a vine that is to produce black berries is dark brown or purple. A few of the blackberry vines of the third generation showed this light color; and in due course, when they came to the fruiting age, they put forth heavy crops of clear white berries of such transparency that the seeds, though unusually small, could readily be seen through the translucent pulp.

Signs of Success—Yellow-White Berries

From among many crosses between the Lawton and the poor "Crystal White," a berry very much improved in size was secured, as shown above, and the form, texture and flavor were brought up to the point, almost, of the good Lawton parent, while the color, though still far from white, was much lighter than even that of the wild "Crystal White."

These were doubtless the first truly white blackberries of which there is any record. But there were only four or five bushes bearing these white berries in an entire generation comprising several hundred individual bushes, all having precisely the same ancestry.

From among the four or five bushes, the one showing a combination of the best qualities was selected and multiplied, until its descendants constituted a race of white blackberries that breeds absolutely true as regards the white fruit.

Now Breeds True from Seed

The descendants of this particular bush were widely scattered and passed out of my control. But subsequently from the same stock, I developed other races, and finally perfected, merely by selection and interbreeding from this same stock, a race of white blackberries that breeds true from the seed, showing no tendency whatever to revert to the black grand-parental type.

This is, in short, a fruit which if found in the state of nature would unhesitatingly be pronounced a distinct species. Its fruit is not only snowy white in color, but large and luscious, comparable in the latter respect to the Lawton berry which was one of its ancestors.

"Was there ever in nature a berry just like this?" a visitor asked me.

Probably not; but there was a small white berry and a large luscious black one, and I have brought the best qualities of each together in a new combination.

The Anomaly Explained

Reviewing briefly the history just outlined, it appears that the new white blackberry had for grandparents a large and luscious jet black berry known as the Lawton blackberry and a small ill-flavored fruit of a yellowish brown color. The descendant has inherited the size and lusciousness of its black ancestor, and this seems not altogether anomalous. But how shall we account for the fact that it is pure white in color, whereas its alleged white ancestor was not really white at all?

The attempt to answer that question brings us face to face with some of the most curious facts and theories of heredity. We are bound to account for the white blackberry in accordance with the laws of heredity, yet at first blush its dazzling whiteness seems to bid defiance to these laws, for we can show no recognized white ancestor in explanation.

A partial solution is found if we assume, as we are probably justified in doing, that the original stock from which the so-called "Crystal White" berry sprang was a pure albino. It has already been suggested that such was probably the case.

There is, indeed, no other very plausible explanation available of the origin of the anomalous berry. White is not a favorite color either among animals or among vegetables. Except in Arctic regions it is very rare indeed to find an unpigmented animal or bird, and white fruits are almost equally unusual.

In the case of animals and birds, it is not difficult to explain the avoidance of white furs and feathers. A white bird, for example, is obviously very conspicuous, and thus is much more open to the attacks of its enemies than a bird of some color that blends with its surroundings. So we find that there is no small bird of the Northern Hemisphere, with the single exception of the snow-bunting, which normally dresses wholly in white. The exception in the case of the snow-bunting is obviously explained by the habits of the bird itself.

And even this bird assumes a brownish coat in the summer.

There are a few large water-fowl, notably the pelican and certain herons that wear snowy white plumage habitually throughout the year. But these are birds of predacious habits that are little subject to the attacks of enemies, and it has been shown that the white color, or bluish white, tends to make the birds inconspicuous from the view-point of the fish that are their prey.

So in the case of the tiny snow-bunting and of pelicans and herons, the white color of the plumage is seen to be advantageous to its wearer and hence is easily explained according to the principle of natural selection. The same is true of the white plumage assumed by those species of grouse and ptarmigan that winter in Arctic or sub-arctic regions; and contrariwise, the pigmented coats of the vast majority of the birds and animals of temperate zones are accounted for on the same principle.

But just why the fruits of plants should almost universally be pigmented seems at first not quite so clear. It is ordinarily supposed to be advantageous for a plant to have its fruit made visible to the birds and animals, that the aid of these creatures may be gained in disseminating the seed. And it must be obvious that a white blackberry would be as conspicuous in the woodlands where this vine grows as are the jet black berries of the ordinary type.

Why, then, you ask, has not natural selection developed a race of white blackberries?

I am not sure that any one can give an adequate answer. Perhaps it is desirable to have the seeds of a plant protected from the rays of the sun, particularly from those ultra-violet rays which are known to have great power in producing

Some Leaf Variations

Not only were the effects of the crosses evident in the berries, but in the leaves as well, as can be seen from the color photograph print above. In his almost endless selection from the variations produced, Mr. Burbank bore in mind not only the color and quality of the berries, but the size, shape and abundance of leaves, since, in the final result, these organs of digestion are to play an important part.

chemical changes. Recent studies of the short waves of light beyond the violet end of the spectrum show that they have strong germicidal power.

It will be recalled that the celebrated Danish physician Dr. Finsen developed a treatment of local tubercular affections based on the principle that ultra-violet light destroys the disease germs. And most readers have heard of Dr. Woodward's theory that very bright light is detrimental to all living organisms.

Possibly too much sunlight might have a deleterious effect on the seeds of such a plant as the blackberry. Indeed, the fact that the berry quickly develops pigments under ordinary conditions, and develops them much earlier than the stage at which it is desirable to have the fruit eaten by birds, suggests that this pigment is protective to the fruit itself in addition to its function of making the fruit attractive to the bird.

But be the explanation what it may, the fact remains that very few fruits in a state of nature are white; and no one needs to be told that fruits of the many tribes of blackberries, with the single exception of the one under present discussion, are of a color fully to justify the name they bear. Yet the experiment in breeding just recorded proves that, at least under the conditions of artificial

Like Leaf—Like Fruit

The color photograph print on this page shows with great clearness the importance of leaves in selection. The big, well-formed leaves are on the bushes with the big, well-formed fruits, and the poorer leaves are usually associated with the poorer fruits. Mr. Burbank often makes a first selection of seedlings from the leaves, not deeming it necessary to wait until the fruits have appeared.

selection, a race of berries may be developed which, though having the flavor and contour of the blackberry, is as far as possible from black in color.

The fact that this race of white berries was developed in the third generation from parents one of which is a jet black fruit and the other a fruit of a brownish tint, seems at first glance to give challenge to the laws of heredity.

Atavism and Unit Characters

Even though we assume that a remote ancestor of our newly developed white blackberry was a pure albino, the case still seems mysterious. Similar cases of reversion to the type of a remote ancestor have been observed from time to time by all breeders of animals and by students of human heredity, and it has been customary to explain such cases of reversion, or at least to label them with the word "atavism."

If this word be taken to imply that all traits and tendencies of an ancestral strain are carried forward from generation to generation by heredity, even though unable to make themselves manifest for many generations, and that then, through some unexplained combination of tendencies, the submerged trait is enabled to come to the surface and make itself manifest, the explanation must be admitted to have a certain measure of tangibility.

Nevertheless there is a degree of vagueness about the use of the word "tendencies" that robs the explanation of complete satisfactoriness.

Meantime the human mind is always groping after tangible explanations of observed phenomena. It is always more satisfactory to be able to visualize processes of nature. It was for this reason that Darwin's theory that natural selection is the most powerful moving factor in the evolution of races gained such general recognition and still remains as the most satisfactory of all hypotheses of evolution.

And it is for the same reason that a tangible explanation of the phenomena of atavism or the reversion to ancestral types has gained a tremendous vogue in recent years.

The explanation in question is associated with the name of the Austrian monk Mendel, who made some remarkable experiments in plant breeding about half a century ago, and who died in 1884, but whose work remained quite unknown until his obscure publications were rediscovered by Professor Hugo De Vries and two other contemporary workers, and made known to the world about the year 1900. Since then a very large part of the attention of the biological world has been devoted to the further examination of what has come to be spoken of as Mendelian principles.

Color Variations in the Canes of the Blackberry

Not only is the leaf a guide to the kind of fruit which a plant will produce, but in many cases the stem or cane gives a reliable indication. With most berries it is the rule that the light stalk will produce the lightest color berry—and the darker the stalk the darker the berry. From the variations above it will be seen that Mr. Burbank was able to select for lightness of color even before he used the leaves as an indication to size and form.

Some Stems of the Blackberry's Cousin

The direct color photograph print above shows some typical rose stems—varying in color, shape and thorniness. The rose, and the blackberry, and the apple, and sixty-two other plants, dissimilar in appearance, are all members of the same family, and often give evidence of the possession of common family traits. In his work with the rose, described later, Mr. Burbank made use of similar methods to those employed in the production of the white blackberry.

And, as is usual in such cases, unwarranted expectations have been aroused in some quarters as to the real import and meaning of the new point of view; also a good deal of misunderstanding as to the application of the so-called Mendelian laws of heredity to the work of the practical plant developer.

In view of the latter fact it is well to bear in mind that such experiments in plant breeding as those through which I developed the white blackberry and hundreds of others were made long before anything was known of Mendel and his experiments, and at a time when the conceptions now associated with Mendelism were absolutely unknown to any person in the world. It is well to emphasize this fact for two reasons: first, as showing that practical breeding, resulting in the bringing to the surface of latent traits,—for example, whiteness in the blackberry,—could be carried to a sure and rapid culmination without the remotest possibility of guidance from "Mendelism"; secondly, because from this very fact the interpretation of my experiments has fuller significance in its bearing on the truth of the Mendelian formulas than if the experiments had been made with these formulas in mind.

This is true not alone of the creation of the white blackberry, but of the similar development of the Shasta Daisy and of a host of other new forms of plant life that will find record in successive chapters of the present work.

But while I would thus guard the reader against the mistake, which some enthusiasts have made, of assuming that the Mendelian formula about which so much is heard nowadays must revolutionize the methods and results of the plant breeder, I would be foremost to admit that the remarkable work of Mendel himself, together with the work of his numerous disciples of the past ten years, has supplied us at once with several convenient new terms and with a tangible explanation or interpretation of a good many facts of plant and animal heredity that heretofore have been but vaguely explicable, even though clearly known and demonstrated as facts.

The case of the white blackberry with which we are at the moment concerned, is a very good illustration in point.

My experiments in the development of that berry, might be interpreted in the older terminology something like this: The big, luscious, black Lawton blackberry proved prepotent when crossed with the small brownish "Crystal White," and the offspring were therefore all large luscious black berries closely similar to the prepotent parent. But the qualities of the other parent were latent in

The Stem Finally Selected

The direct color photograph print above shows the stem of the final white blackberry. By comparing its color with the color of other stems shown, it will be seen that the dark, purplish-brown of the black Lawton has given way to the light greenish stem of the final white blackberry. The color of the stem, it should be understood, is only a guide to the color of the berry which is later to be produced. It does not form the basis of an absolute, fixed law, for outcroppings of old heredity sometimes appear in the stem but not in the fruit. The selection by the stems, is, however, of sufficient certainty to warrant its use in such experiments as the production of the white blackberry. Where it failed as a guide in three or four cases, it succeeded in hundreds or thousands of cases.

these offspring, and,—the tendency to variation having been stimulated by the hybridizing of these different forms,—the offspring of the second generation showed great diversity, and a tendency to reversion to the traits of the more obscure or less prepotent of the two grandparents.

In the still later generations, the conflict of hereditary tendencies continuing, an even more striking reversion, according to the principle of atavism, took place in the case of a few of the many progeny, bringing to light the pure white berry as an inheritance from a remote and long forgotten ancestor.

The Mendelian Explanation

Now this, as I say, would fairly explain the case of the white blackberry in such terms as were universally employed at the time when this interesting fruit was developed.

But the evolutionist of today, considering the same facts, would be likely to offer an explanation in Mendelian terms that would have the merit of adding a certain measure of tangibility to the mental picture of the actual processes involved in the hereditary transmission of traits through which the white blackberry was developed. And there can be no question of the convenience of these terms and of their value in aiding to conjure up such a picture, provided it be not supposed that the presentation of such a formula is to clarify all the mysteries of heredity and to do away with the necessity in the future—as some misguided enthusiasts have assumed—of laborious and patient experiments akin to those through which the triumphs of the plant developer have been achieved in the past.

In a word, the Mendelian formulas, if accepted at their true valuation and for their real purpose, may be regarded as placing new and valuable tools in the hands of the plant experimenter, just as did the formula of natural selection as put forward by Darwin; but we must in one case as in the other guard against imagining that the phrasing of a formula may properly take the place of the practical observation of matters of fact.

Bearing this caution in mind, let us note the changed terminology in which the Mendelian of today interprets the observed facts of the development of the white blackberry. His explanation would run something like this:

When the Lawton blackberry is crossed with the whitish berry, all the offspring of the first filial generation are black because blackness and whiteness are a pair of "unit characters," both elements or factors of which cannot be manifested in the same individual; and blackness is the "dominant" character of the two, whiteness being "recessive."

Baby Plants Awaiting Selection

The very first step in selection comes with the tiny seedlings showing their heads above the ground. At their first appearance it is often possible to judge many of the characteristics of the plant and its fruit, which, later, become confused as the battle of warring heredities grows more acute. Much of Mr. Burbank's work of selection is done from tiny seedlings in the flat.

But the hereditary factors or "determiners" that make for whiteness, though momentarily subordinated, are not eliminated, and half the germ cells produced by the hybrid generation in which blackness is dominant, will contain the factor of whiteness, whereas the other half contain the factor of blackness. And when in a successive generation a germ cell containing the factor of whiteness unites with the germ cell of another plant similarly containing the factor of whiteness, the offspring of that union will be white, their organisms inheriting no factor of blackness whatever.

It may chance, however, that for many successive generations a germ cell containing only the factor of whiteness fails to mate with another similar germ cell and so no white-fruited progeny is produced. In such a case generation after generation the white factors continue to be produced in the germ cells, but the union with a germ cell containing the black factor obscures the result just as in the case of the first cross, because the factor of blackness continues to be dominant.

But, however long delayed, when a cell containing the white factor or determiner does mate with a similar cell, the offspring is white and—in the older terminology—reversion or "atavism" is manifested.

A very simple and tangible illustration of the phenomena in question is furnished by the experiments in animal breeding made by Professor William E. Castle of Harvard. These experiments furnish a peculiarly appropriate illustration in the present connection because it chances that the animals experimented with are comparable to our blackberries in that they are respectively black and white in color.

The animals used in the experiment are guinea pigs.

An Illustration From the Animal World

Professor Castle shows that if a black guinea pig of a pure strain is mated with a white guinea pig of a pure strain, all the offspring of the first generation will be black; and it is therefore said that blackness is prepotent or dominant, and whiteness recessive. But if two of these black offspring are interbred, it is an observed fact that among their progeny three out of four individuals will be black like their parents and one of their grandparents, and the fourth one will be white like the other grandparent.

The Mendelian explains that the factor of whiteness was submerged, dominated by the factor of blackness, in the second generation; but that half the germ cells of these black individuals contained the factor of whiteness, and that by the

White Blackberries on the Bush

The direct color photograph print above gives evidence that Mr. Burbank selected his white blackberries not only for color, taste, size, firmness and the season of bearing, but also for the form, hardiness and other good qualities of the bush that bears them. In the final production of any new fruit all of these qualities and many others must enter into consideration—and a perfect balance or combination of them is the triumph of final selection.

mere law of chance the union of these germ cells brought together about one time in four two of the cells having the recessive white factor; such union resulted in a white individual.

Meantime by the same law of chance the other three matings out of the four brought together in one case two black factors and in two cases a mixture of black and white factors.

As black is dominant, these individuals having the mixed factors would be individually black (just as those of the first cross were black); but their progeny in due course will repeat the formula of their parent by producing one white individual in four.

It should be explained that the Mendelian, in expressing this formula, usually substitutes for the word "factor," as here employed, the newly devised word "allelomorph," although the less repellent equivalent "determiner" is gaining in popularity. He calls the body substance of an animal or plant a "zygote," and he describes an individual that contains factors of a single kind, as regards any pair of unit characters (say only for blackness in the case of our blackberries or Professor Castle's guinea pigs) as a "homozygote"; contrariwise a body having both types of factors (blackberries or guinea pigs of the second generation, for example) as a "heterozygote."

But these big words, while it is convenient to know their meaning, need not greatly concern us. It suffices to recall the convenient terms "dominant" and "recessive"; to recognize that a good many antagonistic traits may be classed as unit characters; and to welcome the conception of the division of the factors or determiners of such a pair of unit characters in the germ cell, as enabling us to form a tangible picture of the *modus operandi* through which the observed phenomena of heredity may be brought about.

Mixed Heritage of the Blackberries

It remains to be said that the case of our blackberries is a little more complex than the case of the guinea pigs just referred to, because there is a second pigment involved. The "Crystal White" berry, it will be recalled, was not white but brownish in color. There were thus transmissible two pairs of unit characters involved as regards the matter of color, namely (1) black versus white, and (2) yellow or brown versus white.

The black factor or determiner dominated absolutely in the first generation; but in the second generation a certain number of germ cells were paired in such a way as to eliminate the black but retain the yellow factor.

It required a third mixture of the germ-cell factors to produce a union in which neither black nor yellow factors appeared, the offspring of this union being of course the pure white blackberry.

The presence of the yellow factor accounts for the further fact, to which reference should be made, that there were various intermediate types of berries, neither black nor white, which appeared in successive generations but which are eliminated by selection as they did not fall in with our plan of development of a white race.

The explanation just given makes it clear that, once a union of germ-cell factors having only the white element was effected, the black and the yellow factors being entirely eliminated from that particular individual, the germ cells arising from that individual would necessarily contain only the factor of whiteness; hence that all the progeny of that individual would "breed true" and produce white berries.

Such is indeed the observed fact with my developed strains of white blackberries. Grown from the seeds, these breed far truer to their parentage than is the case with most cultivated fruits. As to certain other qualities they may vary, but all are white.

The Mendelian explanation obviously cannot add any force to this observed and long ago recorded fact.

But it does serve to explain the observed fixity and permanency of the new and anomalous breed. It enables us in a sense to *understand* the paradoxical fact that a berry having a whole galaxy of black ancestors may have no strain of blackness, no tendency to reversion to the black type, in its composition.

But we must not put the cart before the horse by supposing that the new explanation adds anything to the force of the previously observed facts. Hypotheses are for the interpretation of observed phenomena, not phenomena for the interpretation of hypotheses.

One other word in this connection. To would-be plant experimenters who ask my opinion of matters connected with the old versus the new interpretations of heredity, I am accustomed to say:

"Read Darwin first, and gain a full comprehension of the meaning of Natural Selection. Then read the modern Mendelists in detail. But then—go back again to Darwin."

Bear in mind Professor J. M. Coulter's comment that "Mendelism has extended from its simple original statement into a speculative philosophy," and try for your own satisfaction to separate the usable formulæ from the intricate vagaries of the new creed of heredity.

Let me cite a recent assertion of Professor

The White Blackberry Perfected

The success of Mr. Burbank's production may be judged by the firm, luscious, pure white fruit as shown above. The white blackberry is now a thoroughly fixed race coming true from the seed—a fruit which, if found in the state of nature, would unhesitatingly be pronounced a distinct species. It is whiter than the whitest blackberry man ever saw before and compares in size and lusciousness with its paternal ancestor, the Lawton.

William E. Castle, himself one of the foremost experimenters along the lines of the newest theory:

"As to how a new race is begotten we have not got much beyond Darwin; indeed many of us have not got so far."

The man who has got as far as Darwin in the matter of understanding racial origins,—to say nothing of getting beyond him—even in our day, is no tyro in the study of heredity.

—Read Darwin first; then read the modern Mendelists; and then —go back to Darwin.

The Scented Calla

How Fragrance Was Instilled In a Scentless Flower

NOT long ago a young woman visitor who had learned that the function of odor in flowers is to attract bees and other insects made a remark at once naïve and wise.

"It seems wonderful," she said, "that bees and other insects should have the same taste in perfumes that we human beings have. The rose and the apple blossom are sweet to them as well as to us; whereas one might expect that they would care for something quite different, especially when we remember that cultivated people generally like more delicate perfumes than those that please uncultivated people."

This remark, as I said, was at once wise and naïve.

It was wise because it showed a tendency to seek causes for things in nature instead of taking them for granted as most people are prone to do.

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It was naïve because it quite overlooked the true significance of the function of odors in nature.

A moment's further reflection would have shown the young woman that it is not at all a question of the bee liking the things that man likes, but a question of man having learned to like the things that the bee likes.

The scent of the flower was not put forth to please or displease man, but to please and attract the insect.

And man learned to like the odors that were constantly presented to him largely because they were constantly presented; just as you may learn to like a food—say, for example, olives—by repeatedly tasting it, though at first you do not care for it.

The exception, of course, is the odor that is associated with unhygienic things, such as decaying vegetable and animal matter. These are attractive to the insects that feed on them because the substances that produce the odors are to these insects wholesome. But they do not attract the bee because they contain nothing on which that insect can feed; and they do not attract us because for us the substances that produce them are pernicious.

But doubtless the carrion beetle finds the odor of decayed meat a much more attractive aroma than the odor of orange blossoms.

And, to make direct application to the case in hand, unquestionably the flies and other insects that are useful to the calla in pollenizing its flowers would be quite unattracted by the sweet and pervasive odor that is given out by the new race of scented callas which I am about to describe.

How the Calla Is Fertilized

It was on smelling the perfume of my scented calla that the visitor made the remark I have quoted. And she followed it with this question:

"If the odor of plants is of use to them in attracting bees, why do not all the callas have a perfume like this new one you have developed?"

And here again a moment's reflection would perhaps have supplied the answer. The calla does not need to attract the bee, therefore the production of the chemical substances that give out a sweet perfume would have been a waste of energy for this flower. Perhaps there may have been a time in the past when the calla, like so many other flowers, depended on bees for cross-fertilization, and lured them with its scent; but nowadays the process of cross-fertilization in this plant is effected in a quite different fashion.

If you closely examine the calla you will observe that what you would casually speak of as a single blossom is in reality a case or shield—in point of fact a modified leaf—twisted into a sort of cornucopia and adjusted about a central stalk or "spadix" on which many minute and inconspicuous blossoms are clustered.

The object of this arrangement is doubtless in part to give protection to the flowers, but largely to supply a conspicuous signal to attract night-roving insects, in particular various species of small gnats and flies.

In point of fact the white canopy of the calla affords a very convenient place of refuge for numerous small insects.

Tests have shown that the air inside the calla "blossom," particularly toward its base, where the insects congregate, is perceptibly warmer than the outside air.

It has been proved by recent experiments that the chemical processes associated with plant growth generate heat. Germinating seeds, for example, give out a measurable quantity of heat. So it is not strange, perhaps, that the partially confined air at the base of the tubular calla flower-case is at all times a little warmer than the surrounding atmosphere.

In any event the insects find this a snug corner, the attractiveness of which is further enhanced by

The Spadix of a Calla Lily

From this direct color photograph it will be seen that the central stalk within the lily, called the spadix, is in fact a composite flower itself, on which many minute and inconspicuous blossoms are clustered. These blossoms may be clearly seen on the print above.

the presence of a certain amount of edible pollen. In short, for such insect tribes as like the particular fare which the calla offers, its beautiful white tube constitutes a highly attractive lodging-place and lunchroom.

Meantime, while the insects are lodging at the base of the stalk on which the true flowers grow, these flowers shed their pollen and let it settle on the backs of the visitors.

And when, in due course, the insects resume their voyaging, they carry the pollen with them and in time transport it to other calla blossoms; for when they enter the new flower they are likely to find the stalk at its center a convenient alighting place, and crawling down this are sure to leave some of the pollen in contact with receptive pistils.

That the pistils shall be those of a different plant from the one that supplied the pollen is ensured by Nature's familiar device of having the stamens and pistils of the same flower ripen at different times.

A Gift of Nature

All this sufficiently explains the utility of the large white modified leaf or spathe which we commonly speak of as the calla's flower, and also the normal habit of this flower in producing only the musty odor which is rather disagreeable to us, but which is obviously attractive to the particular insects which the calla needs as coadjutors.

But it does not explain how it chanced that among a large quantity of seedlings of a tribe of calla known as the "little gem," I one day found a single specimen that not only lacked the disagreeable smell of the others, but had a mild yet unmistakable aroma that was distinctly pleasing.

Explanations aside, such a specimen did appear among my callas, and it was by raising seedlings from this anomalous specimen and carefully selecting the best specimens for successive generations that I developed the perfumed calla.

The first plants that grew in the first generation from seeds of my first scented calla showed no improvement over their parent in point of fragrance. But in the second generation, as so often happens, there was a marked tendency to variation, and from among the numerous seedlings of this generation I was able to select one that had a fully developed and really delightful perfume.

By propagating this specimen as usual, by division, scented callas precisely like the mother plant were soon developed in quantity.

Other races showing the quality of scent-production in varying measure were produced from the seed, but no one of the seedling varieties ever equalled the selected plant, and the finest fragrant callas in existence to-day are all the descendants, through the process of division, of the original second generation seedling.

This new race of callas was named the "Fragrance."

Fortunately it chanced to combine with the habit of perfume production the habit of abundant and constant blooming. Indeed, in this regard it probably excels all other varieties of calla.

The New Calla a "Sport"

It thus appears that the perfumed calla was developed through selection and in the short period of two generations, from a perfumed individual that appeared "spontaneously" among some thousands of odorless seedlings.

Using a term that is peculiarly popular in recent years, we might say that so marked a variation from the normal or usual form of calla constituted a "mutation."

In the size and color and general appearance of its flower, as well as of its entire structure, the new calla precisely resembled its fellows. Yet we are surely justified in speaking of so very marked an anomaly as the production of a strong perfume as constituting an important departure from the normal.

No one knows precisely what the chemical

A Freak Calla

This Calla Lily, found on Mr. Burbank's grounds, gives a clear idea of the relation of the spathe to spadix. It will be seen that while the spadix bears the blossoms, the spathe is, in point of fact, a modified leaf twisted into a sort of cornucopia around it. Through some lack of balance in the heredity of the plant shown above, the spathe took back to the days, evidently, when this transformation was in the making.

changes are that produce the perfume of a flower, or through precisely what transmutation of forces one flower is made to produce an odor quite different from the odor of other flowers.

But for that matter no one knows just what are the conditions that induce the stimulus that we interpret as an odor of any kind. The sense of smell seems the most mysterious of our senses.

But whatever these inherent conditions may be, they constitute changes in the intimate structure of the plant itself that must be admitted to be important in character, inasmuch as they have to do with the well-being of the plant, and may even determine—through their appeal or lack of appeal to insects—the perpetuation or the elimination of a species.

In the case of my scented calla it was perfume alone that differentiated a particular individual from thousands of other individuals growing in the same plot.

On this basis alone I selected out this particular flower, put it in a plot by itself, gave it every encouragement, and determined that its progeny should live and perpetuate the particular strain it represented; whereas but for this single feature of variation, that individual plant would in all probability have been destroyed along with hundreds of others.

The development of the scented calla, then, through artificial selection based on the recognition of the value of fragrance as an addition to the attractiveness of this flower, represents in a small way and in epitome the history of the development of numberless races in nature through the operation of natural selection.

In this particular case, natural selection probably would not have resulted in the production of a race of scented callas, because, as already pointed out, fragrance of this character has no value for this particular flower. It might even chance that the fragrance which to our senses is exquisite would prove unattractive or even repellent to the flies that normally frequent the spathe of the calla and aid it in perpetuating its species.

In that case natural selection would certainly ensure the early destruction of the race of scented callas. It may well have been through such discriminative selection on the part of insects that the calla lost its scent in the past ages. For of course natural selection can operate quite as effectively in weeding out organisms that have undesirable traits as in perpetuating organisms that show favorable variations.

One process is necessarily complementary to the other; they are two sides of the same shield.

In another connection we shall have occasion to deal more at length with the processes of natural selection; and we shall see numberless examples before we are through of the way in which artificial selection is instrumental in developing new races of plants.

Foundations of Natural Selection

But for the moment I will consider a little more at length the question of the origin of the variation which resulted in giving this particular calla a perfume that was not normal to its race. In so doing, we shall gain a clue to the genesis of other types of variation or mutation through which various and sundry new races of cultivated plants have originated, and through which also, we have every reason to believe, numberless species of animals and plants in a state of nature have been evolved.

The presentation of this subject puts us in touch with one of the newest and doubtless one of the most important aspects of the problem of evolution.

Since Darwin we have fully understood that all evolution of organic forms must have its origin in variations. No two individuals even of the same species are precisely alike, and it is not at all unusual to find individuals of a species showing very considerable differences, even as regards the

Another Freak Calla

This oddity was observed on one of Mr. Burbank's yellow Calla plants. It will be noted that the true leaf shows a tendency to turn yellow, while the spathe has the green markings of the leaf on its back. This is but one of innumerable freaks or sports such as are encountered in large quantity production of plants; and it is from these oddities, often, that new ideas of old and useful heredity within the plant are made evident to the plant improver.

essentials of size and form and function. Indeed, a certain range of such variations is considered to be absolutely normal.

One would never state, for example, that any particular bird has a wing or beak or tail of precisely a given length; instead of this the ornithologist records the *average* or mean length, or the limits of variation shown by different specimens.

And it is universally recognized, since Darwin gave us the clue, that the building up of new species must be brought about through the selection of favorable variations. A bird with an extra long wing, for example, might be able to fly a little faster and secure its insect prey with greater facility than its fellows; and this slight advantage might be instrumental in saving the life of such a bird, and thus enable it to transmit its peculiarity to offspring that would constitute a long-winged, swift-flying race.

Take the following incident as a tangible illustration:

In the summer of 1904 it chanced that there was a severe drought in New England and there were entire regions in which the insects upon which the common house martin feeds failed to be hatched at the usual time. The result was that there was dearth of food for the martins, and a very large proportion of these birds died of starvation.

In some cases forty or fifty birds would be found starved to death in a single bird-house.

There are entire regions in New England to-day where the martin is a rare or unknown bird, although prior to 1904 it was abundant.

Now we may reasonably assume that any individual martins that escaped were those that had either greater powers of flight or a stronger inherent tendency to make wide flights in search of food than their fellows. The few individuals thus saved furnish us a concrete example of the survival of the fittest through natural selection. And this illustration is cited at length because it makes tangible the fact, to which I shall have occasion to revert time and again, that the processes of nature through which species have been developed in the past are still in operation everywhere about us.

Many people are disposed to think of natural selection as a principle referring to past times and to the development of organisms long since perfected.

In point of fact past times are like present times in the operation of their laws. The re-actions between organism and environment are now what they always were. No race is perfected, no organism freed from the struggle for existence; although, of course, under the conditions of civilization the operation of "natural selection" may be modified through man's influence, and the conditions of life for a given organism radically changed by artificial selection.

Evolution Through Mutation

But let us not forget our theme. With the case of the scented calla to furnish our text, I was about to speak of those variations from the normal on the part of any given organism which lie outside the ordinary range of variation and which therefore constitute so definite and pronounced a departure that they have long been spoken of as "sports."

To these the present day evolutionist, following Professor Hugo de Vries, gives the name of "mutations."

It has already been said that the appearance of a scented calla constitutes such a change. But of course the anomalies that are usually listed as mutations are as a rule of an even more noticeable character. A classical illustration was given by Darwin himself in the case of the Ancon ram, which was born with legs only half the normal length, and from the progeny of which was developed a short-legged race of sheep.

But the word mutation had not come into

Mr. Burbank's Original Yellow Calla

The plant from which this flower was developed is of African origin. It is a not distant relative of the familiar White Calla, belonging to the Genus Richardia. These plants, although universally called Callas by the florist, are not so named by the botanist, the true Calla being a quite different flower of no great horticultural importance. The Yellow Calla, known also as the Pride of the Congo, was originally of a greenish yellow color, but has been made to take on the rich hues above shown by selective breeding.

vogue in Darwin's time, and the idea of evolution through such marked departures from the normal was subordinated, in Darwin's interpretation of the origin of species, or at least in that of his immediate followers, to the idea of advance through the preservation of slight variations.

So when, just at the close of the nineteenth century, Professor Hugo de Vries came forward with his "mutation theory," it had all the force of a new doctrine, and was even thought by some enthusiasts—though not by its originator—to be in conflict with the chief Darwinian doctrines.

The observations that led Professor de Vries to the development of this theory were made on a familiar American plant that had found its way to Europe and was growing in profusion by the roadside near Amsterdam. The plant is known as the evening primrose.

Professor de Vries noted a hitherto undescribed variety of this plant in a field near Amsterdam. He took specimens of the plant to his famous experimental gardens and carefully watched the development of successive generations of seedlings.

To his astonishment he produced in the course of a few generations more than a dozen divergent types of evening primrose, all descended from the original plant, each of which bred true to the new form suddenly assumed. Professor de Vries spoke of these sudden and wide variations from type on the part of his evening primrose as constituting "mutations."

He conceived the idea that similar mutations or sudden wide variations had probably constituted the material on which natural selection had worked in the past. Such mutations being observed to occur in the case of the evening primrose, it is not unnatural to argue that similar mutations must occur in the case of other organisms; and it requires no argument to show that such wide variations offer better material for the operation of the laws of natural selection than could be offered by the minute and inconspicuous variations that had hitherto been supposed to constitute the basis of evolutionary changes.

There were many reasons why the mutation theory appealed to contemporary biologists, thus accounting for its very cordial reception.

For example, there are numberless instances in nature where the development of a useful organ is exceedingly hard to explain on the basis of natural selection, because the organ in its incipient stages could have no utility. Similarly a modification in the location of an organ—say the shift in the flatfish's eye until both eyes are on one side—is difficult to explain as a process taking place by infinitesimal stages, on the basis of natural selection.

A slight shift in position of the eye of the flatfish would have no utility whatever. It is only when the shift has become sufficient to bring the eye on the upper side of the fish that the creature would have any advantage over other flat fish whose eye is on the under side.

If we imagine a mutation in which a fish appears with an eye distorted in location sufficiently to be usable while its owner lies flat on its side in the mud, we can readily understand how such a mutation might be favorable to the individual and thus might furnish material for the development through natural selection of a race of flatfish having both eyes on one side.

We have every reason to believe that the races of flatfish now existing have recently—in a geological sense—developed their observed condition of having the eyes thus located; indeed proof of this that amounts to demonstration is furnished by the fact that the young flatfish even to this day is born with its eyes located like those of other fishes, the migration of the eye, so to speak, taking place as the individual develops the racial habit of lying on its side.

But as I said, it is unquestionably difficult to conceive how the useful distortion came about

White and Yellow Callas

A glance shows the close resemblance in form between the white Calla and its yellow cousin. As might be expected, Mr. Burbank has been able to hybridize the different Callas, producing interesting new varieties. Some of Mr. Burbank's new Callas are of gigantic size, whereas others bear flowers only an inch and a half across.

unless it began suddenly as a "sport" or mutation. This is one instance among many.

And so Professor de Vries' observation, which proved that mutations do sometimes seemingly occur "spontaneously" in nature was seized on as affording a solution of one of the puzzles of evolution, and the mutation theory was pretty generally regarded as a valuable supplement to the Darwinian theory of evolution.

It should be clearly understood, however, that neither Professor de Vries himself nor anyone else speaking with authority, has thought of the mutation theory as in any sense contradicting the Darwinian theory of natural selection. On the contrary, it is to be regarded as supplementing and supporting that theory. If creatures are subject to large variations in a single generation, such variations afford peculiarly good material for the operation of natural selection. Moreover, evolution by mutation would presumably be much more rapid than evolution that depended for its leverage upon minute variations.

What Causes Mutation?

Incidentally the idea of relatively rapid evolution, thus given plausibility, answered the objection of certain geologists who had questioned whether the earth had been habitable long enough to permit the evolution of the existing forms of life through the cumulative effect of slight variations.

The mutation theory is thus in many ways acceptable. But to give the theory finality it is obviously necessary to proceed one step farther and ask this question: What causes mutation? And it is equally obvious that the question must be hard to answer.

Professor de Vries, to be sure, made the assumption that the changes in his evening primrose were probably due to altered conditions of nutrition incident to the growth of the plant in a new soil. He further developed a thesis that probably all species are subject to mutation periods, which recur at more or less regular periods of their life history, and which thus ensure a degree of variation that will make racial evolution possible.

The authority of de Vries sufficed to give wide vogue to his theory; yet it must be admitted that the explanation offered lacks tangibility and at best amounts to little more than begging the question.

To say that altered nutrition produces variation in a plant is in effect to state the fundamental truth that *all plants are more or less responsive to their environment.*

But there is nothing specific in the case of the primrose that explains in any precise way the relation of the change to the particular differences, let us say, between the soil of the original home of the primrose and the soil of Holland. Moreover in numberless other instances plants have been transplanted from one region to another without showing any such pronounced tendency to develop new races.

It was recognition of the difficulties thus presented, undoubtedly, that led Professor de Vries to devise the rather visionary hypothesis of *periods* of mutation with which his theory was cumbered.

But it is a well recognized law of logic that one should never seek remote and obscure explanations of observed phenomena unless all explanations of a more tangible character have been proved untenable. And it has seemed to me from the outset that in the case of the evening primrose a very much more plausible explanation is at hand than the one devised by the originator of the mutation theory.

In a word, the varied tribes of evening primrose which Professor de Vries developed in his gardens at Amsterdam were overwhelmingly suggestive of various and sundry new forms of hybrid plants that I myself have developed year after year in my experimental gardens at Santa Rosa.

The primus blackberry, the phenomenal berry, and the sunberry, are, if you wish so to consider them, instances of pronounced mutation, inasmuch as they are fixed forms of plants that vary widely from the parent forms.

In a single row I can show walnut trees six inches high that are of the same age with others six feet in height, both grown from seeds of the same tree. The Shasta daisy and the white blackberry are mutants in the same sense. And as the reader will discover in due course, the list of such anomalies might be extended to tiresome lengths.

In a word, it is perhaps not too much to say that my entire work has consisted in dealing with mutations in plant life. My chief work might be held, and I believe justly held, to be an exposition of the truth of the theory of mutation insofar as it applies to the explanation of the origin of species.

Over and over again, hundreds of times in the aggregate, I have selected mutants among my plants, and have developed from them new fixed races. But in the vast majority of cases I knew precisely how and why these mutants originated.

They were hybrids; and they were mutants *because* they were hybrids.

And so from the outset I have believed that

Professor de Vries' celebrated evening primroses had the same origin. It is true that the parent form was not known to be hybridized, and that there was no known form of evening primrose at hand through which hybridization could have taken place.

But the precise origin of the original plants found near Amsterdam is entirely unknown; and the curious conformity of their offspring, under Professor de Vries' observation, to the habitual variation of hybrid races in the third and subsequent generations is so pronounced that it cannot well escape the observation of anyone who has had large experience with such races.

This fact was at first overlooked by most biologists, largely because they lacked such experience. But now there is a growing tendency to take this view of the case.

Attempts have even been made in very recent years to produce a similar series of mutational forms of evening primrose by direct hybridization of existing forms. And while the results have not been absolutely definitive, they are unquestionably suggestive; and there is without doubt a growing appreciation of the fact that plants may be made to take on the notable changes which we described as mutations by the hybridizing of allied races; and that this explanation of the origin of mutation

The Scented Calla

This color print shows Mr. Burbank's famous scented Calla. It will be seen that the flower retains the physical characteristics of the ordinary Calla from which it was developed. The scented variety was developed by selective breeding, the original scented specimen being a "sport" that appeared among the almost numberless specimens in Mr. Burbank's garden. By similar selective breeding Mr. Burbank has developed and improved the odors of many other flowers.

has full validity, whether or not it be accepted as the sole explanation.

We shall see the truth of this contention illustrated in scores of cases in the course of these studies.

The Final Interpretation

Meantime for the purposes of present illustration it is necessary to revert to the case of our scented calla.

After what has just been said it will be obvious that I would explain this mutation as a reversion due to cross-fertilization.

In other words, some remote ancestors of the calla may have been scented, and a chance mingling of ancestral germ plasms in the course of the production of thousands of seedlings of the calla, may have led to such a union of submerged hereditary factors as enabled this latent propensity to make itself manifest.

According to this view, the case is comparable to that illustrated by an experiment in which Professors Bateson and Punnett hybridized two white-flowered peas of different strains and produced offspring bearing flowers colored blue and pink and purple.

The white parent forms were so nearly identical as to be entirely indistinguishable except that a magnifying-glass showed the pollen grains of one form to be round and the pollen grains of the other form to be oval. This insignificant difference, however, is full proof that the plants belong to different strains.

The union of the divergent strains seemingly brought together pairs of hereditary color-factors —if we hold to the Mendelian explanation—that had been separated and hence had gone unmated for an indefinite number of generations.

In the same way, we may suppose, I had brought together, through a happy chance, in the course of these breeding experiments with the calla, two strains that bore complementary odor-factors, the union of which released and made tangible the latent quality of perfume-bearing, which, in all probability, no calla of either strain had outwardly manifested for hundreds or perhaps for thousands of years.

—No race is perfected—no living thing is freed from the struggle for existence.

Large Plum With Small Seed

This plum represents a stage of transformation. By hybridization and selective breeding a tendency to decrease in the size of the stone has been developed. But as yet the adjustment between stone and flesh of this particular race of plums has not been fully worked out—there is a cavity between the stone and the flesh. We shall see in other illustrations that the condition has been corrected in perfected varieties of plums.

The Stoneless Plum

An Experiment in Teaching a Plant Economy

I WAS showing some specimens of the remnants of stones in various specimens of my new plums to a visitor one day. I indicated a stone that was like the crescent of the new moon in shape.

"This," I said, "is my plum as it was when the stone was only partially taken out of it. And this"—indicating another one with only a fragment of stone not as large as a grain of wheat—"is the same plum four or five generations later."

The visitor laughed. "That," said he, "reminds me of the museum that showed a skull labeled 'The skull of William Shakespeare,' and another labeled 'The skull of William Shakespeare when he was a boy.' There is this difference, however, that Shakespeare's head, according to the museum record, got larger as he advanced in age, whereas

Standard Plum and Large Stone

Here we see another plum at a stage of development when the relation between the stone and the flesh of the fruit is still defective. In this case the stone, instead of decreasing in size, has grown larger. Mr. Burbank's next problem with this particular fruit was to retain the tendency to grow a large fruit, but to induce the stone to decrease in size. The problem was solved by further experiments in hybridizing and selection.

A Plum With Small Stone and Much Meat

Here the problem of reducing the size of the stone has been solved, and the defect shown by the plum depicted on page 102 has been overcome. There is no longer a cavity between the stone and the flesh of the fruit. Yet this is not a cling-stone. It is desirable that the stone should part from the flesh just as the fruit ripens, making a free-stone, but the severance should not be sufficient to cause an appreciable cavity. Mr. Burbank has produced many plums that conform to this ideal condition.

your plum stone became smaller." And then, becoming quite serious, my visitor inspected a series of fragmentary plum stones that had been placed before him, and added:

"To make a stone grow smaller was certainly a notable feat. How did you manage it?"

This is a question that has been asked more often, in connection with the stoneless plum, than in the case of almost any other of my plant productions. For a plum which looks on the outside precisely like any other, but which is found to be stoneless, never fails to excite surprise.

Even visitors who know what to expect, when asked to bite through one of these specimens, can seldom refrain from exclamations of wonder when the teeth go right through the fruit as readily as they would through a strawberry.

Many persons are not greatly interested in the daisy that combines four specific strains, because they know nothing of the difficulty of making such a union, and are quite unmoved by the spectacle of a white blackberry or a fragrant calla, because they have seen white fruits before, and because fragrant flowers are rather the rule than the exception. But no one ever saw an edible stone-fruit without a stone until one was produced here on my farm.

So "How did you do it?" is the universal question of laymen and scientific botanists alike on seeing this really remarkable fruit.

And when an attempt to answer the question is made, the story seems absurdly short and simple; yet to my mind it recalls reminiscences of what was perhaps the most strenuous series of experimental efforts that I ever undertook—a quest that occupied a considerable share of my time for a period of fifteen years, and which even now is not altogether completed.

As you follow the outline of this story, please recall that while it takes but a phrase to tell of the pollenizing of two plum flowers and the production of one anomaly in the first generation and of some other anomaly in the second, in reality a period of five or six years has elapsed between the pollenizing experiment and the observation of the second generation results.

When this is borne in mind and it is further recalled that breeding through many generations is necessary to secure the results desired, it will be clear that the production of a stoneless plum was an achievement that required its full share of patient waiting.

The Raw Materials

At an early stage of my almost endless series of experiments in the hybridizing of plums, I chanced to hear of a so-called seedless plum that was said to grow in France, where it had been known for a long time as a curiosity. About 1890 I sent to the Transom Freres Nurseries in France and secured twigs of this plum, which was known merely as the *Sans Noyau.*

These were grafted on one of my plum trees, and in due course produced a crop of fruit, which as expected, proved to be a blue-black, cranberry-sized fruit, extremely sour, soft, and unfit for eating either raw or cooked. The original shrub, as I have been informed, and as it grew here, is a rambling, thorny bush rather than a tree, utterly worthless for any purpose except the one for which I desired it.

The fruit, besides being flavorless and unpalatable, was scanty in yield.

Moreover the fruit was by no means seedless, notwithstanding its French name. It was only partially stoneless, as most specimens produced fair-sized kernels in the fruit, and every kernel had a thick rim of stone around one side partially covering the kernel. While it therefore lacked much of exhibiting the condition of stonelessness that I had hoped to see, it did, nevertheless, show a tendency to abandon the stony covering that has always characterized all the fruits of the plum family.

A Typical Stoneless Plum

In this stoneless plum the seed, with its germinal substance, is retained, but the stone has been almost altogether eliminated. The resulting fruit is a plum of such unique character that you may bite through it almost as readily as you would bite through a strawberry. The produdion of this stoneless plum is one of Mr. Burbank's greatest achievements. It was accomplished through a long series of hybridizing experiments fully explained in the text.

From the outset I was convinced that by proper hybridizing and selective breeding it could be made valuable.

Next season the blossoms of the freak plum were fertilized with the pollen of the French prune and with that of numerous other plums and prunes.

The seedlings from these crosses were grafted to ensure their earlier bearing. In the first generation I obtained some plums fully twice as large as their seed parent. Most of these had stones, however, and were soft, sour fruits. A very few of them were partially stoneless, and from these the work was continued.

Getting Results

The next generation showed some general improvement in the growth of the tree and the size and quality of the fruit. All the seedlings of the cross from the *Sans Noyau* upon the French prune were grafted and fruited, even though many of them showed the thorny, dwarfed, ill-shaped type of tree of the uncultivated ancestor.

After two or three generations there was a marked tendency to improvement.

In a large lot of seedlings, in 1904, I obtained two that seemed to me of favorable appearance—for much can be known from the quality of leaf and stem long before the time of fruiting.

And when, two years later, the grafts thus selected bore fruit, it was delightful to find my predictions verified; the fruit was almost absolutely stoneless, only the faintest splinter of stone occasionally appearing. And combined with this stoneless condition there were qualities of size and flavor that made the fruit practically equal to the French prune. Moreover, as is often the case with hybrids one strain of which is wild stock, the new plum proved to be a very good bearer.

So my ideal of an eatable plum having no stone about its seed was almost achieved.

I say *almost* achieved because there still remained, in the case of the plums of best quality, a fragment of shell which varied from a small crescent about one side of the kernel to an almost invisible granule. There were some individual plants among the numberless seedlings that bore fruit in which the stone was absolutely eliminated and, in some cases, the seed also.

But it proved extremely difficult to combine this quality of entire stonelessness with the desirable qualities of size and flavor, lacking which the fruit could have no practical value.

Further hybridizing experiments, aimed at the production of an absolutely stoneless plum of fine flavor, are still under way; but in the meantime there are several varieties actually in hand that are of most admirable quality and yet stoneless. In the ordinary French prune, from three to six per cent. of the entire fruit is stone; while in my stoneless prune called the "Conquest" the fragment of stone does not represent more than a thousandth part of the bulk or weight of the fruit.

And among the eight or ten hundred varieties of stoneless plums now growing in my orchard, there are sure to be some that will show still further improvement.

Why the Task Was Difficult

The task of producing a stoneless plum had proved very difficult chiefly because it had all along been necessary to bear in mind a number of quite different objective points.

It was not sufficient to produce a stoneless plum. From the practical standpoint there would be no object in that unless the fruit about the stoneless kernel was of good size and of palatable quality. And, unfortunately, there appeared to be no tendency to correlate stonelessness with good quality of fruit.

In point of fact the tendency was quite the other way; and, indeed, this was to be expected in view of the fact that the original partially stoneless plum was a small, acid fruit growing on a wild bush.

The problem was to combine two lines of ancestry that were in many respects directly in conflict. It would have been impossible to do this had it not proved that stonelessness and good quality of fruit, although not originally combined, have the attributes of what may be called unit characters, and hence can be assembled in a single fruit in the later generations of a hybrid progeny.

The Origin of the Stone Fruits

A very natural question arises as to what had originally caused the little French "bullace"—as the *Sans Noyau* is sometimes called—to develop the extraordinary tendency to give up the stony seed-covering which no other member of the family had ever been known to renounce.

The question is doubly significant when we recall that some sort of shell or stony covering is almost absolutely essential to the preservation of the seeds of plants in general. The shell is often very thin, as with the seeds of most garden plants. It may be reduced to a mere filament of cellulose, as in the case of a grain of wheat. With pulpy fruits it is usually a very significant covering, of which the seeds of the apple and orange afford typical examples. And with the great tribe of fruits represented by the plums, cherries, peaches, apricots, and almonds, this

Peach and Almond Stones Compared

This illustration shows the similarity between the stones of the peach and the almond, at the same time revealing characteristic differences. Some horticulturists believe that the almond was the original stock from which the peach was developed through selective breeding in prehistoric times. Others do not accept this theory, but all are agreed that peach and almond are pretty closely related, and at least have common ancestors. Mr. Burbank made interesting experiments in hybridizing the almond and the peach which are fully described in another volume.

shell has been developed until it is veritably stone-like in texture.

Just why this extraordinary development of the protective seed covering was necessary or advantageous in the case of this particular tribe of plants, it would perhaps be difficult to say.

It is altogether probable that the original progenitor of the family of stone-fruits grew in central Asia. I have received from that region a shrub that may perhaps be regarded as the prototype of the entire race of the stone-fruits—not perhaps the direct progenitor, but an early offshoot from the ancestral stock which has remained in the original environment and has not, perhaps, very markedly changed from the original state during the hundreds of generations in which the other branches of the family were spreading southward and westward across Asia and Europe.

If we could know just what the enemies of the primitive Asiatic stock of the stone-fruits were like, we could perhaps surmise the reason for the development of the unusual seed-cover.

Perhaps the stone was necessary to protect the kernel from the teeth of monkeys or primitive men; perhaps it was more particularly needed as a protection against climatic conditions, to ensure preservation during semi-arctic winters; or to keep vitality in the kernel during protracted periods of drought, since, unlike most other fruits, the seeds will rarely germinate if fully dried.

As to all this we can only surmise. But we may have full assurance that the thick, stone-like seed-cover served a useful purpose, else it would never have been developed and so persistently preserved in all the divergent races of stone-fruits that were evolved under the new conditions of southwestern Asia and southern Europe to which these fruits found their way.

The roving tribes of Arabia developed a modified form of the fruit adapted for preservation by drying, and now termed the apricot. Other people consciously or unconsciously selected and developed the almond; and yet others the juicy and luscious peach; while the plum ran wild and put forth a galaxy of hardy offspring that made their way to the north of Europe and also, along some now obliterated channels, to the Western Hemisphere.

But each and all of these descendants maintained, and some of them like the peach intensified and elaborated, the unique characteristic of a horn- or stone-like protective covering for the seed.

And so, it becomes matter for wonderment that with all these uncounted generations of

The Stoneless Seedling

Another of Mr. Burbank's stoneless plums. Many a visitor to Mr. Burbank's orchard has been amazed to find it possible to cut directly through a plum that exteriorly looks no different from ordinary plums. (Note the plum at the right, offering no obstacle to the knife blade.) Some visitors are skeptical and cut cautiously into the plum expecting to encounter a stone, and are chagrined when they find their suspicions unfounded.

heredity clamoring for fruit with a stony covering there should have developed in France a member of the tribe, even though it be an inconspicuous outcast, that rebelled against the family tradition and dared to produce a seed that lacked a part of the habitual covering.

How the Freak Originated

As to just how this break with tradition came about, we can perhaps make a better guess than we can as to the precise origin of the tradition.

It seems likely that the little bullace lost the power to produce a protective stony covering for its seed through the impoverished condition due to some defect in the condition of the soil in which it chanced to grow. Unquestionably the production of the stone makes a strong draft upon the resources of the tree. Obviously the material to supply this dense horny structure must come from the soil, and in case the exact chemicals needed are supplied in scant quantity, the shrub might be forced to economize in producing a shell for its fruit kernel, just as a hen is forced to economize in the shell covering of her egg in case lime is lacking in her food.

The same sort of economy is practiced when the human child finds inadequate nourishment. In such case the bones may be not only small but defective in mineral substance, a well-recognized

An Improved Stoneless Seedling

The same variety of stoneless plum shown on page 117, at a later stage of development. The earlier one was stoneless, but of unsatisfactory shape, and somewhat lacking in size. Selective breeding brought the improvement here shown. In this case, as in so many others, it was necessary to attain one object at a time. Mr. Burbank first sought to secure a plum that was stoneless even if it lacked quality. Then the quality was bred into the plum, the stoneless condition being retained.

type of abnormality resulting with which medical men are familiar.

So it seems plausible that a paucity of proper food materials was the explanation of the origin of the original *Sans Noyau.*

It is in keeping with this explanation that the *Sans Noyau,* is, as we have seen, a small scraggly shrub, a mere dwarf as compared with the average stature of trees of its family; and that its fruit is reduced to the proportions of a small berry, and is utterly lacking in those qualities of sweetness and flavor that are the almost universal characteristic of other stone-fruits.

In a word, then, it is highly probable that the plum that supplied the character of stonelessness, upon which my experimental endeavors in the production of a marketable stoneless plum was founded, was a pathological product.

I may add that many other "sports" or mutations in the vegetable world that have furnished a basis for the evolution of new races or species may very probably have had the same origin.

Up-Hill Work

This explanation of the origin of the *Sans Noyau* makes it easier to understand the difficulties that attended the progress of this experiment.

Had the little plum been absolutely stoneless—so that no factor whatever bespeaking a stony fruit

Three Stages of Development

At the left is the original wild French plum, called the Sans Noyau — of insignificant size and practically inedible. It is almost stoneless. Mr. Burbank improved the plum by hybridizing it with cultivated varieties, retaining the stoneless condition and introducing the qualities that make a commercial fruit. The central figure shows the plum at an intermediate stage of development; at the right the same fruit as represented by its improved stoneless descendant a generation or two later.

remained as part of its heritage—there would probably have been no very great difficulty in producing through hybridization a stoneless fruit of good quality in the second or third generation.

All experiments seem to show that the stone condition is, as might be expected, prepotent, or, in the Mendelian phrase, dominant.

So in crossing an ordinary plum with a stoneless one, it was to be expected that the offspring of the first generation would bear stone-fruit. But the latent or recessive trait of stonelessness may be expected to reappear in a certain proportion of the offspring of the second generation; and the stoneless fruit thus produced may be expected to breed true.

Such is what might be expected provided one were dealing with an absolutely stoneless plum as one of the progenitors.

But unfortunately we are not dealing with an absolutely stoneless plum, but only with one in which the tendency to produce a stone has been minimized *or* partially suppressed. And so our relatively stoneless plum of the second generation still retains traces of the hereditary propensity to produce the stony covering; and, as we have seen, this propensity manifests itself in the fragmentary stone, sometimes reduced to a mere speck in size, that many of my stoneless plums exhibit.

Nevertheless there remains not a doubt that from subsequent generations, from the stock in hand, an absolutely stoneless plum that retains all the valued qualities of the fruit and in all sizes, colors and flavors desired will be produced.

That it has been possible to eliminate the stone altogether, advancing thus markedly in this regard upon the original partially stoneless form with which the experiment began, suggests the truth of a view now held by some prominent biologists, notably by Professor William E. Castle of Harvard, that a unit character may be modified in successive generations—not merely blended or made into a mosaic with other characters, but actually modified as to its potentialities.

Professor Castle instances in support of this view the case of guinea pigs bred by him that developed a full-sized fourth toe on the hind foot from a rudimentary stump of a toe.

The experiments just cited illustrate the opposite condition of causing a rudimentary organ—in this case a plum stone—to be altogether eliminated.

It should not be overlooked that both experiments are perhaps capable of interpretation in other terms. In each case what actually happens may perhaps be better explained as reversion to a very remote ancestor. Doubtless there were among the ancestors of the guinea pig races with four toes; and doubtless if we go far enough back we should find ancestors of the plum that produced a seed having no stony covering. And we are perhaps not far wrong in assuming that it was the long-subordinated influence of this vastly remote ancestor that, in the case of my plums, sided with me, so to speak, against the forces of the more recent heredity, and made possible the ultimate success of my hybridizing experiments.

The Value of the New Product

We are so accustomed to putting up with the annoyance of the stone in the fruit that we for the most part never give it a thought. But a moment's reflection makes it clear that the plum stone serves man no useful purpose, while the inconvenience it gives us is obvious.

It requires no argument to show that a solid fruit without a stone would be far more acceptable.

But this is not the only reason, although perhaps a sufficient one, for the development of the stoneless fruit. The other reason looks to economy of production and saving of material from the standpoint of the tree itself. It has been estimated that a tree requires several times as much solid material and the expenditure of far more energy, to produce the stony covering of

Seedling Plum with Stem Attached

This fruit has a stone like that of ordinary plums. The cut fruit shows the attachment of the stem to the stone. Stone and stem serve somewhat the purpose of the beams and girders of a building. The question of the firmness of attachment between the stem and stone is sometimes an important one. Prunes should be so loosely attached to the stem that they fall of their own weight when ripe. Yet the attachment must not be so loose that the fruit will fall before it is ripe.

the fruit seed than to grow the flesh of the fruit itself.

So it might well be expected that other things being equal, a tree bearing stoneless fruit would prove at least twice as productive as one bearing stone-fruit.

Under the conditions of nature, this increased fruitage would by no means compensate for the loss of the protective stony covering, for the seed unprotected by its coat of mail would be at the mercy of any bird or animal or insect that attacked it.

There would probably be no representative of the stone-fruit family in existence to-day were it not for the protection afforded the seed by its hard and indigestible covering.

Regardless of animate foes, the seed would perish from the effect of sun, wind, rain, and frost, if denied protection.

And this is by no means a mere matter of inference. One of the great difficulties that attended the experiments which I have just narrated, was the preservation of the stoneless seeds from one generation to another. It was found to be exceedingly difficult. Various insects, especially aphides, millipedes and eel-worms, would get among them and quickly destroy them. Fungous diseases also attacked them. And for

One Result of Stonelessness

The picture on page 125 showed the normal attachment of the stem to the stone of the fruit. The stoneless plum obviously lacks this support. Hence if the plum is very large the flesh may be drawn out at the point of attachment of the stem by the weight of the fruit, thus pulling the plum out of shape, as shown in this figure. So strength of skin and firmness of texture are points that Mr. Burbank must bear in mind in developing a new race of stoneless fruits.

several years more than three-fourths of the seeds kept for planting were thus lost.

At a fairly early stage of the experiment I had large quantities of seeds in hand, for I was operating on an expansive scale in order to have wide opportunity for selection. Several hundred thousand plum seeds, all stoneless, were once placed in cold storage, at freezing temperature, as soon as they were gathered and cleaned. Some were placed in sterilized sawdust, and some in charcoal dust, and some in sand.

Another assortment, similarly packed, was kept in boxes in a cool shady place until the first of January, when all were planted. In both lots, the seeds that had been kept in sand were in better condition than those preserved in the sterilized redwood sawdust. Those kept in charcoal differed little from the other lots. The ones in cold storage had suffered from blue mold more than the others, but both lots were in fair condition.

All were planted on the same day in rows side by side. The seeds that had been kept in cold storage germinated at once, and in a week were all practically above ground. The seeds of the other lot, which had come from the same trees, did not commence to germinate for about six weeks. Yet later in the season very little differ-

Double Seeds Take the Place of a Stone

In some cases the cavity left in the plum by the removal of the stone is filled by the development of a double seed. We have seen in other illustrations that the hereditary forces seem to be puzzled, if this expression be allowed, in determining how to deal with the altered conditions of the internal structure of a fruit that lacks the supporting stone at its center. One solution of the difficulty is shown in this picture.

ence could be seen between the two lots; on the whole the cold storage seeds showed rather the poorer growth.

Further Improvements of Method

An even better method of preserving the seed was presently developed, and I was finally able to preserve the stoneless seeds almost as securely as if they had their original protective covering.

My new method consists in washing the stoneless seeds in clear fresh water when first removed from the fruit; immersing them for a few minutes in a week solution of "Bordeaux mixture" (sulphate of copper and lime-water), then rinsing for a brief period in fresh water, and placing them in damp sawdust that has been sterilized by boiling, care being taken that the sawdust is barely moist, not wet. The box containing the seeds is placed on the north side of a building, in a cool, shady place, and examination is made from time to time to see that the seeds do not become too dry or infested with insects or mold.

If treated in this way, the seeds are practically all saved; they may be planted out of doors like other plum seeds, and they will germinate promptly.

It is obvious that a seed requiring such careful treatment to preserve it all the winter would

Another Stoneless Plum Compromise

Here the cavity left by an eliminated stone is filled by enlarging the seed itself. This is not desirable from the standpoint of the horticulturist, but it is one way of overcoming the defect of a large cavity within the fruit, which necessarily weakens the structure of the fruit itself. Further breeding experiments may reduce the size of the seed while increasing the pulp in such a way that no cavity will remain.

stand small chance of being able to perpetuate its kind in a state of nature. But on the other hand, it must be admitted that it is well worth while to give the amount of attention required to the preservation of these seeds, in view of the enhanced value of their product.

It will be understood, however, that the average fruit-grower will not be required to concern himself about the seeds, as his orchards will be propagated by grafting in case of this fruit as is customary with all orchard fruits.

There can be little doubt, then, that the time is almost at hand when all our plums will be grown without stones, since the experiment of removing the stones from a large number of varieties can now be followed up without great difficulty.

The pioneer work has been done, and the cross breeding of my best present varieties of stoneless plums, to secure all the desirable qualities of any existing plum, may readily be effected.

Even though the fruit should not be of better quality than that which it supplants, the fact that the elimination of the stone permits an increased abundance of fruit, to say nothing of the value of the stoneless fruit itself, will offer an inducement that the progressive fruit raiser will find conclusive.

Many Plums on One Tree

A typical branch of a plum tree in Mr. Burbank's orchard. Growing within easy reach are four or five varieties of plums that are very different from one another in size and form and color, as well as in quality of flesh. Of course these plums are of quite different ancestry, and they would not have grown normally on the same tree. But Mr. Burbank grafts cions of many stocks on the same branches, to economize space. Several hundred varieties may be found growing from a single trunk.

It should be added that the plum which has been induced to vary in the matter of seed production, is not always content merely to have cast out the stone but sometimes tends to eliminate the seed itself.

The Seed Also Must Go

One of my stoneless plums has nothing but a jelly-like substance to take the place of the seed. It is probable that plums actually seedless as well as stoneless will prove favorites with some fruit growers.

Of course plums that present this anomaly cannot be propagated from the seed. But in this regard they do not differ from a number of cultivated plants, including the potato, the horse-radish, and the sugar-cane. And for that matter it must be recalled that very few orchard fruits are reproduced from the seed. The favorite varieties of apples and pears are so blended that they do not breed true from the seed. If you were to plant the seed of a Baldwin apple, a Bartlett pear, or a sugar prune, there is only the remotest chance that you would produce a seedling that would resemble the parent.

Yet apples and pears and prunes are propagated year after year by means of buds and grafts. The same method of propagation would of course suffice for the seedless plum.

Ancestor and Descendent

This picture shows the wonderful contrast in size between the original wild partially stoneless plum and Mr. Burbank's perfected stoneless prune. Many generations lie between the two, yet the essential character of stonelessness that gave the little plum value has been retained in the remote descendant, while the strains of numerous cultivated plums have been bred in, so that the offspring of the dwarf plum is now large in size and of fine quality of flesh.

It would still be possible, however, to produce new varieties of seedless plums by using the pollen of these varieties to fertilize the flowers of other plums that were stoneless but not seedless.

The seedlings from such a cross would tend to vary in successive generations, as all hybrids do. A certain number of the offspring of the second and later generations would doubtless be seedless, and it would thus be possible to develop new varieties of seedless fruit from a parent stock that is itself incapable of producing viable seed.

The stoneless hybrids already produced represent almost every color of the plum—white, pale yellow, orange, scarlet, crimson, violet, deep blue, almost black, striped, spotted, and variously mottled. They vary indefinitely in quality. Some of them are of abnormal size. They ripen from the middle of June until Thanksgiving.

So the stoneless plum already constitutes a new race having numberless varieties, and the possibilities of further improvement are limitless.

—In producing stoneless fruits, we are simply helping plants to catch up with evolution.

The Royal Walnut

Speeding the Growth of a Leisurely Tree

IF ON visiting my grounds you were to notice two trees, one ten times as large as the other, growing side by side, you would perhaps be surprised to be told that the two are of the same age and grew from seed of the same parent. And it perhaps would not greatly clarify the matter in your mind to be told that these are varying individuals of a remarkable hybrid known as the Paradox Walnut.

But probably your interest would be aroused in a tree that could show such diversity of progeny.

The tree in question was developed more than twenty-five years ago. One of its parents was the native California black walnut tree; the other parent was the European tree usually called the English walnut, but with somewhat greater propriety spoken of as the Persian walnut.

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The European tree had been introduced in California a number of years before the time of my experiments, and it thrives in our climate and produces abundant fruitage. I had heard of a supposed natural European hybrid walnut, and I determined to make the experiment of fertilizing the flowers of the California species with pollen from the Persian.

The experiment itself presented no particular difficulties and the results were of a striking character.

The nuts that grew from the hybridized flowers were to all appearance unchanged. This, of course, is quite what might have been expected, for the influence of foreign pollen on the ovum of a plant manifests itself in the innate qualities of the seed, and not in the exterior qualities of the fruit immediately produced. But when the hybrid nuts were planted the following season, a part of the seedlings that sprang from them showed at once the effects of the intermingling of racial strains.

As compared with seedlings of either the California or the Persian walnut, they manifested an enormously enhanced capacity for growth. Indeed they sprang forward at such a rate as presently to dwarf their pure breed relatives.

The phenomenal growth of these hybrid trees

A Sixteen Year Old Paradox

At sixteen years of age, Mr. Burbank's new Paradox walnut trees were sixty feet in height and as much in breadth of branches—the trunk being two feet in diameter at about four feet from the ground. Meantime English walnuts on the opposite side of the street averaged only eight or nine inches in diameter at thirty-two years of age, and had a spread of branches only about one quarter that of the youthful Paradox.

continued year after year. The tree so far outstripped all competitors in the matter of growth that it might fairly be said to represent a new type of vegetation.

On this account, and in recognition of sundry other anomalies, I named them Paradox.

At sixteen years of age these trees were sixty feet in height and as much in breadth of branches, the trunk being two feet in diameter at about four feet from the ground. Meantime English walnuts on the opposite side of the street averaged only eight or nine inches in diameter at thirty-two years of age, and had a spread of branches only about one-fourth that of the youthful Paradox.

In addition to its quality of rapid growth, the Paradox has wide-spreading branches with a tendency to droop. It makes a beautiful shade tree. The leaves are of extraordinary length, sometimes measuring three feet, although usually only about half that. Another curious characteristic is that the foliage has a delicious apple-like fragrance, of which the foliage of the parent tree gives no suggestion.

These anomalies of growth and foliage show the mingling of racial strains. A further result of this mingling is shown in the fact that the hybrid tree produces very few nuts. It is obvious that the two strains brought together are so variant

The Blossom of the Walnut

The walnut, like many other trees, is a wind loving plant and depends upon the swish of its branches in the breezes and the breezes themselves to carry its pollen from limb to limb and tree to tree. The direct color photograph print shown here is that of the pistillate, or pollen-receptive blossom of the walnut tree, upon whose slightly sticky surface the flying pollen finds lodgment, its grains fertilizing the seed, combining with it to produce a crop of walnuts.

that their progeny is made relatively sterile. The sterility is not absolute, however, for the few nuts produced germinate readily if planted.

But another anomaly manifests itself in the characteristics of the seedlings thus produced; for these are the ones that show such extraordinary variation in size.

In the same row, as already intimated, there will be bush-like walnuts from six to eighteen inches in height side by side with trees that have shot up to eighteen or twenty feet; all of the same age and grown from seeds gathered from a single tree. This rate of growth continues throughout life, and the fraternity of dwarfs and giants has been a puzzle to layman and botanist alike.

These second generation hybrids vary as much also in regard to foliage and general characteristics of form and development as in size. Some resemble the California walnut, others the Persian ancestor, and there are scores of variations, the manner of growth of some of which—notably those that trail their limbs along the ground like a gourd or squash—bears scant resemblance to that of any walnut. From this extensive variation, it has been possible to select trees of even more rapid growth than the second generation hybrids, and the field seems to be open for the production, through selection in successive generations, of trees of still wider diversity of form and growth. Curiously enough the wood of the Paradox walnut is exceedingly hard, even harder and more close-grained than that of the ordinary black walnut. This is surprising in view of the rapid growth of the tree. Ordinarily trees that grow rapidly have soft wood, as every cabinet-maker knows.

The Paradox further justifies its name by producing a wood that has great firmness of texture and is well adapted to take on a cabinet finish.

All in all the production of the Paradox hybrid, and the development of a race of hard-wood trees of exceedingly rapid growth, constitutes a genuine triumph in tree culture. A tree that grows to the proportions of a handsome shade tree and furnishes material for the cabinet-maker in six or eight years, has very obvious economic importance.

The Royal Walnut

At about the same time when the Paradox was produced, I undertook another series of hybridizing experiments with walnuts that resulted in a tree scarcely less anomalous.

These experiments consisted of the mating of the California walnut with the black walnut of the Eastern United States. The latter tree pro-

A January 1 Walnut Graft

The walnut graft shown above was made by Mr. Burbank on January 1, 1913, and, as can be seen, was at that time but a tiny cion.

The Same Graft Six Months Later

The color photograph print above shows the rapid progress made by the grafted cion pictured opposite. This photograph was taken on July 1, 1913, six months to a day after the graft was made.

duces perhaps the finest cabinet wood grown in America, but it has almost disappeared from our eastern forests owing to the rapacity and lack of foresight of the lumberman. The California and eastern walnuts are rather closely related, yet the divergence is sufficient to give the hybrid a character markedly different from either parent.

In some respects this hybrid, which was christened the "Royal," showed characteristics analogous to the Paradox. It had the same tendency to extraordinarily rapid growth, and in subsequent generations it showed the same tendency to produce a varied company of dwarf and of giant progeny. There was also a considerable variation in foliage, although not the extraordinary diversity shown by the second generation seedlings of the Paradox.

In one important respect, however, the Royal hybrid differed fundamentally from the other. Instead of being relatively sterile, it showed the most extraordinary fecundity. The first generation hybrids probably produce more nuts than any other tree hitherto known. At sixteen years of age one of these trees produced a harvest of nuts that filled twenty apple boxes, each about two feet long by one foot in width and depth.

In one year I sold more than a thousand dollars worth of nuts from a single tree.

The nuts themselves are closely similar in appearance to those of the parent trees, but are individually larger. Unfortunately seedlings grown from the nuts cannot be depended upon to reproduce all the good qualities of their hybrid parents. Like most second generation hybrids, they tend to "throw back" to the divergent grandparental strains.

To propagate the race extensively, therefore, it is advantageous to adopt the well-known method of grafting.

It has been found that root stocks of the Royal hybrid furnish very valuable stocks on which to graft the English walnut in California. On most soils a tree grafted on this hybrid will produce several times as many nuts as a tree of corresponding size growing on its own roots. The trees are also much less subject to blight when they are thus grafted.

Grafting the Walnut

The importance of the new walnut and the fact that it may best be propagated by grafting makes it desirable to add a few details as to the method by which grafting is effected; for in the case of this tree the process is far more difficult than with ordinary fruit trees.

Grafting the walnut is not, indeed, as difficult as grafting the pecan or the hickory, with both of which species the process was until recently found impossible of accomplishment. In this regard the walnut is rather to be likened to the fig, both being difficult to graft, yet not presenting insuperable difficulties for the skilled operator.

Persons who first attempted to graft the walnut in California often failed four times out of five; and budding was even less successful. But the importance of the subject led to a careful study of methods, and today grafters who thoroughly understand their work are so successful that they scarcely have more than two or three failures in a hundred successful grafts.

To attain such success, however, it is necessary to attend carefully to the various stages of the process. The grafting should not be attempted until quite late in the season; just after the buds begin to start is the most opportune moment. Hard wood should in all cases be selected for grafting; the pithy tips are utterly worthless for this purpose. Some grafters claim that only about two cions should be used from the base of the last year's growth where the wood is very firm.

Of course the principle of fitting the inside bark or cambium layer of stock and cion accurately together applies here as in the case of every other tree. Further details of the method

Wood of the Paradox

It might naturally be supposed that the Paradox would produce a soft wood like that of most quick-growing trees. Such is not the case, however. The wood of the Paradox is as hard, almost, as that of the black walnut, and has the beautiful walnut grain shown in the photograph print above.

will be given in a subsequent chapter, where the special methods of grafting and budding will be more fully examined. It suffices for the moment to emphasize the fact that these methods of propagation are as advantageous in the case of the walnuts, whether hybrid or of pure strains, as in the more familiar case of fruit trees.

Of course the stocks on which to graft must be grown from nuts, and I have already pointed out that the seedlings are likely to show diversity. But all that is necessary is to plant the seeds rather thickly, and then to save the seedlings that show the best qualities.

Starting a Walnut Orchard

A practical method of producing a permanent and profitable orchard with a foundation to last for a century, is to plant some seeds of the Royal hybrid in groups of three or four at intervals of fifty feet each way. By the end of the first season the strong growers will have asserted themselves, and the others can be weeded out. There will almost surely be at least one good tree in the group. Failing that, there will be other groups in which there are extra seedlings of good quality that may be transplanted.

The seedlings should be allowed to grow for four or five years, the ground about them being cultivated and may be used for crops of corn,

Two Inches in Diameter in One Year

The cross section of a Paradox walnut trunk pictured above shows the annual rings of the tree, or its yearly growth. The photograph is made exact size, and it will be noted that some of the markings are an inch apart, thus showing that the tree increased in diameter two full inches within the year.

potatoes, beans, or pumpkins, but preferably not sown with grain, lest the growth of the trees be checked.

At the end of five or six years there should be a fine walnut orchard with trees having trunks three to six inches in diameter.

Now the stock is ready for grafting. The stock branches selected for this purpose should not be over two or three inches in diameter. The cions grow rapidly and an orchard produced in this way surpasses all others. Its trees have a natural black walnut vigorous system of roots, with undisturbed tap root. A year's growth has been saved by not transplanting, and a start equivalent to the growth of several years has been gained by using the faster-growing hybrid.

So the English walnut grafted on this stock becomes a producing tree at a very early age, and an orchard of English walnuts thus grafted is worth at least twice as much as one on its own roots.

The tree thus grafted has not only the advantages mentioned, but it is more wide-spreading and therefore more productive than the original tree; and the spread of limb is duplicated by the root system, which thus ensures a good supply of nourishment and the capacity to produce large crops even in dry seasons.

Variation in Walnut Leaves

As in his work with all other plants, Mr. Burbank pays strict attention to the selection of those seedlings which have the most and the best leaves, and the best leaf formation. Many seedlings, promising in other respects, have faulty leaves, and promptly go to swell the bonfire of rejected plants which Mr. Burbank burns every few months.

We have seen that the hybrid walnuts of both the Paradox and the Royal types have the peculiarity of producing trees of quick growth and gigantic stature in the first filial generation, and a mixture of dwarfs and giants in the second generation.

The Strange Traits of Hybrids

The tendency to surpass their parents in size is a characteristic that is very commonly manifested when plants of different species are hybridized. It is a familiar and now well-recognized fact that the crossing of diverse strains of living creatures, plant or animal, tends to result in what for lack of a better term is usually described as increased vitality.

It would appear as if the conflict of new tendencies so stimulates the cellular activities as to give them an unwonted capacity for reproduction.

In this case we are not concerned, as we were in some of the other hybridizing experiments already examined, with the prepotency or dominance of the qualities of one parent. Instead of this there is a distinct blending of characteristics so that the new product is in many respects intermediate between its parents in matters of foliage and fruit. But in growing capacity it far surpasses them both.

Black Walnuts

This color print shows the nut of the California black walnut sawed in half. The heavy wooden formation of the shell is characteristic of this species as opposed to the thin paper shell of the English walnut. Mr. Burbank's quick-growing Paradox takes back to its black walnut parentage in thickness of shell, although it resembles the English walnut in outward appearance.

Thus we have produced, as the offspring of the slow-growing English walnut and the not very rapidly growing California species, a tree that grows so rapidly as presently to tower far above either of its parents.

As to form of leaf and fruit the hybrid may resemble one parent in one direction and the other parent in another. The leaf of the Paradox walnut, for instance, more closely resembles the leaf of the English parent. The outside appearance of the Paradox nut is also similar to that of the English walnut. But on breaking the shell we find that it is thick and strong like the shell of the American species, and the kernel is relatively small, quite different in form as well as in flavor from that of the English walnut.

It cannot be said that any one has a very clear notion as to precisely what the changes are that give to a hybrid race this enhanced vitality. But this mystery is after all only part of the great all-pervading mystery of heredity, which in turn is merged with the mysteries of life processes in general.

Why Some Are Dwarfs

What I shall consider a little more at length here, however, is the conduct of the seedlings of the second generation grown from either the Royal or the Paradox hybrids.

Some English Walnuts

Mr. Burbank's Paradox walnuts very closely resemble the English walnuts shown here, but instead of having thin paper shells like these, they have the thick, woody shell of the black walnut. The Paradox, however, was not selected as a nut-bearing tree, but as a quick-growing lumber tree. It produces very few nuts, in fact, but such as are produced will germinate readily if planted.

How does heredity explain the observed fact that some of these are dwarfs that can by no process of urging be made to attain anything like the average stature of walnuts in general, whereas others, sprung from nuts grown on the same stalks, are giants that surpass even their hybrid parent, not to mention their moderate-sized grandparents. The fact of this diversity is unquestionable. It affords a surprise to all who inspect the trees of this strangely diversified fraternity.

But how explain it?

A clue to the explanation is gained when we learn that the California walnut, which, it will be recalled, was a parent form in each of the hybrid strains, is a tree showing great variability in the matter of size when growing in a state of nature. In the northern and central parts of California it is usually a large spreading tree, often with gracefully drooping limbs. But farther to the south it becomes a mere shrub, and on the mountains and hills about Los Angeles it is only a bush. The nut diminishes in size correspondingly until, in Texas and Mexico, it is scarcely larger than a pea.

When growing still further to the south, in New Mexico and Texas, the black walnut is sometimes classified as a different species.

It appears to me, however, that these dwarfed southern forms are only varieties that have acquired different characteristics through the influence of what for them has proved an unfavorable environment. In any event there is no reason to doubt that the dwarf form and the relatively large one are descended from the same original stock, though doubtless divergence has gone on through numberless generations.

Meantime the English or Persian walnut, the other parent of the Paradox, is also a variable tree. In its native home it is very small, and even the cultivated variety cannot be depended upon to reproduce a given racial strain when grown from the seed.

It is obvious, then, that the tendency to dwarfness, which appears in such conspicuous fashion in some of our second generation hybrids, may be accounted for as reversion to dwarfed ancestral strains in both parents in the case of the Paradox and of one parent in the case of the Royal.

The tendency to grow relatively large prevailed in the strains of walnuts that were used in my hybridizing experiments, and the prepotency or dominance of this tendency is clearly shown in the hybrids of the first filial generation. But the latent tendency to dwarfness, which in the Mendelian phraseology would be termed a recessive trait, is able to reassert itself in a certain number of the offspring of the second filial generation, causing these to "throw back" to their dwarfed ancestors in the fullest measure.

The capacity for large growth has been absolutely left out of their individual make-up.

In the Mendelian phrase they are pure recessives; or, using the more technical terminology, they are "homozygous" as to the hereditary factors or determiners of the unit character of dwarfness.

The reader may or may not feel that the new terminology adds to our comprehension of the phenomena. But in either case the fact of the appearance of the dwarf specimens of the second generation among the hybrids is at least in a sense explained by our knowledge that there were dwarfs in their ancestry.

How Account for the Giants?

But while we are thus supplied with a more or less satisfactory explanation of the appearance of the dwarf hybrids, the colossal companions of the same generation are as yet unaccounted for.

It is a familiar fact, as just pointed out, that hybrids of different species do tend to take on new capacities for growth. But what hereditary warrant have the upstarts for thus out-doing

A Grafted Walnut Stump

When Mr. Burbank began his experiments with the walnut, he found that those who attempted grafting this tree failed at least four times out of five, and that budding was even less successful. By giving careful attention to the various stages of the process, as explained in the text, he was able to make successful walnut grafts in large quantities, averaging only two or three failures to one hundred grafts.

their parents? So far as we are aware, there is no record of a pure bred walnut of any of the three species involved that ever showed such capacity for rapid growth or such propensity to continue growing until it attains colossal proportions as the hybrids manifest.

There is no recorded or observed ancestor to whom we can appeal in explanation of the development of these new races of giants.

As yet we are not denied at least a hypothetical explanation that may perhaps account for the observed colossal growth of these new races of trees. The explanation demands that we go back in imagination through very long periods of time, and consider the ancestors of our walnuts not merely for hundreds of generations but for thousands or perhaps for millions of generations.

It is necessary, in short, to trace backward the ancestral history of the walnut to those remote epochs when the primordial strain from which the present trees have developed grew in tropical regions, and, in common with tropical vegetation in general, doubtless acquired the habit of luxuriant development.

It is permissible even that we should place in evidence the exuberant vegetation of that remote geological era known as the Carboniferous Age.

In that time, as the records in the rocks

$20,000 Worth of Walnut Seedlings

This color photograph print shows a pile of Burbank walnut seedlings ready for shipment, which brought $20,000. Note the strong root growth of the seedlings, this being one of the main points which Mr. Burbank has selected for.

abundantly prove, the conditions of climate now restricted to the tropics prevailed even in the temperate zones, and the vegetable life was characterized by the abundant production of colossal forms.

In successive ages the climate changed, and it became necessary for the plants that were unable to maintain existence under the changed conditions to adapt themselves in size and in structure to a less bountiful supply of food-stuffs drawn from both soil and air; for the soil of the temperate zone is relatively arid, and the air probably became progressively less rich in carbon, owing to the permanent storage of vast quantities of this substance in what ultimately became the coal beds.

So it came about that all the descendants of the colossal plants of the Carboniferous Era formed races that were dwarfs by comparison. Here and there a straggling species, like the California redwoods, preserved a reminiscence of its imposing heritage. But in general the trees that make up our forests in the temperate zone are but insignificant representatives of a lost race of giants. These, then, are the remote ancestors that may be invoked in explanation of the rapid growth and relatively gigantic stature of our hybrid walnuts.

Some Japanese Walnut Variations

In his experiments, Mr. Burbank has not only gone east for the English walnut, which is in reality the Persian walnut, but he has gone west to Japan and China for the walnuts which grow there, in seeking out new characters to combine with the native California walnut. The nuts shown in the color photograph print above are variations found among the Japanese branch of the species and illustrate clearly the changes in appearance as well as in other characteristics which long continued environment works in plants.

In this view the exceptional growth of these hybrids betokens reversion to remote ancestral strains that for countless generations have not been able to make their traits manifest, but which have always transmitted these potentialities as submerged and subordinated tendencies. The admixture of the divergent racial strains—one from Europe, the other from California, or in the case of the Royal, from origins separated by the breadth of a continent—sufficed to bring together factors of growth that for all these generations had been separated, and the atavistic phenomenon of a giant walnut came into being.

Thus interpreted, the case of the big walnut is not dissimilar to the case of our white blackberries or to that of the fragrant calla.

In each of these instances, as in that of numberless others that we shall have occasion to examine, a mixture of racial strains brings about a reversion to the structure or quality of a remote ancestor.

In the case of the walnuts we have had occasion to go back a few thousand generations farther than in the other cases, but there is ample warrant for believing that nature sets no limit on the length of time throughout which a submerged character may be transmitted, with full possibilities of ultimate restoration.

Wood of the Royal Walnut

A fourteen-year-old Royal walnut, cut down and quartered, is shown in this direct color photograph print. The trunk of this tree was two feet one inch in diameter, four feet above the ground.

We shall have occasion to examine further evidence of the truth of this proposition, drawn from a quite different field, in a later chapter. Here, for the moment, we may be contented merely to place our colossal walnuts in evidence.

Towering above their dwarf blood-sisters, they present a vivid object lesson in heredity that appeals directly to the senses and strangely stimulates the imagination.

—Nature sets no limit on the length of time throughout which a submerged character may be transmitted.

The Winter Rhubarb

Making a Crop For a High-Priced Market

MORE than one enthusiast has declared that the most important garden vegetable that has been introduced to the world in the past half century is the giant winter rhubarb.

This no doubt is an over estimate, if for no other reason than that it overlooks the Burbank potato. Still, there is no question that my winter rhubarb has proved to be of very great economic importance. Although introduced quite recently, it has already made its way to all quarters of the globe, and it has proved of unusual value in regions where no other rhubarb had hitherto been, or could be grown.

At the Cape of Good Hope, for example, efforts to grow rhubarb had been made for a century at least, and always without success; but the new variety proves an especially satisfactory crop there, as elsewhere, in warm, arid climates. The plant has aroused very unusual interest in conservative Great Britain, where the older varieties thrive and have been extensively grown, specimens having been obtained direct from my plantation by Robert Holmes, a member of the Royal Horticultural Society, and others. The royal gardens of England are now supplied with it.

Meantime the Emperor of Japan and the King of Italy obtained it directly from my gardens, and the plant has been taken back to its original home in New Zealand, whence the original stock came, and in its improved or, one might better say, metamorphosed condition, it now finds favor there, whereas its ancestral form was justly regarded as a plant of no importance.

The Qualities of the New Rhubarb

It must not be supposed that this widely extended approval of the rhubarb is dependent on any mere caprice. It is based on qualities of the most enduring and substantial character. Otherwise, it would not have been possible to plant thousands of acres of this crop in California and to find a ready market for the entire product in the eastern United States. In point of fact, so eager has been the market that the rhubarb has been quite often called by its growers the "king

Crimson Winter Rhubarb

This picture shows that Mr. Burbank's new winter rhubarb retains the characteristic form of the stalk of the ordinary rhubarb, and its general appearance, except that the new form has a more uniform tendency to redness of color. The peculiarity of the new plant here shown is that it puts forth its stalk in the winter at a time when the ordinary rhubarb is dormant. The original plant from which this new variety was developed was imported by Mr. Burbank from New Zealand.

mortgage lifter." More than one substantial fortune has been made by growing it here in California and shipping it to the eastern States during the holiday season when fruits and green vegetables are relatively scarce.

It retains, as to general appearance, the aspect of a greatly enlarged stalk of the familiar rhubarb or pieplant of the eastern vegetable garden. But the stalks are of a characteristic rich crimson color, and as brought to the table the sauce made from them is not only delicious in flavor, suggesting the strawberry and raspberry, but it is quite devoid of the stringiness or fiber-like texture and the disagreeable "ground taste" of the ordinary pieplant.

Many people who have hitherto regarded pieplant as a plebeian dish to be avoided are enthusiastic in the praise of the new product.

The crimson winter rhubarb produces not only far larger stalks than the old New Zealand prototype, but at least ten times as many of them to each plant. The stalks begin to appear in great abundance early in September and continue to produce a product of unvarying quality for eight to twelve months together—in California throughout the entire year—instead of for a few weeks in the spring. So the popularity of the winter rhubarb from the standpoint of the grower as well as of the dealer and consumer, is not hard to understand.

It may be added, as further evidencing the unusual qualities of the new plant, that it grows in almost any soil, although giving quick response to good conditions of cultivation like the older varieties; that it propagates readily from root division and under these circumstances breeds altogether true to the perfected type; and that it is hardy and requires no unusual attention, so that any amateur may grow it in his garden even more readily than he grows the ordinary rhubarb.

It must be understood, however, that the plant cannot thrive in latitudes where it is buried under snow, as the steady production of leaves appears to be essential to its very existence.

In the colder parts of California it does indeed cease to grow actively in the heart of winter, but even then it submits to adverse conditions reluctantly, if the phrase may be permitted; that is, that it stops putting forth new leaves only when the conditions are exceedingly unfavorable and immediately resumes new growth when the slightest change for the better in the weather occurs.

The Origin of the Winter Rhubarb

The importance of the new plant, and its wide departure from the traditions of the rhubarb family, might lead one to suppose that the production of the new variety had been a task of great difficulty. Perhaps from the standpoint of the average plant breeder it could hardly be said that its creation was altogether easy; yet compared with some of my other plant developments the production of this one was at least relatively simple.

The original stock from which the new variety was developed, came to me from the antipodes. It was sent by the firm of D. Hay & Son from Auckland, New Zealand.

The first two or three shipments were lost, as the plants died on the way, but at last I obtained half a dozen very diminutive roots that showed some signs of life. These, as anticipated, produced stalks during the winter instead of following the conventional rhubarb custom of putting forth stalks for only a few weeks in the spring.

The stalks of this original winter rhubarb, however, were very small—about the size of an ordinary lead pencil—and certainly not worth cultivating for immediate use, as they would have proved quite unmarketable. The plant was admitted to have no great value in New Zealand. Indeed, in point of quality of stalk the imported plant bore no comparison with ordinary pieplant of our gardens.

The Blossom of the Rhubarb

The illustration shows the inconspicuous character of the individual blossoms of the rhubarb, and the way in which they are massed together, as is usual with very small flowers. In hybridizing the rhubarb it is only necessary to dust one head of flowers against another. Of course self-fertilization may take place in many cases, and it will be necessary to examine the seedlings themselves to determine which ones are hybridized.

It was solely and exclusively the quality of winter-bearing that made the plant appeal to me and suggested to me the possibility of developing from it a valuable addition to our list of garden vegetables.

My original stock of half a dozen plants soon increased to a hundred or more. These plants produced seed abundantly in successive years, and all this seed was carefully planted and the seedlings that grew from it, to the number of hundreds of thousands, were closely examined and tested as to various desirable qualities.

From among the thousands I was able to select here and there a plant that showed exceptional qualities of growth, standing well up above its companions of the same age. Of course selection was made of the plants showing this exceptional virility, and in the course of a few years I had thus developed, by persistent selection, a race of plants that grew with extreme rapidity, and to a size, by comparison, quite dwarfing that of the original parent stock.

These fast-growing descendants of the New Zealand plant had not only the desirable qualities of texture and flavor of leaf stalk already referred to, but they retained and advanced upon the tendency of their ancestors to grow constantly throughout the year. This anomalous tendency,

Giant Rhubarb and Crimson Rhubarb

The original winter rhubarb had a stalk no larger than a lead pencil. By selective breeding Mr. Burbank improved the plant until it was of marketable size, while retaining the quality of winter bearing that was about the only merit of the original. Subsequently Mr. Burbank developed descendants of this original stock that were of gigantic size, excelling his original winter rhubarb somewhat as that excelled its New Zealand ancestor. The contrast is shown in this picture.

rather than the improvement in the other qualities of the plant, is obviously the one that requires explanation. Remarkable improvement in size and in other desired qualities through selection, is a more or less familiar method of plant development.

But the production of a race of pieplant that departs radically from the most pronounced and characteristic trait of the rhubarb family, namely brief period of bearing, is something that requires explanation.

A clue to the explanation is found when we recall that the plants were sent me from a region lying on the other side of the equator. The plants were exceptional even there in that they had shown a tendency to bear—that is to say to produce juicy leaf-stalks—during the cold season. Through some unexplained freak of heredity or unheralded selective breeding, they had developed a hardiness that had enabled them to put forth their leaves much earlier than is customary with all other races of rhubarb.

The difference was only a matter of weeks, and was of no greater significance, perhaps, than the observed difference in time of bearing between different varieties of other vegetables and fruits. Everyone knows that there are early and late-bearing varieties of most commonly cultivated vegetables and fruits—summer apples and winter apples furnish a familiar illustration.

Perhaps someone had discovered a root of rhubarb that chanced to have peculiar qualities of hardiness, and had propagated it until he had a variety that began bearing while the relatively mild New Zealand winter was still in progress.

But this is only the beginning of the story. The sequel appears when we reflect that the season that constitutes winter in New Zealand is coincident with the summer time of the Northern Hemisphere.

So when we say that the crimson rhubarb was productive during the winter in its original home, this is equivalent to saying that it had the habit of bearing during our summer time. Transplanted to California, the New Zealand product continued to put forth its stalks, quite in accordance with its hereditary traditions, during what, according to its ancestral calendar, was the winter season, although the climatic conditions that now surrounded it were those of summer.

The Influence of Environment

But meantime this plant, like every other living organism, was of course subject to the directly stimulative influence of its environment. Its hereditary traditions had developed what we may speak of as an instinctive tendency to grow at a given time of year regardless of climatic conditions; but they had also given it an equally powerful tendency to respond to the stimulus of cold weather, and to become productive not merely in the *season* of winter but under the *climatic conditions* of winter.

In other words, the combined influences of heredity and of immediate environment were here as always influential in determining the conditions of plant growth.

But, whereas in New Zealand the environment of winter—characterized by cold temperature—coincided with the calendar months of June, July, and August, in the new environment of California the conditions of winter were shifted to the calendar months of December, January, and February. So the two instincts, one calling for productivity in June, July and August, and the other for productivity during cold weather, were now no longer coincident, but made themselves manifest at widely separated seasons, thus producing a perpetual rhubarb.

So the net result was that, merely through the retention of old instinctive habits under the transformed conditions imposed by migration to the Northern Hemisphere, the winter-bearing rhubarb of New Zealand was transformed, by most careful and persistent selection, into a summer- and

A $1,200 Acre

A single acre of ground will grow $1,200 worth of crimson winter rhubarb, the roots of which may be planted in such a way that the leaves almost cover the surface of the earth. The stalks are reproduced as fast as they are pulled, so that the crop is continuous. The plant does not thrive unless it is permitted to bear throughout the season.

winter-bearing plant in California. And inasmuch as there are no sharp lines of demarcation as to just when the pieplant begins and ends bearing, the two seasons tended to merge, with the practical result that some of these plants became all-the-year bearers.

The Power of Habit

Possibly the use of the words habit and instinct as applied to a plant requires a few words of elucidation.

We ordinarily take the habits of a given plant so much as a matter of course that we are prone, perhaps, to overlook their close correspondence with the habits of birds and animals and other animate creatures. Yet a moment's consideration will make it clear that we may with full propriety speak of the fixed or regular "habits" of plants, and that there is no logical reason why we should not speak of them as being determined by "instinct," which after all suggests only the spontaneous response to environing conditions, present or reflected through heredity.

And the force of the various instincts or habits, in the case of the plant, as in the case of birds and animals, is overwhelmingly powerful and quite beyond the possibility of change in any given generation.

To cite a single illustration from the case in hand, every gardener knows that he cannot by any process of cultivation make the ordinary rhubarb plant change its fixed habit of spring production. No amount of coaxing and no manner of soil cultivation or fertilization can take from the rhubarb the impelling force of the hereditary tendency to put forth its stalks in the spring time rather than in summer or fall or winter.

And a similar fixity of habit characterizes in greater or less measure, most other familiar cultivated plants. Artificial selection has extended the season in certain cases, and early or late-bearing varieties have been developed as already noted; but for each variety the habit of producing at a given time of year is one of the most fixed and—as regards any given generation—unalterable of tendencies.

Recalling this it will not seem strange that the Australian winter rhubarb retains its habit of winter production notwithstanding the fact that it had been transplanted to a hemisphere where the climatic conditions of its winter were diametrically changed.

Illustrations From Birdland

Perhaps the all-importance of this inherent tendency to gauge habits in accordance with the calendar will be more clearly apprehended if we cite an illustration from another branch of the organic world.

Take the migrations of birds as a familiar instance. If you watch the birds at all, you have doubtless noted that the migrants that come to temperate regions from the tropics arrive each spring in your neighborhood at a date that you may fix in advance with almost entire certainty.

The hardier birds, to be sure, such as the robin, the blue-bird, and the meadow-lark, retire before the blasts of winter somewhat unwillingly and they begin their northward migration at a period that may vary by a good many days or even weeks according to the forwardness or backwardness of the season. But the coterie of tender birds—orioles, vireos, wood-robins, tanagers, fly-catchers—which spend the winter in the region of the equator, must begin their northward migration without regard to the climatic conditions, inasmuch as their winter home is a region of perpetual summer.

They start northward merely in obedience to an instinctive time-sense that has been implanted through long generations of heredity, and they move across the zones with such scheduled regularity as to reach any given latitude almost on a fixed day year after year.

In Massachusetts or New York or in Ohio or

A Lone Giant

This picture shows a single plant of the Giant Winter Rhubarb that grows to the height of almost four feet. The handsome crimson stalk contrasts finely with the green foliage.

in Iowa, for example, you will find the last flight of migratory birds, comprising the various species of wood-warblers and vireos, the orioles, and the scarlet tanager, making their appearance between the tenth and fifteenth of May each year, quite without regard to the advancement of the season.

And a few months later you will note, if you are observant, that these and the other migrants disappear in the fall, having taken up their return voyage at about the same calendar period year after year, although in one season the September days may be as hot as August and in another season they may have the chill of November.

Countless generations of heredity have fixed in the mechanism of the bird's mind the instinct that impels it to migrate at a fixed season; and no transient or variable conditions of the immediate environment can alter that instinct, even though, in a given case, its alteration might be vastly to the advantage of the individual.

Even Unto Death

As proving the latter point, and as further illustrating the force of the instinctive time-sense under consideration, let me recall the case of the martins to which reference was made in an earlier chapter—the case in which these birds starved to death because in a particular season drought prevented the hatching out of their insect food.

Everyone knows that the martin is a bird of very swift and powerful flight. Its estimated speed is more than a mile a minute, and it habitually remains hour after hour on the wing. It was easily within the capacity of the martins that starved to death in New England to have shifted their location at the rate of something like two or three thousand miles a day.

And assuredly within half that distance, probably within two or three hundred miles at the most, they would have found an abundant supply of food.

Now the season at which the martins actually starved was August; only a few weeks, therefore, before the time of their regular autumnal migration. Had the birds lived another month they would instinctively have begun a long journey to the south, and a single night's flight would have brought them to regions where no doubt their food needs would have been abundantly supplied. From a human standpoint, it would seem only natural that the birds, deprived of food, should have begun their seasonal migration a few weeks before the usual time; whereby their lives would have been saved.

Whoever understands the force of hereditary instinct will realize that such a departure as this was for the birds impossible.

The instinct of migration comes to the martins in September, not in August, or at least not in early August. The habit of migration is no more determined by any conscious judgment of the bird than is the habit of spring growth determined by a conscious judgment of the rhubarb.

The force of untold generations of ancestors impelled the martins to remain where they were, even though starvation was the penalty.

Wings they had, with which they might have sought and found a new environment where food was plentiful; but they were powerless to use the wings at this particular season, because the particular week had not arrived at which the hereditary clockwork of their organisms would strike the hour for migration. Taken by and large, it is better for the race of martins that they should not migrate until September; this fact had been established through the test of thousands of generations, and the result was registered indelibly in the organism of every bird. Were it possible to destroy the racial tradition in the interests of any single generation, the life-habits of the species would become so variable and desultory that racial continuity would be endangered.

So the individuals of a generation throughout a large region were sacrificed to a racial instinct

Another View of the Giant

This picture shows the Giant Winter Rhubarb with leaves spread to reveal the tangle of stalks growing from a single cluster of roots. In addition to producing gigantic stalks the plant is wonderfully prolific, as this picture suggests.

which in the main was beneficial to the species. It will be clear, I trust, how this illustration bears directly on the case of our winter rhubarb.

Restoring Submerged Instincts

It could make no difference to the roots of this plant that they had been unwittingly transplanted from a land where winter comes in July to a land where that month betokens summer. The instinct of bearing at that particular season had all the force of the instinct that impels the bird to migrate at a given time; and this instinct could by no chance be repressed in a given generation, any more than the martins could make over their migratory instinct to fit a transitory condition.

But all this leaves quite unexplained the other fact, which bore so important a part in our story, that the New Zealand rhubarb when transplanted to California assumed a new habit of bearing during the cold season of the Northern Hemisphere which corresponded to the summer of its original habitat and therefore to a calendar period at which its immediate ancestors had been accustomed to assume a condition of dormancy.

How is our theme of the power of instinctive habit to be made to coincide with this seemingly illogical departure?

Our answer is found, as it has been found in the explanation of other anomalies of plant development, in an appeal from the immediate ancestry of the rhubarb to the countless galaxies of its vastly remote ancestry. We have already pointed out that all plant life traces back its origin, if you go far enough, to the luxuriant tropical vegetation of the Carboniferous Era.

But in the case of the rhubarb it is not necessary to go back so far as this to find an ancestry habituated to tropical conditions.

In point of fact the rhubarb is, in all probability, a tropical plant that has but recently migrated to temperate zones—using the word recently in the rather wide sense necessary when we are dealing with questions of racial development under natural conditions. In other words, it is perhaps only a matter of a few hundred generations since all the ancestors of the existing rhubarb tribes were growing in the tropics, and hence, like tropical plants in general, were all-the-year bearers.

In more recent generations, this habit of perpetual bearing has been modified, in case of the rhubarb as in case of nearly all plants of temperate zones, to meet the altered conditions of a climate in which summer and winter alternate.

To adapt themselves to this change of climate, plants were obliged to go into retirement in the winter season, and natural selection preserved only the races that showed this adaptability of habit. Thus the common race of spring-bearing rhubarb, as we know it, was developed.

But the latent capacity to bear at all seasons—to live a fully rounded life throughout the year—which may be considered the normal and inherent propensity of all living things, and which is observed to be the habit of tropical plants in general, was never altogether lost. Submerged generation after generation and century after century, the hereditary factors that make for perpetual growth were still preserved, capable, under changed conditions, of being resuscitated and of making their influence manifest.

The changed conditions came, in case of the rhubarb, when the plant found itself in the new environment of California.

New soil, new atmosphere, new climate—all these are stimulative. Then successive generations of the plants were bred from seeds, and we have already seen that the mixture of strains thus effected tends to have a disturbing influence on the germ plasm, permitting new combinations of characters and resulting in the development of new forms.

We saw this in the case of the Shasta daisy and very notably in the case of the hybrid walnuts. We shall note the same thing again and

Ready for Shipment

The handsome appearance of the stalks of the Crimson Winter Rhubarb adds greatly to the attractiveness of this "vegetable and fruit" in the market. Mr. Burbank has given particular attention to the development of plants that will grow stalks of a uniform size, this being an obvious additional advantage in marketing the product. The color of the Winter Rhubarb gives it added attractiveness when it finally comes to the table.

again in connection with a multitude of other plants.

In the case of the rhubarb, the response was almost immediate. Artificial selection enabled the plants that manifested the atavistic tendency in largest measure, to propagate their kind.

And thus, in the course of a few generations —though not without making selection among hundreds of thousands of individuals—I was enabled to assist the plant to bring to the surface the long submerged tendencies that impelled it to grow fast, to grow large, and to grow perpetually.

No New Principle Involved

And thus the crimson winter rhubarb as it finally came to perfection in my gardens is accounted for. In developing it, no new principle was invoked, no new method even. I merely took advantage of opportunities afforded by the translation of the plant from one hemisphere to another, and aided the plant in putting forth potentialities that had long been repressed but which still stubbornly persisted as latent factors or submerged tendencies in the racial germ-plasm.

Perhaps the matter seems rather complex as thus explained; and indeed all matters pertaining to living organisms are complex in the last

Roots of the Rhubarb

The Winter Rhubarb, like many other cultivated plants, does not always breed true from the seed, and it may best be propagated by root division. This is a very simple matter, however, nothing more being necessary than to cut the roots into small pieces, as here shown, and plant them. Of course the plant thus propagated reproduces absolutely the qualities of the parent plant. A garden plot may be rapidly stocked from a single root.

analysis. But the methods of operation were in practice simple.

Granted certain conditions and certain hereditary tendencies; granted, in other words, the materials with which to work, it required only clear-eyed selection and patient waiting—the encouragement of some tendencies in the right direction and the suppression of other tendencies in the wrong direction—to produce the desired result.

Propagating the Winter Rhubarb

To make the story complete, however, it should be recorded that, although the winter rhubarb was developed by mere selective breeding of a pure strain, yet the experiment was not carried forward without numerous tests of the hybridizing method.

From the outset the New Zealand plant was crossed with the native rhubarb, hoping thus to stimulate variability.

And, almost needless to say, variability was stimulated. The hybrid plants took on sundry forms and diverse habits. But it chanced that no one of these forms was an improvement on those that were secured by selection from the pure New Zealand stock.

Nor did this New Zealand stock, even when developed into my new all-the-year bearer, prove capable of sure propagation from the seed. It can readily be propagated by dividing the roots or by cutting out little sections of the root containing a bud, so there is small necessity of development from the seed. But in this case, as with so many other cultivated plants, it is essential to use this method of propagation if we wish to have an absolutely fixed variety.

An obvious explanation would be that the original New Zealand rhubarb was of mixed racial strains. This, indeed, would account for its tendency to vary, and contribute to its successful development in California. The inter-breeding which produced the winter-bearing strain, may have been done quite by accident in New Zealand, the plants that came to me embodying the full possibilities of development without further hybridizing.

Perpetual Bearing Now Fixed

It should be added, however, that even when grown from seed, the new winter rhubarb *always* manifests the tendency to perpetual bearing. This one trait is fixed, though some of the other qualities of the plant are still variable.

Using the new terminology we may say that the tendency to winter-bearing is a unit character that is latent or recessive, and that the winter rhubarb has no factors of the opposite trait of

A Christmas Gift

This box of Winter Rhubarb was photographed on Christmas day. At this season there is a dearth of fresh vegetables in the market, and such a box of rhubarb would make a very acceptable present. The ancestral tendencies that make this variety of rhubarb a winter bearer are fully explained in the text.

limited bearing and therefore cannot revert so long as it is in-bred. When crossed with the spring-bearing race, however, the offspring sometimes revert to the old habit, as might be expected.

As already noted, nothing is gained by such crossing. Nor is there any necessity for the growth even of pure-bred seedlings. Propagation by root-division answers every purpose, and, thus multiplied, the new crimson winter rhubarb, in its perfected varieties, constitutes a fixed race and is a permanent acquisition to the list of garden vegetables.

—It required only clear-eyed selection and patient watching—the encouragement of tendencies in the right direction and the suppression of tendencies in the wrong direction —to produce the result.

Preparing for Pollenation

At the left, a cherry blossom about to open. In the center, the same blossom with petals removed, showing the group of stamens. At the right, the same blossom, from which the pollen-bearing anthers at the ends of the stamens have been removed, so that self-fertilization may not occur. Pollen from another flower is applied with the finger tip or a camel's hair brush to the pistil which lies at the center of the stamens, and cross-fertilization is thus effected.

THE BURBANK CHERRY

THE EXPLANATION OF A DOUBLE IMPROVEMENT

"HOW MANY assistants have you in your orchard?" a visitor asked me.

And when I replied, "About a hundred thousand this morning, I fancy," my visitor looked quickly this way and that across my eighteen acre Sebastopol farm, and then seemed politely incredulous.

"I don't see quite so many," he remarked. "In fact I can see but eight."

"No," I said, "you don't *see* them; but you can *hear* them if you listen. They are mostly up there among the cherry blossoms. Notice how their wings hum as they go from flower to flower."

"You mean the bees?"

"Just so; the bees—they are my most important helpers at this season. I should get no cherry crop without them, and for that matter no plum crop, no apple crop, and very few flower seeds.

In fact, most of us who grow fruit would soon go out of business, or reduce our farms from acres to square feet, if it were not for the bee helpers buzzing about from blossom to blossom."

"But do you depend entirely upon the bees to pollenize your cherries?" my questioner continued.

"Not altogether. I am obliged to do some pollenizing, particularly at the beginning of an experiment, to make sure of the exact cross that I desire. But after the experiment is under way, I for the most part leave the work to the bees. They operate, as you see, on a large scale, making a thousand pollenizing experiments where I could make one. And in the end the results of their work are highly satisfactory."

How Pollenization Is Effected

To illustrate the necessity for the aid of the insect helpers, I usually show the method by which cross pollenizing is effected when done by human hands.

I select a blossom that is almost mature but has not opened, and cut it across with a very thin, sharp knife, taking the petals about half way down, thus amputating all the stamens, but leaving the pistil.

Pollen which has previously been collected upon a watch crystal from some open flowers is

Ready for Pollenation

A detached cherry blossom in which the pollen-bearers are mature. The pollen may be shaken into a watch crystal for future use or it may be applied directly to the head of a flower prepared in the way shown on page 200. The object, of course, is to bring the pollen of one flower to the pistil of another. The bees aid constantly in accomplishing the same purpose.

applied by lightly touching the finger to it, then to the stigma, taking care to cover the top of the stigma completely with the pollen.

This is a simple enough procedure, but it must be done carefully, as the number of tests that one experimenter can manage is limited.

Moreover, it is necessary, of course, in a case that calls for hand pollenizing, to mark the blossom with a tag of some sort, else there would be no record of the experiment, and no way of telling whether it finally proved successful. Again, it is usually desirable to remove other blossoms from the cluster in which the artificially pollenized one grows, to give a better opportunity for development of this individual.

If, finally, we are to make absolutely certain that no other pollen comes in contact with the stigma, thus guarding against the possibility of fertilization of the flower by other pollen than that intended, it may be desirable to tie a paper bag over the flower.

The latter procedure is not usually necessary, particularly if care has been taken to cover the stigma with pollen, as once this is done there is almost no danger that any foreign pollen will find lodgment. Moreover, the flower from which the petals have been cut, as just described, will not attract the bees, and would probably not be fer-

Seeking Aid of the Bee

The method of pollenizing on a large scale sometimes employed by Mr. Burbank is to place a branch of wild cherry blossoms, as shown in this picture, on a cultivated tree. The bees will then effect cross-pollenation, and the virile qualities of the wild cherry will be introduced into the strains of the cultivated ones. As in the case of the hybrid plums, the offspring of later generations may manifest the good traits of both ancestral strains in combination.

tilized at all if our experimental pollenization should fail.

Time the Limiting Factor

But even when restricted to the essentials, the process takes time; and although some thousands of hand-pollenations are done annually in my gardens and orchard, yet, as intimated, we try to leave the bulk of this work to the bees. Of course, these otherwise admirable helpers make no distinction between different varieties of blossoms, passing freely from one tree to another, regardless of the variety; but they usually confine their attentions on any given day to trees of a single species; that is to say, they do not ordinarily pass from cherry blossoms to the blossoms of the plum or almond, even if all are in season. They seem to prefer not to mix their sweets. So they do not distribute pollen to the wrong flowers as often as might be supposed.

Where I wish to make pollenizing experiments on a larger scale, I sometimes place a branch of a cherry tree in full bloom among the branches of the tree of another variety, with which I wish to effect hybridization. The bees then transfer the pollen from the borrowed limb to the flowers on the surrounding branches, and a thoroughly satisfactory cross pollenation is often thus brought about.

Too Much Stone

This picture shows some South American cherries which have very large stones and a minimum supply of flesh. Obviously such fruits would have no value in the market, yet it is by using such material in his hybridizing experiments that Mr. Burbank produces some of his most important results.

If a visitor who observes my cherry trees in the blossoming time chances to visit my orchards a little later, at the time of fruiting, he will probably be disposed to admit that my method of experiment has had very satisfactory results. For the cherries that grow on my trees are among the largest and most luscious, as well as the most abundant, that have ever been produced.

The visitor will perhaps be surprised to find many scores of cherries quite different in appearance growing on the same tree. This, however, is the result of grafting.

Seedlings grown from seed produced on a single tree may vary widely, but the immediate fruit of any individual tree is fairly uniform, unless the tree has been grafted.

But trees on my farm always *are* grafted, so the phenomenon of divers varieties of fruit on the same tree is a familiar one.

An Unstable Race

The cherry is at best a variable fruit. Like most orchard fruits, it cannot be grown dependably from seed. But, of course it is necessary in producing new varieties to work from seedlings, and from the standpoint of the experimenter who wishes to produce new varieties, it is fortunate that the tendency to vary exists. For, as our other experiments have taught, in the case of plants already described, it is only when a tendency to vary from a fixed racial type has been brought about by hybridization, or otherwise, that the material is furnished upon which the experimenter can build.

In the case of the cherry, all the familiar varieties are the result of hybridizing experiments performed either consciously or unconsciously in the past.

By working with the seed of any existing variety, one secures plants of numerous types that suggest different possibilities of development.

The Ideal Cherry

In the course of my experiments, however, I have had occasion to bring together, through artificial pollenization, various standard varieties of the cherry, and, although I have not found it necessary to send to foreign countries, yet the stock with which I have worked represents races which have been developed in regions as widely separated as Russia, the eastern United States, California, and Japan.

It has been my aim to combine the desirable qualities of different races of cherries from these widely separated regions, and the task here, as in so many other instances, has chiefly consisted in persistent selection among multitudes of seedlings of widely diverse types.

On the Tree

The Early Burbank Cherries here shown grow in profusion and have a peculiarly rich appearance as they hang on the tree, in contrast with the handsome heavy foliage. It is particularly necessary that the cherry tree should have good foliage to protect the fruit against the elements, and the Burbank cherry is ideal in this regard.

The foundation stock with which I chiefly worked was the variety known as Early Purple Guigne, crossed with the Black Tartarian; but in subsequent crosses the qualities of Russian, French and American cherries and of numerous others were introduced, in an attempt to achieve the ideal cherry.

A familiar but notable characteristic of the cherry, in which it differs markedly from most other fruits, is its habit of ripening at the very beginning of summer, while many of the small fruits are not yet in blossom. This characteristic gives the cherry peculiar commercial value, as it comes on the market at a time when there is a scarcity of fruits.

It occurred to me many years ago that there would be a still greater advantage if a cherry could be produced that ripened several weeks earlier than any variety then on the market.

So early ripening was one of the first ideals at which I aimed. With that object in view I naturally selected for my early hybridizing experiments specimens growing on trees that were observed to bear earlier, even if by only a few days, than surrounding trees.

To come at once to the sequel of the story, I may say that I was able after many years of experimentation to produce a cherry that ripens about three weeks earlier than any variety hitherto grown in California. This result was achieved by persistent selection, generation after generation, of specimens that manifested the early-fruiting propensity. But the full bearing of the story cannot be understood unless attention is given to the almost numberless complications that were involved.

Seeking Many Ends at Once

Had the only object sought been the production of a cherry that ripened very early, it would not have been very difficult to attain success.

In that case all other qualities could have been disregarded, and attention given solely and exclusively to the question of time of fruitage. The cherries that ripen earliest each season being selected, I should presently have produced a race of early bearers, beyond peradventure. Selection carried through a comparatively small number of generations would have sufficed to give me what I sought.

But a moment's reflection makes it clear that there would be no commercial value in a cherry that ripened earlier than its fellows, unless this cherry combined with the quality of early ripening other qualities of size and abundance and fitness for shipping, that give the cherry its value as a market fruit. It is obvious that in selecting

At $3.10 a Pound

Burbank Cherries of which these are samples have brought $3.10 a pound at wholesale. The high price is due not alone to the fine eating qualities of the fruit but to the fact that it comes on the market a week or two earlier than other cherries. Mr. Burbank had early-bearing constantly in mind in developing this remarkable cherry—along with eight or ten other desirable qualities.

my cherries it was constantly necessary to bear in mind not merely one quality but several qualities, and it requires no great knowledge of plant experimentation to see that this greatly complicated my problem.

Diversified Qualities Required

In point of fact, the qualities that are required in a really satisfactory commercial fruit are much more diversified than the ordinary observer would ever suspect.

In the case of the cherry there are at least a dozen quite distinct qualities, which might be spoken of as unit characters, that must constantly be borne in mind.

A cherry that will bring a good price in the market must be large in size; it must be attractive in color; it must be sweet and savory to the taste; and it is of prime importance, particularly from the California standpoint, that the fruit shall be of such texture and quality of skin as to bear shipment across the continent, and so reach the Eastern market in good condition.

As much as this will be obvious to every eater of cherries.

But from the standpoint of the fruit-grower, there are many other qualities that are no less important. It is necessary that the tree that bears the cherries shall be hardy and able to with-

The Ideal Cherry Tree

The tree here shown was selected by Mr. Burbank as representing his ideal of a cherry tree. It will be seen that the tree is low and spreading, so that the fruit may readily be plucked by a man standing on the ground or on a low step ladder. This form represents the modern idea in contrast with the old idea that the trunk of the tree should be bare of branches to the height of several feet.

stand the frosts; that it shall have the quality of vitality that makes it immune to the attacks of insects; that it shall have abundant foliage to protect the fruit from the sun; and that it shall be a prolific bearer no less than a bearer of fruit of marketable quality.

All this, in addition to the quality of earliness of bearing to which reference has already been made.

If we add that there are certain minor qualities, to be borne in mind, such as the question of length of stem, number of cherries to the cluster, and tendency of the fruit to cling to the stone in one case or leave it readily in another, an inkling will be gained of the complications of the problem in heredity that confronts the developer of an improved race of cherries.

But the full significance of these complications can scarcely be appreciated wholly by any one who has not been confronted by them in actual practice.

If I have been able to overcome them in a relatively brief number of years, it is because I have worked persistently, selected with discrimination, and invoked the aid of the bees in making experiments on a large scale.

The modern student of heredity, in dealing with cases such as this, is able to give a somewhat

The Earliest Cherry

By further experiments in selective breeding, Mr. Burbank has developed a cherry that is even earlier than the one that bears his name. This new cherry is of handsome form and color and a profuse bearer, as the illustration shows. There is, of course, a limit to the development of the habit of early bearing, but what this limit is can be determined only by long series of experiments in selective breeding. Mr. Burbank is constantly on the lookout for individual fruits that show peculiar qualities, and these are carefully preserved as material for further experiments.

tangible illustration of the difficulties involved with the aid of simple mathematics. He does this on the basis of the Mendelian interpretation of the method of transmission of unit characters of which we have learned something in an earlier chapter.

The Complications Illustrated

It will be recalled that we had occasion to consider such opposing traits as blackness and whiteness in our white blackberry, large size and dwarf size in the case of our walnut trees, stone fruit versus stoneless fruit in cases of our plums, and perfume versus lack of perfume in cases of the calla, as pairs of unit characters that are mutually exclusive in case of any individual, but which both tend to recur in the second generation of hybrid offspring.

It will be recalled, too, that a specific illustration of the formula according to which such recurrence takes place, was found in Professor Castle's experiments in crossing a black guinea pig with a white one; in which case, although all the offspring were black, the quality of whiteness reappeared in one-fourth of the descendants of the second filial generation.

Now it should be observed that this ratio of one in four is a ratio that has been found to hold good in a very great number of experiments

A Yearling Cherry

This picture shows the remarkable qualities of form and foliage of a typical Burbank cherry tree one year old. Mr. Burbank selects his seedlings always with an eye to many qualities of form and vigor of growth, and color of leaf, that the less practiced plant developer might overlook. He also eliminates any plants that show susceptibility to mildew or other fungus diseases. Hence his orchards are made up of trees that are relatively immune to disease and that do not need to be sprayed.

applied to various races of animals and plants, when a cross has been made and a record kept of the results with reference to a single pair of unit characters, such as blackness versus whiteness in the case of the guinea pigs. In such a case, where the offspring of the second filial generation are interbred, it has been clearly demonstrated, that on the average, one-fourth of the offspring of the second filial generation will resemble the paternal grandparent, and one-fourth the maternal grandparent; the remaining half being of mixed heredity.

Stated otherwise, there is an even chance that in any group of four offspring of the second filial generation, one individual will resemble each grandparent as regards a given unit character.

Applying this rule to the case of our cherries, and considering for the moment only the matter of early-bearing versus late-bearing, it should result, if these qualities constitute a pair of unit characters, that by crossing an early-fruiting cherry with a late-fruiting one, the descendants of the second generation would show one specimen in four growing early fruit, one in four growing late fruit, and two of intermediate tendencies.

All that would then be required would be to breed exclusively from the one-fourth that were early-bearers, destroying the three-fourths that

A Black Giant

A few years ago Mr. Burbank found this fine black cherry on one of the branches of a cherry tree that is grafted with several hundred varieties. Naturally this branch was carefully guarded and the seeds of these cherries were preserved for further development.

lacked this quality or had it mixed with the undesirable quality.

Not So Simple in Actual Work

But, unfortunately, the simplicity of the formula vanishes as soon as we come to consider a second, and third, and fourth pair of unit characters.

Here also the formula has been worked out in mathematical terms; and it appears that when several characters are involved, we at once come to deal with numbers that are no longer easy to keep track of. Moreover, the various pairs of unit characters may be juggled in an almost infinite variety of ways.

We are seeking, for example, (1) an early-bearing cherry of (2) good size, (3) fine color, (4) sweet taste, and (5) good keeping quality.

Suppose, for the sake of argument, we consider each of these to constitute, as contrasted with the opposite condition, one member of a pair of unit characters.

Then it appears that, according to the theory of chances which underlies the interpretation of the Mendelian formula, the probability that any given combination of these five qualities will appear in an individual specimen of the progeny of the hybrid generation is only one in about five hundred.

The Improved Giant

These are the improved descendants of the black cherry shown on page 221. They represent perhaps the finest cherry ever developed up to the present time, although still finer ones will doubtless appear in Mr. Burbank's cherry colony in succeeding years. All the cherries in Mr. Burbank's colony are now of aristocratic lineage, and new combinations among them are made through cross-pollenation each season. New seedlings are raised and grafted into the colony, so there are always cions on the tree that are not yet in bearing, and each recurring cherry season brings its surprises.

We shall have early-bearers that are of good size and taste, but lack shipping quality; other early-bearers that are good shippers but lack size or taste; yet other specimens that have size and taste and shipping quality, but lack the quality of early bearing; and so on throughout all the possible combinations of five pairs of qualities.

But the combination of all the desired characters in a single individual will take place very rarely indeed.

And when we advance from five pairs of unit characters to ten or twelve, as we have already seen that we must do in the case of our cherry, the matter becomes almost infinitely complex. As we increase the number of qualities under consideration, the number of possible combinations among them increases at an alarming geometrical ratio.

It appears that whereas there is an even chance, when only a single pair of qualities was in question, of producing one offspring like each parent in each group of four; and whereas there is the same even chance of producing one offspring like each parent in every group of 256 individuals when four pairs of unit characters are in question—when we have to deal with ten pairs of unit characters the possible arrangements have become so bewildering and complex that there is

A Stalwart Infant

The seedling cherry here shown, putting forth its solid clusters of blossoms while only knee-high, illustrates two or three of the characteristic qualities of the Burbank orchard fruits—notable the qualities of early and prolific bearing. Mr. Burbank constantly selects with these qualities in mind, with the result that his orchard trees generally bear fruit at a far earlier age than ordinary ones. This precocious little sapling is a typical plant in Mr. Burbank's gardens.

even chance of producing a single offspring like each grandparent only in each group of *more than a million progeny!*

Quantity Production Necessary

Such a computation, as made in accordance with the Mendelian formula, in itself serves to supply a ready answer to those Mendelians who have questioned the necessity of making experiments on the elaborate scale that I have all along followed out. According to strict Mendelian reasoning, it is clear that we must deal with thousands of seedlings in order to stand a chance of securing a single one that shows a desired combination of qualities, when six or eight qualities are in question—and I seldom work with less than twice this number in view.

And the case is even more complex than this computation would show, because I am always concerned not merely to combine a half dozen or a dozen desirable qualities, but to have a wide range of choice among numerous individuals showing this combination, that one may be found which exhibits the desired qualities in the superlative degree.

It is fair to assume, then, that I should never have secured the Burbank Cherry, and following it my newer varieties of cherries that: (1) fruit weeks before the usual cherry season, and

The Abundance Cherry

This shows the actual size and appearance of one of Mr. Burbank's newest cherries, called the Abundance. Like the Giant Black Cherry, it is the product of crossing between the various highly developed members of the cherry colony. Mr. Burbank does not introduce a new fruit unless it is equal to any existing variety in all its qualities, and superior to any other in at least one quality. The Abundance Cherry fully meets these conditions, its pre-eminent quality being its habit of prolific bearing. In size it is also notable, as the illustration shows.

(2) produce a superabundant crop of fruit of (3) the largest size, (4) best color, (5) firmest texture, and (6) finest quality; growing in (7) easily gathered clusters on (8) trees of fine shape that are (9) hardy and (10) immune to the attacks of insects, had I not extended my experiments far beyond the narrow limits of hand pollenation, with the aid of my hosts of indispensable helpers, the bees.

So the biometric computations give fullest support to the practical methods that I have employed for the past forty years.

Meantime, the results of my experiments—proving the possibility of segregation and reassembly of these diverse qualities—give vivid illustrations of the fundamental truth of the theory of unit characters, *if these be properly interpreted.*

Good Fruit From Bad Ancestors

As a further illustration in point, note this curious circumstance:

I have in various instances used as a parental stock, for purposes of hybridization, a cherry that produced a totally worthless fruit. The object of this selection was to introduce into a developing strain of cherries some good quality—say prolific bearing—that the otherwise worthless cherry showed in high degree.

The immediate progeny of this cross would be of no value as the bad qualities of the worthless cherry were dominant. But among the remoter descendants I have been able to discover individuals that combine the quality of prolific bearing with the good qualities of the other parent stock, and in which the undesirable qualities of the original worthless ancestor were quite eliminated.

It must be clear that this result could not have been brought about if the various pairs of qualities—large size versus small size, sweetness versus sourness, prolific versus shy bearing, and the like—had not been separated in the germ plasm of the hybrids in such a way that the unit characters could be sorted out and any good quality transmitted to the later generations, unimpaired by its contact with the opposing bad quality.

In other words, had there been a blending of traits in the sense in which the older experimenters imagined the traits of hybrids to be blended, we should have had at best a cross in which the qualities of the worthless cherry were mingled with those of the valuable one; a race which, if somewhat better than its worthless ancestor, was somewhat worse than its valued one.

And it would never have been possible to breed out altogether the undesirable qualities that the original cross had introduced.

Separating the Traits

But we have seen in the case of the cherries, as we had previously seen in the case of some other plants, and as we shall have occasion to see in numberless others in future, that it is possible to breed traits into a hybrid strain, and then breed them out again.

In point of fact, no progress in the production of new varieties could have been made along the lines of my experiments, were it not for this possibility.

My Shasta daisy, for example, is not intermediate in size between the species from which it sprang, but larger than any of them. My white blackberry is not intermediate in color between the parental strains, but is of a far purer white than its light colored ancestor. My stoneless plum is more stoneless than the race from which it sprang, although that race has been crossed again and again with strains of plums that invariably produce a stony seed covering. Some of my hybrid walnuts are far larger than either parent stock, and some are far smaller than either.

And so on throughout the list of the hybridizing experiments through which the new races of

Truly Abundant

This picture shows a branch of Abundance Cherries greatly reduced in size. A comparison with the life-size cherries shown on page 227 will give a still better idea as to the bulk of fruit on the branch here shown. Few other qualities of an orchard tree are more carefully considered by Mr. Burbank than the capacity to bear fruit abundantly and bear it every season. The Burbank products show these qualities in remarkable degree—and the Abundance Cherry is near the head of the list.

plants have been developed at Santa Rosa. Everywhere we find evidence of the segregation of unit characters and their re-commingling and re-assortment in later generations.

Nowhere else, probably, can there be found such an aggregate mass of testimony to the operation of this principle as will be supplied in the pages that tell of my various experiments in plant breeding.

We shall have occasion to see that there are cases in which there is a blending of traits, and we shall find an explanation of such blending. But, as the cases already presented sufficiently illustrate, the carrying forward of characteristics unblended, and the possibility of their restoration after long submergence in new combinations, constitutes the underlying principle that makes possible the rapid development of new forms of plant life.

And, reverting to the cases in hand, there is no better illustration of the truth of this proposition than that furnished by the new cherries which present in superlative measure, in a single individual, ten or a dozen clearly definable qualities that have been sorted out and brought together from the commingling of widely divergent ancestral strains.

The traits that were developed through

response to the environment in widely scattered geographical territories and through hundreds of generations, have been brought together, in combinations never hitherto presented; with the result that my early-bearing, large sized, bright colored, and highly flavored cherries constitute essentially a new variety of fruit, while at the same time they evidence with full force the all-compassing influence of the laws of heredity.

—According to strict Mendelian reasoning, it is clear that we must deal with thousands of seedlings in order to stand a chance of securing a single one that shows a desired combination of qualities, when six or eight qualities are in question — and I seldom work with less in view.

Prune-Drying

A typical California scene in a prune-growing district. The prunes are spread out in boxes in the sun to dry and cure. This process must take place rapidly or the prunes would be ruined by fermentation.

The Sugar Prune

How a Tree Was Changed To Fit the Weather

PROBABLY you have heard the story of the General who declared it impossible to build a bridge across a certain stream that obstructed the march of his army until he had plans and specifications and blue prints for the work. While he waited for these—so the story goes—a subordinate built the bridge, and reported to his superior with the suggestion that it might be well to march the men across the bridge forthwith and then make the drawings at leisure afterwards.

A visitor at my orchard told me this story, and applied it to the case of some of my newest varieties of plums.

"It appears to me," he said, "that your custom resembles that of the young soldier who built the bridge without the plans and specifications. You appear to have developed a good many of your fruits on the same principle. You seem to have gone ahead and produced the fruit, while a more cautious experimenter would have been occupied in designing hybridizing methods and testing unit characters, and would not have been fully prepared to start on the actual constructive work until about the time you finished."

Whatever the force of this comparison, it is true that I have often succeeded in producing a fruit of the finest quality by methods that to a less practiced experimenter might look haphazard; methods that did in point of fact lack something of the precision that an investigation conducted solely for purposes of scientific record rather than for practical results might have required.

Such is the case with a large number of experiments in plum breeding. Here I have dealt with such vast numbers of individuals and brought into the hybridizing tests such varied and so many races, that accurate record of every step of a series of experiments extending over a term of years was quite out of the question.

My "Combination" plum has a pedigree, could it be accurately traced, that includes strains of almost every race of plums under cultivation.

From the seed of this strange hybrid you may produce trees that will bear fruit closely similar in all respects to at least a score of entirely

The Giant Prune

One of Mr. Burbank's earliest important prunes is here shown greatly reduced in size. The Giant was introduced in 1893. It has many exceptional qualities, and is particularly prized as a market plum to be eaten fresh. As a drying prune it is surpassed by other of Mr. Burbank's more recent developments.

different well known varieties or races of plums. The mixed pedigree of the product is recorded in this motley galaxy of offspring; but details as to all the parental crosses, tracing back along an experimental search of thirty years duration, are not to be had. The original parents used in the first cross are of course known; but successive generations deal with tens of thousands of seedlings. So it was impossible for anyone who was carrying out, as I have been, not less than three thousand different plant breeding experiments each year, involving in the aggregate not fewer than six thousand different species, to trace accurately, much less to record, each and every cross-fertilization among the myriad blossoms of my orchard.

Yet a chance hybridization might by good fortune effect precisely the needed combination of qualities to give me a fruit that had eluded my most earnest efforts at systematic breeding.

Very often, to be sure, I can judge from the result what the racial strains most probably were that were blended to produce the new hybrid. But even this is not always possible, and not a few among the thousands of new varieties of plums that have originated in my orchard are of untraced and untraceable pedigree, at least as regards some of their strains.

When I say that something like seven and a half million seedlings of the plum have passed under my hand and eye in the course of my many series of experiments in the perfection of this fruit, the reader will not wonder that there are gaps in the record.

Difficulties Involved

On the other hand, it must be understood that there are almost numberless instances in which the hybridizing of different strains of plums has been effected by hand, in accordance with the most rigid scientific methods, and accurately recorded in my plan books. Indeed, this is true in almost all cases of the first cross through which a tendency to variation has been brought about.

The first generation hybrids are usually very much alike, and inspection of them often gives no clues to the ultimate results to be expected. But in the next generation all the divergent characteristics of both racial strains fight for representation, and the diversity of forms produced may baffle accurate description.

Beyond this stage it is usually necessary for the practical breeder to turn over the task of cross-fertilization to the bees, contenting himself with keeping a sharp outlook for seedlings that show desired combinations of traits.

How diversified these traits may be in case of a market fruit has been illustrated at some length in the preceding chapter. In this respect, most plums are at least as complex as the cherry, and the requirements in the case of the "perfect" prune are even more exacting.

The word prune, it should perhaps be explained, is applied in California to any plum that can be dried with the stone in place without fermentation of the pulp. The quality that permits such drying is largely dependent on the amount of sugar that the fruit contains. There are prunes and prunes, as even the most unpracticed observer must know, and there are gradations of size, flavor, and sugar content that are vastly important from the standpoint of the orchardist and by no means without interest from the standpoint of the consumer.

One of the tasks I early set myself was to produce a prune that should excel all others in the qualities, singly and combined, that make for perfection in this valuable fruit. I think I may fairly claim to have accomplished that end, although I shall not pretend that my ideal of a perfect prune has thus far been quite attained. I am not sure that I should be over-pleased if it had been; one does not really wish to reach the end of a trail, leaving nothing to strive for, no unknown territory to explore.

After the Lye Bath

This picture shows the Giant Prune as it appears after being dipped in lye to produce the cracking of the skin that will facilitate drying. This is the final test that a prune must pass. If its skin does not crack properly, or if its sugar content is insufficient, the prune will not dry rapidly enough to escape fermentation. Many prunes that are otherwise of fine quality cannot meet this test.

It is a matter of more or less authentic record that the prune was originally introduced into California by a French sailor named Louis Pellier, who came to San Francisco in 1849 with the first horde of gold seekers.

PRUNES FROM FRANCE

Failing to make his fortune in the mines, this young man, in association with his brother who had presently joined him, established a nursery and conducted it with a certain measure of success until 1856 when one of the brothers returned to France to bring back a bride. He brought also some prune cuttings. And these, notwithstanding the long journey by way of the Isthmus, were still alive when California was reached.

They were immediately grafted upon plum stock, with entire success.

The most important of the varieties of prune thus introduced was the common French prune, sometimes known as the prune d'Agen. The descendants of this stock made up the large prune orchards of California for the ensuing half century.

The French prune, while not without its good points, is by no means a perfect fruit. It is a cling-stone, which is a serious defect in a prune. Moreover, the stone itself is rather large in proportion to the flesh. The fruit ripens too late to be profitable in some parts of the country, and the risk of having the crop destroyed by the early rains is a serious defect everywhere. Neither is the tree a strong grower, or a very reliable producer, or of the most symmetrical growth.

It occurred to me, therefore, when I first took the matter in hand, that among the essential qualifications of the ideal prune at which I must aim would be early ripening and the production of a larger, still sweeter free-stone fruit that would be borne in profusion.

The Ideal Prune

We have had occasion to point out that the common orchard fruits do not breed true when grown from the seed. Explanations of this fact have been given, and fuller explanations will appear in subsequent chapters.

Here it suffices to note that the prune is no exception to the rule.

Very seldom does the seed of a prune tree produce a fruit that much resembles the prune.

Usually the fruits are of all sizes, shapes and colors. They are sweet, sour, bitter, as the case may be. Some of them crack and others remain smooth. The trees on which they grow are many of them ill-shaped, weakly, or subject to disease. Although the parent form may have been an early

A Peeled Giant

The Burbank Giant Prune when dipped in boiling water sheds its skin very rapidly. This gives it peculiar value as a plum for canning, and its large size and agreeable flavor are additional merits.

ripener, the seedling may produce fruit that ripens so late as to be useless.

All of which serves to give an inkling of the difficulties that beset the plant experimenter who sets out in pursuit of an ideal prune.

Moreover, the variety of characteristics required to make up the ideal prune is far greater than the novice might suppose. It is a matter of course that the fruit should be large and well flavored—though not too large, lest it become too difficult to dry; and that it should be produced in abundance.

But there are various equally essential points that the novice might overlook.

There is, for example, the matter of quality of skin, determining the fitness of the fruit to undergo the lye bath which is an essential part of prune curing.

It is necessary to dip the prunes in this bath, consisting of a solution of potash or lye, in order that the skin may crack in such a way as to permit the rapid evaporation essential to quick drying. But in a very large number of cases, prunes that have every other essential quality fail when subjected to this final test. It is not too much to say that I have developed hundreds of new varieties of prunes that were well nigh perfect as to quality, but which had no commercial value whatever because they failed to stand the acid—or to be literal the alkali—test.

So the experimenter is always confronted with the possibility of failure at the very last, even when his efforts seem to have met with complete success at the earlier stages. With the utmost solicitude, therefore, he must watch the fruit as it passes through the potash bath.

If the skin peels from the fruit instead of cracking, that particular variety is worthless, no matter what its other good qualities.

Moreover, the cracks in the skin must be very small and numerous. If they are too far apart by the hundredth of an inch the prune will have a rough appearance that mars it from the commercial standpoint. If the skin is too thin, so that in gathering and handling the fruit is bruised, it can never make a commercial prune. But on the other hand, the skin must not be too thick as then it would not be properly cut by the lye. In a word, there must be the most nicely balanced qualities of the skin of the fruit, and without this final touch, the prune is a failure, even though it grows to seeming perfection on the tree.

The intrinsic qualities, in addition to perfection of skin, that I aimed at from the outset, were large size, increased production of sugar, and early ripening.

A Stoneless Prune

This shows one of Mr. Burbank's most remarkable productions, the stoneless prune, called the Conquest. A very tedious series of experiments was necessary to produce a fruit retaining the essential qualities of the prune, yet lacking the stone. Mr. Burbank has finally accomplished this by hybridizing experiments in which his stoneless plums were crossed with improved descendants of the French prune. This is obviously the prune of the future.

The matter of size is doubly important because this largely determines the price that a prune brings in the market. The sugar content is obviously important because upon this chiefly depends the drying quality of the fruit. And the matter of early ripening is at least as essential as any other quality, because the prune is dried in the sun, and the fruit that ripens late in the season not only often lacks sunshine to complete the process, but may be absolutely ruined by the rains which begin to fall in the early autumn.

How I Achieved Success

When I began my quest of a perfect prune, in the year 1879, it at once occurred to me that something might be accomplished by hybridizing the French prune with another variety known as the English Pond's seedling but usually called in California the Hungarian prune. This was a large and handsome fruit, while the French prune brought to the combination the qualities of rich flavor and relatively high sugar production. If these diverse qualities could be combined in a single fruit, I saw that a great advance would be made.

The little French prune was selected as the mother tree and many thousand blossoms were hand pollenated from the Hungarian.

The offspring of this cross were as variable as had been expected, and among the seedlings were some that produced fruit of superior quality. Four years later, at the meeting of the California State Horticultural Society, I had the pleasure of exhibiting no fewer than seventy varieties of these crossbred seedlings. And in 1893 two new plums were introduced as representing the best selection among the almost myriad forms of the hybrid progeny.

One of these new plums was named the Giant, the other the Splendor.

The former is a handsome plum practically intermediate in qualities between the original parents. It has peculiar value as a shipping plum, and in particular it gained popularity with the canners because its skin has the property of rolling away from the fruit when placed in boiling water, leaving the rich, honey-colored flesh. But these, of course, are not the qualities desired in the prune.

The other variety, named the Splendor, is about one-third larger than the common French prune and contains something like five per cent. more sugar; its quality and flavor are also superior. It has, moreover, the drying qualities of the prune, and it was freely predicted by many who knew it that it would soon completely displace its French progenitor.

Prune Dipping

Another typical California scene, in which the prunes, spread in trays, are being subjected to the lye bath before being placed in the drying yard. The lye bath destroys any germs that are present and cracks the skin of the fruit to facilitate evaporation. It is the only artificial process to which the prunes are subjected. The dried prune is merely a plum preserved by its own sugar. All prunes are plums, but only plums having a high sugar content are ranked as prunes.

But unfortunately it had one single peculiarity that placed it at a disadvantage; namely, the propensity of the fruit to cling to the tree when ripe.

It dries into a first class sweet prune, but it dries on the tree, and that is an insuperable defect, because the prune grower demands that the fruit shall fall naturally to the ground. He does not wish to be obliged to take the trouble even to shake the tree.

So the unfortunate propensity of the new prune to hold to its moorings, so to speak, greatly marred its value.

At Last, a Superlative Prune

In the year 1899, however, after almost twenty years of continuous and laborious effort, I was finally able to present a prune which met the expectations of the most sanguine; a prune which combined all the good qualities of its progenitors and combined them in superlative degree, and which, in addition, had the peculiarly desirable quality of ripening about the first of August, three or four weeks in advance of the usual period of the prune harvest.

This almost perfect prune was placed on the market in 1899 under the name of the Sugar Prune.

A description of the new fruit was given by

Mr. B. M. LeLong, secretary of the California State Board of Horticulture, as follows:

"The sugar prune is an extremely early prune, ripening August 1st; it grows superbly with yellow flesh, tender, and rich in sugar. The skin is very delicate, at first of a light purple tinted with green, changing at maturity to dark purple, covered with a thick white bloom. The form is ovoid, slightly flattened, measuring five by six and a half inches in circumference, average size fifteen to a pound, which is two or three times larger than the French prune; the fruit stock is short, and severs very easily from the stem as the fruit reaches maturity; the pit is of medium size, flattened, slightly wrinkled and most often separated from the flesh; the skin is so thin or porous that the fruit begins to shrink on the tree as soon as ripe."

To add to the value of the sugar prune, the tree on which it grows is unusually vigorous and very productive.

Analysis of the fresh fruit at the State University discloses the fact that it is nearly one-fourth sugar—the exact amount being 23.92 per cent., contrasted with the 18.53 per cent. sugar content of the French prune, and the 15.33 per cent. of prunes in general.

Not only does the sugar prune contain far more sugar than any of the varieties from which it

A Result of Over-Dipping

A prune must be dipped in lye, but the lye must not be too strong, nor can the fruit be left too long in the bath. Too much dipping may be disastrous, producing a condition of the skin that makes proper curing impossible. The dipping of the prune is, therefore, the only part of the process of prune production that requires expert attention.

sprang, but it fully equals the French prune in flavor, and it is two to three times as large. It is far more productive, and can be grown for one-third to one-half the cost of producing the French prune. In flavor it is fully equal to the celebrated Imperial, and, in most striking contrast to that fruit, it is exceedingly productive.

Add that the new prune excels all other varieties in the extreme earliness of its time of fruiting, and it will be obvious that the sugar prune marks at least a long step towards the ideal at which I aimed. It ripens at a time when the weather is hot and dry, so that it can be rapidly cured. A month or so later when the other varieties are maturing, the weather is often foggy and cloudy and sometimes even rainy, so that fruit curing is carried on under difficulties and often with serious loss.

It is not strange, then, that the sugar prune met with an immediate and enthusiastic welcome from many fruit growers, although of course there were regions in which a prejudice was shown against it, such as always meets any new product.

In the markets of the East, the demand for the sugar prune was soon far in excess of the supply.

A Wonderful Laboratory

We have seen that the essential quality of the prune, and that which differentiates it from plums in general, is its inherent tendency to produce a large percentage of sugar.

A great number of fruits share with the prune the capacity to manufacture sugar, but few other fruits have the power in such supreme degree. The manufacture of sugar by fruits is so familiar a phenomenon that we usually take it for granted and give it no thought. Yet a moment's consideration makes it clear that this capacity is one of the most extraordinary functions in the whole list of vital phenomena.

Holding a ripe prune in my hand I am sometimes led to reflect that this is in many ways the most remarkable of chemical laboratories.

Within the cellular structure of this fruit, a combination and metamorphosis of chemical products is brought about that the most skilful of human chemists is unable to duplicate. Every chlorophyll bearing plant, to be sure, possesses in greater or less measure the capacity to manufacture starch and to transform this substance into a soluble sugar. But the fact that this attribute is characteristic of plants in general, does not make it the less mysterious for the thoughtful observer.

The chemist is able to analyze starch, and he tells us that it is a compound each molecule of which contains six atoms of carbon, ten atoms of hydrogen, and five of oxygen.

But while he makes his analysis and determines the proportions of the component elements, he is careful to assure us that these elements are doubtless associated in very complex combinations of which his analysis gives him only a vague inkling.

If we glance at the formula by which the chemist represents a molecule of starch—$C^6 H^{10} O^5$—the thought at once suggests itself that this seems to be a union of six atoms of carbon with five molecules of water; for of course we are all familiar with the formula H^2O as representing water, however little we may know of the other niceties of chemistry.

And in point of fact, this is about the way in which the chemist regards the matter.

Starch is a compound of water and carbon. The plant secures the water from the soil and the carbon from the atmosphere, where it exists in the form of carbonic acid gas, which is given out constantly from the lungs of every living animal.

With these simple and universally present materials, then, the wonderful chemist of the plant laboratory builds up the intricate substances that we term starch.

This substance is stored away in the plant cells, not for the moment available for the purpose of nutrition, but constituting a reserve store of

Too Free a Stone

Mr. Burbank has given great attention to the production of freestone fruits, the advantages of which are obvious. This picture shows that such a fruit may not be without its disadvantages. Here is a prune, the flesh of which was so loosely attached to the stone that it broke away at too early a period, leaving a large cavity. Such fruit will obviously shrink very much in drying. The defect must be corrected by selective breeding before this particular prune has commercial value.

food material upon which the tissues of the plant can draw at need.

Starch itself is insoluble in the juice of the plant, but to make it available whenever needed, it is only necessary for the plant chemist to add to the compound the constituents of a molecule of water, namely two atoms of hydrogen and one of oxygen, and the starch is transformed into a soluble sugar called glucose or levulose.

This substance, dissolved in the juice of the plant, may then be transferred to the place where it is needed; which, in the case under consideration is the flesh of the fruit.

The process of starch manufacture and of transformation of starch into sugar, with the final storing of the sweet product in the flesh of the prune, constitutes, as I have just suggested, one of the most marvellous manifestations of the power of vegetable cells. Indeed, it is precisely this capacity that differentiates vegetable tissues from all animal tissues whatever; for the biologists tell us that no living organism, high or low, save only the vegetable, is capable of manufacturing a single molecule of starch, much less a molecule of sugar out of inorganic materials.

So a thoughtful person can scarcely fail to regard even so plebeian a thing as a prune with a certain measure of wonderment, almost of

The Sugar Prune and Its Parents

Mr. Burbank's Sugar Prune was developed by selection from a cross between the French prune and the Hungarian prune. From the former it inherited sweetness and flavor and from the latter size. It improved on each parent, however, manifesting the vigor that is not unusual with hybrids. The French prune is still largely grown in California, but its improved descendants must ultimately displace it.

awe, if he allows himself to reflect on the mysterious processes that have taken place within its structure.

The Elements of Variation

From the present standpoint, however, we are not so much concerned with the mysteries of plant chemistry as with the extremely practical fact that the new sugar prune developed in my orchard has the fixed habit of setting its sugar-making laboratory in operation several weeks earlier than had been the custom with the ancestral races of prunes.

This interesting and important change of habit had been brought about, as the reader who has perused the earlier chapters will surmise, by a process of selecting, generation after generation, the individual prunes that manifested a tendency to early fruiting. But here as elsewhere we are confronted with the question as to how it was possible thus to change so markedly the habits of a plant within a few generations.

The answer carries us back in imagination, along lines we have followed in studying other plant histories, to the remote ancestors of the sugar prune.

We are led to reflect that the time of fruiting of a given plant is largely dependent upon the climate in which the plant habitually grows. Now

Thirty-two to the Pound

This sugar prune is particularly notable for the sweetness of its flavor, as its name would imply. It also has an advantage over other prunes in that it ripens in August, three weeks before the French prune. This gives opportunity for the curing of the prune before the wet season, a matter of great practical importance.

there must have been ancestors of the prune that grew far to the north, for the plum is a hardy plant. Among some of the remote and now untraceable ancestral strains, there were doubtless some that produced their fruit at least as early as the first of August, perhaps even earlier.

And although (when interbreeding occurred) the hereditary tendency to early fruiting had been made subordinate to the late-fruiting tendencies of other races of plums that had grown in milder climates, yet the potentialities of early fruiting were never altogether lost.

Hence among the multitude of seedlings that were produced by my hybridizing experiments, this trait, along with a multitude of other submerged ancestral traits, was now able to make itself manifest. And it was my task, by a comparatively simple process of selection, to make sure that the character was preserved.

The matter is perhaps made a little clearer if we reflect that in any race of domestic plants, there is a considerable range of variation as to size of fruit, abundance of bearing, and time of fruitage. Such variations represent, as we have pointed out, the varying traits of diverse strains of ancestors. But it must be observed that there are always some clearly defined limits beyond which variation does not readily go.

The Best Prune—The Burbank Standard

This six-inch prune is named the Standard. It is a cross between the Sugar prune and the Tragedy, and it is considered by Mr. Burbank to be almost an ideal prune. Many experts concur in pronouncing it the best prune ever produced. Its trees are enormous and never failing bearers, and the fruit is of the largest size and of splendid quality.

Among all the thousands of types of prunes grown on the seedlings of my hybrid colony or on grafts on some receptive tree, there will be individual fruits varying, let us say, from one-half inch in length to perhaps two and a half inches—but by no chance will there be a fruit four inches in length.

Similarly among my seedlings there will be some that ripen their fruit as early as the first of August, but none that ripen so early as the first of July.

Fruits of other species may ripen far earlier; the cherry does so habitually. But the ancestors of the plum have lived under conditions that made it unnecessary for them to mature their fruit much before midsummer. So their range of habit in this regard, as recorded in the stored hereditary tendencies, was strictly limited. And the possibilities of variation among my hybrid seedlings are correspondingly limited, because, as I have hitherto pointed out, heredity is but the symbol of the sum of past environments, and the hereditary limitations of any common race of plants to-day are determined by the aggregate limitations of all their ancestors.

Reversion to the Average

Such an analysis, in which the varying conditions that environ the different strains of a

A Luscious Fruit

This shows a specimen of the Standard prune, natural size. This prune is so large that nine or ten of them weigh a pound. The stone is so relatively small that it represents only 3.5 per cent of the total bulk. It is also free-stone—a very great merit, as every eater of prunes will admit. These massive prunes are often sold in the market as plums to be eaten fresh.

hybrid's ancestry are kept constantly in mind, serves to give us a clue to the observed tendency of families or strains of animals or plants to revert in successive generations toward a given mean or average.

It has long been observed that, as a general rule, the offspring of human parents that are exceptionally tall tend to be shorter than their parents; whereas, contrariwise, the offspring of dwarfs tend to be taller than their parents.

In studying races of animals and plants, biologists have discovered that this tendency, spoken of as tendency to revert to a mean, is universal.

The matter has been especially studied in recent years by the Danish biologist, Professor W. L. Johannsen, of Copenhagen. His studies of barley and of kidney-beans show that any given race of these plants is really made up of a number of subordinate races, representing different strains of the ancestral pedigree, and that when the plants are self-fertilized, the progeny tend to group themselves into a few more or less permanent types.

There are limits of variation as to size, color and qualities but the progeny as a whole do not tend to have offspring that approach the half-way mark between these two extremes. Rather they break up into groups, each group tending to reproduce itself in such a way as to form a new

The Standard Prune After Drying

This shows the Standard Prune, actual size, after drying. It may be compared with the fresh fruit shown on page 265. There is of course very considerable loss of size in drying, but the giant Standard after suffering this reduction is still as large as many other prunes in fresh condition. Mr. Burbank first offered the Standard in 1911, and its merits are already coming to be widely appreciated.

subordinate race or "pure type." Thus from the same mixed stock sundry races of relative giants and of relative dwarfs, as well as numerous intermediate races, are formed.

Now it would appear that such a case as that of the prune, in which we are able to work out by artificial selection a race characterized by tendency to early fruitage, is in keeping with these studies of the so-called "pure lines" of descent to which Professor Johannsen has given attention.

But it must be understood that it is exceedingly difficult to carry the experiment in the case of the prune to the stage at which the type becomes absolutely fixed, for the reason that there are so many other qualities to be considered.

This matter of varying qualities represented in the same seed we have discussed before, and we shall have occasion to refer to it again and again. Here it suffices to note that the case of the prune is akin to others that we have examined, for example the hybrid walnuts and the early cherries, in that the qualities for which we have bred are so numerous and so varied that they can be aggregated only in one seedling among many thousands, and could not be fixed without a long series of generations of additional breeding.

Fortunately this is of no practical consequence, because the prune, like other orchard fruits, may best be propagated by grafting. From a single seedling we may thus develop, in due course, an entire orchard or a series of orchards.

Such is in practice the method of propagating the sugar prune. It is obvious that plants thus grown partake of the very substance of the original seedling; they are part and parcel of it, and fruit grown from such grafts will be uniform in quality, within the limits of variation that characterize the individual specimens of any fixed race.

—When I say that something like seven and a half million seedlings of the plum have passed under my hand and eye in the course of my many series of experiments in the perfection of this fruit, the reader will not wonder that each individual cross has not been recorded.

The Petunia

Mr. Burbank has made many very interesting breeding experiments with the Petunia. Samples of his productions are shown in this color reproduction. Perhaps the most interesting single experiment with this flower was that in which Mr. Burbank hybridized the Petunia and the Tobacco plant. The resulting hybrid was a very curious plant which combined the characteristics of both parents. Mr. Burbank named it the Nicotunia. It was facetiously described as a petunia that had acquired the tobacco habit. Unfortunately the hybrids lacked vitality, and did not produce a permanent race.

Some Interesting Failures

A Petuna With the Tobacco Habit—And Others

A WELL KNOWN and appreciative critic, after a visit to Santa Rosa, commented on my work in a way that seemed to suggest that what most appealed to him was the great variety of experiments constantly being carried on.

"Every plant seems to appeal to Luther Burbank," he said. "This appeal is quite unlike the appeal that is made to the botanist or even to the horticulturist; Burbank likes it because it is a plant and because he would like to try to modify it. Therefore he grows everything he can, no matter where it comes from or of what kind. He cultivates with personal care, multiplies the stock to the limit of his capacities, scrutinizes every variation, hybridizes widely, saves the seeds of the forms that most appeal to him, sows again, hybridizes and selects again, uproots by the hundreds and thousands, extracts the delights from every new experience, and now and then saves out a form that he thinks to be worth introducing to the public.

"Every part of the work is worth the while of itself; at every stage the satisfaction of it is reason enough for making and continuing the effort. Every form is interesting, whether it is new or the reproduction of an old form. He shows you the odd and intermediate and reversionary forms as well as those that promise to be of general use.

"All this leads me to say that the value of Mr. Burbank's work lies above all merely economic considerations. He is a master worker in making plants to vary. Plants are plastic material in his hands. He is demonstrating what can be done. He is setting new ideals and novel problems.

"Heretofore, gardeners and other horticulturists have grown plants because they are useful or beautiful: Mr. Burbank grows them because he can make them take on new forms. This is a new kind of pleasure to be got from gardening, a new and captivating purpose in plant growing. It is a new reason for associating with plants. Usually I think of him as a plant-lover rather than plant-breeder. It is little consequence to me whether he produces good commercial varieties or not. He has a sphere of his own, and one that

Tobacco Plant

Mr. Burbank has made important experiments with various members of the tobacco tribe. This picture shows a specimen of unusual vigor of growth, illustrating the possibilities of development in that direction. Mr. Burbank's experiments with the plants of this family have largely been made for their scientific interest rather than in the attempt to develop commercial varieties. Not being a user of tobacco himself, he does not take the personal interest in the latter aspect of the work that he otherwise might.

should appeal to a universal constituency. In this way, Luther Burbank's work is a contribution to the satisfaction of living, and is beyond all price."

Such appreciative notices of one's work are of course agreeable, and I am bound to admit that what is said about my love of experimenting with any and every kind of plant is altogether true.

There is one point, however, at which I am forced to part company with the commentator. To me it *is* a matter of vital consequence as to whether I "produce good commercial varieties or not." It is necessarily so, inasmuch as I have all along made a living by the sale of the products of my experiments.

Had I not produced good commercial varieties, my practical success would have been something quite different from what it has been.

Nevertheless, it of course is true that the successful commercial varieties of plants and fruits are comparatively few in number as contrasted with the vast numbers of forms with which I have experimented. It could not well be otherwise, for it would be a strange and novel form of experiment that led always to success. But of course the public in general hears of, and in the main cares for, successes only. There is seldom any reason for exploiting a failure. And so my long list of experiments that have led to no practical result has scarcely been heard of by the public in general.

Some of these, however, are in themselves highly interesting, and I have thought it worth while to take the reader into my confidence to the extent of telling about three or four series of experiments which produced no permanent new forms of flower or fruit, and which from the commercial standpoint resulted only in loss of time and money.

There are certain lessons to be drawn from these that I think will command the reader's attention and interest.

A Misguided Petunia

One of the most curious hybridizing experiments that I ever performed consisted of crossing the common garden petunia with a variety of tobacco, known as *Nicotiana Wigandioides rubra.*

In this cross the petunia pollen was used to fertilize the pistil of the tobacco plant. The seed thus produced was planted in the summer, as soon as it ripened, and possibly two hundred plants were raised.

When about a foot high the plants were placed in boxes in the greenhouse to keep over winter. They revealed no inclination to bloom, nor did they vary greatly from the parent tobacco plant,

A Tobacco Hybrid

In hybridizing the Petunia and the Tobacco, Mr. Burbank used the tobacco as the mother parent. The offspring at first resembled the tobacco plant, but subsequently they showed great diversity of form, some of them becoming trailers like the petunia. The specimen here shown is a hybrid between two relatives of the tobacco, the Nicotiana Wigandoides rubra and the Nicotiana glauca. The crossing of the petunia and the tobacco has peculiar interest because the plants belong to different genera.

except in the matter of growth, which was very uneven, some of the hybrids being two or three times as large as others. The foliage was somewhat unusual; yet its resemblance to the tobacco was so great that a casual observer would have doubted whether the cross had really been made.

In a word, the characteristics of the tobacco plant seemed to preponderate.

But towards spring, when the plants were set again out of doors, they soon began to show the influence of their mixed heritage. Some of them turned crimson, and others pink; yet others remaining green. Moreover, the plants themselves developed a great diversity of habit. Even during the winter some of them had begun to fall over and show a tendency to trail like vines. As the second season advanced, some of these became genuine trailers like the petunia, and produced blossoms altogether different in color from the red flowers of the tobacco plant.

These plants did not bloom very abundantly, but their great diversity of form and peculiarity of foliage and flower made them a very striking lot of plants.

Some of them grew four or more feet in height with large tobacco-like leaves, and others were trailing dwarfs that to all appearances might have belonged to an entirely distinct race.

The plants that closely resembled the tobacco parent were, for the most part, weeded out. The ones that gave evidence of their hybrid origin were carefully nurtured. But it was noticed towards fall that although the tops grew splendidly, there seemed to be an unusual lack of roots. The plants would come to a certain size, and then take on what could perhaps be best described as a "pinched" appearance, from lack of vitality incident to their defective roots. There was, however, a great difference among the individual plants, some of them remaining strong throughout the season.

When the plants were taken up, it appeared that the sickly ones had produced only a few long, frail, wiry roots. It appeared to have been impossible for them to develop a thoroughly good root system. Evidently most of the new plants had inherited the rank-growing tops of the giant tobacco and the smaller, less efficient roots of the petunia.

A visitor whose attention was called to this peculiarity remarked facetiously that my petunias had obviously been stunted in growth and vitality through acquiring the tobacco habit, just as boys are stunted when they make the same mistake.

It is only fair to recall, however, that the petunias had no choice in the matter. Their

Rare Exotics

These seedlings in a plot in Mr. Burbank's garden have grown from seeds sent by missionaries and by travelers. The plants are mostly unnamed, and they are here being given opportunity to reveal themselves. Mr. Burbank has received thousands of specimens from all parts of the world, and he looks upon each seed as possible material for interesting and valuable future experiments.

association with the tobacco had been thrust upon them.

Owing to the lack of vitality of the hybrids, and the fact that they seemed unlikely to develop additional characteristics of exceptional interest, the plants were not especially sheltered, and they perished from freezing during the ensuing winter. Thus the experiment of hybridizing the petunia and the tobacco came to an end; not, however, without illustrating one or two suggestive points of plant breeding to which further reference will be made in due course.

Some Mongrel Potatoes

Inasmuch as my first experiments in plant breeding had to do with the potato, it is not strange that the tribe of plants to which this vegetable belongs have always had for me a rather exceptional interest.

Early in the course of my California work I secured specimens of a remote cousin of the cultivated potato which grows in our southwestern States and which is known to the Indians as the Squaw potato (*Solanum Jamesii*).

It is a wild rambling potato, spreading in all directions by tubers that seem to be connected by long strings. Although used for food by the Indians, this potato is hardly worth the notice of the gardener, except for its hardiness. This trait suggested that it might possibly be crossed to advantage with other species. But although several crosses were effected with other species of the potato, nothing of value came of them.

An allied species, however, namely the *Solanum Commersoni*, a worthless form introduced from Europe, gave more interesting results.

This plant, although recommended as a valuable commercial product, really had very little value. Like most wild potatoes, it scattered its tubers widely from the hill; moreover it had a bitter taste that made it unpalatable. The blossoms, however, were handsome, and, unlike the blossoms of the ordinary potato, they were quite fragrant.

Moreover, the blossoms were produced in astounding profusion. But they did not ordinarily produce seed. When I crossed the plant with other tuberous Solanums, however, I produced a number of seed balls. By cross-fertilization the plants had acquired a virility that they otherwise lacked.

These hybrid seeds produced many strange forms of potato plants. Some had extremely large blossoms in great quantities, others extremely small ones; the blossoms varied in all shades from deep blue through sky blue to red and white. Some of the blossoms might have been thought

Tomato-Potato Graft

The grafting of potato tops on tomato roots and of tomato tops on potato roots have constituted some of the most interesting of Mr. Burbank's grafting experiments. The manner of grafting is not altogether unlike that employed in the case of trees, but the experiment has peculiar interest because Mr. Burbank has been able to unite the stems of these plants, but has not been able to cross-pollenate them successfully.

not unworthy to be introduced as garden ornaments. But they offered no advantage over numerous flowers already in existence, and as the tuber proved worthless, these experiments also were discontinued.

But by far the most interesting experiments that I have made with the wild potatoes were made by combining the form known as the Darwin potato (*Solanum maglia*), a yellow fleshy tuber with big seed balls, with the common potato, and with various other tuberous Solanums. Thus I produced a plant which yielded balls of fruit at least three or four times as large as those ever produced by the ordinary potato.

In one case, the fruit of this hybrid proved to have an excellent flavor, in some respects superior in quality to the tomato. It was white when ripe, and had also a highly pleasing aroma. The flesh of this fruit resembled that of a firm tomato. To the taste it suggested a delightful commingling of acids and sugars.

As the fruit grew on a hybrid potato vine, and in itself had much the appearance of a tomato, it was christened the "Pomato."

The name itself was appropriate enough, but was unfortunate in that it led to the unauthorized assumption that the fruit was really a cross between the tomato and the potato. In point of fact, I have never been able to cross these two plants, and there was no strain of the tomato in the ancestry of the new fruit.

The pomato plant produced fruit abundantly, but very few tubers, and when the latter were planted, the vines seemed to run out, giving their entire attention to the production of seed balls. But the seed when planted never reproduced itself exactly true to form, showing its hybrid quality by the production of unique and abnormal forms.

Thus there was no practical method of propagating the pomato, the tubers being wholly absent or merely rudimentary, and the seed not producing a satisfactory product.

It is probable that if I could have found time to continue the experiments, I should have been able to fix the race through selection, and thus have added a fruit of an altogether new variety to the list of garden products.

But to have done this would have necessitated experiments on a large scale, and this would have required more time than I could give at the moment.

I think it not unlikely, however, that some one will take up the experiment in future and develop a fruit comparable to my pomato that will have commercial value.

Step-Mothered Potatoes

These potatoes were grown on roots on which a tomato top was grafted. The tomato leaves have supplied material for the unwonted purpose of making potatoes, but the product is of a dwarfed and perverted character. When the potato vine is grafted on the tomato roots, no potatoes are grown underground, but they may grow from the axils of the leaves in the air, as shown in some of Mr. Burbank's early experiments.

One of the most curious hybridizing experiments that I have ever conducted was made in an effort to test the limitations of affinity between the various members of the rose family. I had on my place a bush of the California dewberry, a plant that differs from most other members of the family in that its staminate and pistillate flowers are borne separately.

The particular bush in question had only pistillate flowers, and as it grew in isolation, it ordinarily bore no fruit, as its flowers were seldom fertilized. At most it occasionally developed single drupelets, a result no doubt of partial fertilization from grains of pollen accidentally brought from a distance by wind or insect.

The isolation of the plant, and the fact that it bore unisexual flowers, seemed to offer a favorable opportunity for experiment.

Some Hybrid Berries

Upon this plant I applied the pollen of various species of plants of the same family. The list is a striking one, for it included the apple, the mountain-ash, the hawthorn, the quince, the pear, and various kinds of roses.

I worked at these hybridizations attentively during the blooming season of the dewberry in the summer of 1886.

The pistils thus fertilized developed an abundant crop of fruit, and in the ensuing season I raised from these berries between five and six thousand seedlings.

Never on earth, perhaps, was there seen a more widely varying lot of seedlings that were the immediate offspring of a single plant. The hybrids took almost every possible form that could be suggested as combining the traits of the various parent plants. Most of them were absolutely thornless. Many grew upright like the apple tree, showing nothing of the drooping tendency even of the raspberry, much less the trailing habit of the dewberry. The leaves were generally quite smooth, some resembling those of the pear, others being partially trifoliate, and most of them assuming strange and unusual forms.

When this motley company came to the time of blooming, there was still another surprise, for 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 pink and quite small; others were white. A large number of plants, however, did not bloom at all, although they were attentively cared for, and were otherwise normal.

From these strange hybrids I not unnaturally expected to raise a remarkable variety of fruits.

The Strawberry-Raspberry Hybrid

By hybridizing the strawberry and the rapsberry, Mr. Burbank produced an extraordinary plant which at first trailed along the ground like the strawberry, and then sent up tall shoots in imitation of the other parent. The hybrid plant blossomed, but unfortunately did not produce fertile fruit.

I had hopes even of being able to produce something of real value, at any rate from the second generation.

But when it came time for the fruits to ripen, another surprise awaited me; only two plants out of the five thousand produced a single fruit. One of these was a plant somewhat resembling a raspberry bush, and this produced a number of ill-tasting berries of a yellowish-brown. The other bush produced insignificant fruits of an orange-yellow color.

Though unpromising in themselves, these fruits were carefully watched and guarded, for I felt convinced that possibilities of strange variation were contained in them, if only I could get from them a few seedlings. But when the fruits were fully matured, I examined the seeds and found all of them hollow. They were nothing but shells, containing no kernel.

So by no possibility could I get a single seedling of a succeeding generation.

Some of the most curious of the plants were preserved for another season, but they proved as unproductive as before; and as I needed the ground for other purposes I felt constrained to destroy the entire company of curious hybrids. In all my experience I never destroyed a lot of plants with more sincere regret.

An experiment perhaps even bolder was made at about the time of my experience with the hybrid dewberries. This was the hybridization of the strawberry and the raspberry.

The attempt to cross plants of such unlike appearance would seem to most experimenters absurd. Yet the cross was successfully effected. The raspberry was selected as the pistillate plant, and pollen was applied from whatever strawberry was at hand. It was impossible to choose as to the latter point, for the strawberry is for the most part out of season when the raspberry blossoms. I had to use such material as I could find.

The pollenation proved effective, and the raspberry plant produced a full crop of fruit.

There is no very marked immediate effect observable from such a hybridization. The pulp of the berry seems not to be affected; but the essential seeds within the berry are enormously modified, as the sequel showed. For when the raspberry seeds were planted in the greenhouse, the young hybrid plants that came up in profusion had all the appearance of ordinary strawberry plants. No one who inspected them casually would suspect their hybrid origin.

The raspberry, the pistillate parent on which the seeds had grown, has leaves with five leaflets. But there was no leaf of this character among all

Leaves of Strawberry-Raspberry Hybrids

The strawberry-raspberry hybrids produced by Mr. Burbank had leaves which were uniformly trifoliate, but which varied greatly in size and shape. Characteristic samples of the different forms are here shown. It was peculiarly to be regretted that the hybrids were not fertile, as a new and highly interesting form of fruit would doubtless have resulted had it been possible to establish a permanent race combining the blood of the strawberry and the raspberry.

the hybrids; without exception their leaves were trifoliate like the leaf of the strawberry.

In other words, in the matter of foliage, the strawberry plant was entirely prepotent or dominant, and the characteristics of the other parent were latent or recessive.

When the hybrids were old enough, they were carefully set out in rows in the open field. For a month or more after transplanting they showed no inclination to depart from the habit of the strawberry. To close inspection it might appear that the main stem was unusually thick, and that the leaves were a little more wrinkled than is usual with the strawberry, and their edges slightly more serrated. But aside from this, the hybrid plants were seemingly true strawberries.

About the first of June, however, the plants began to throw out underground stolons, whereas strawberry runners are normally on the surface. These stolons suggested roots of the raspberry, yet the new plants that sprang from them here and there were exactly like the strawberry plants. So at this stage it would seem that the influence of the mother parent had been but 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 the height of from two to five feet. These canes were absolutely thornless, as were all other portions of the plant; they were as smooth as strawberry plants in leaf and stem, but their form and manner of growth now departed strangely from the traditions of the trailing parent.

Obviously the influence of the raspberry parent had at last made itself potent.

Some of the plants were yellowish, indicating that the berries would probably be yellow; others were reddish. There were no blossoms the first season, but the ensuing year panicles of blossoms of great size were put forth, some of the bunches being twelve inches in breadth—far larger than those usually seen on the raspberry. In a single panicle there were sometimes several hundred flowers. The individual blossoms were generally larger than the flowers of the raspberry, but slightly smaller than those of the strawberry.

In the center of each blossom was a miniature berry, which might be said to resemble either a strawberry or a raspberry, being so small that its exact characteristics could hardly be distinguished.

I was quite sure I had a valuable cross, and that at least one might be found among the many that would produce fruit. But in this I was disappointed; not a plant produced a single berry. The miniature fruit remained unchanged

Seed Time

This view, taken on one of Mr. Burbank's experiment farms at seed time, will give an idea of the magnitude of the experiments that are carried out. Quantity production is the motto that has all along inspired Mr. Burbank, and to which he in large measure ascribes his success. By producing enormous numbers of seedlings he has rare opportunity for selection. The method is wasteful, like the methods of nature herself; but it leads to marvelous results.

in size until it finally dropped from the bush in the fall.

The following season a few of the plants bore one or two fruits having two or three drupelets each, like mere fragments of a normal raspberry. But not a seed was found. The plants were as sterile as mules. So here the experiment ended, and the hybrid strawberry-raspberries followed the hybrid dewberries to the brush heap.

Why the Experiments Failed

If now we consider the results of these various experiments, it will be clear that they have certain elements in common. In all cases the hybridizing was effected between species that are botanically related. Some of them (petunia and potato, dewberry and its mates, strawberry and raspberry) belonged to different genera, however, and in no case was the relationship between the mated forms very close. And this fact is of course of salient importance in enabling us to comprehend the results.

It is almost axiomatic to say that the hybridizing of plants becomes increasingly difficult in proportion as the attempt is made to cross more and more distantly related species. Even within the same genus it is very often impossible to produce a hybrid that is not sterile.

I might cite in further illustration of these difficulties the experiments through which I have hybridized the apple with the pear, and with the quince; the cherry with the plum; and the peach with the almond, with the Japanese plum, and with the apricot, without in any of these cases producing a product of value. These crosses, like the ones just detailed, bring together racial tendencies that are too widely divergent to be harmonized.

It would appear that it is essential to the differentiation and perpetuation of species that bounds should be set on the possibility of producing a disturbing influence through hybridization. When plants, even though sprung from the same origin, have diverged so widely and for such periods of time as to produce forms differing from one another so greatly as, for example, the mountain-ash, the apple, and the rose differ from the dewberry; or the strawberry from the raspberry—it would seemingly not be advantageous in the scheme of evolution to permit the hybridizing of these forms.

The mutations that would be produced, were such hybridization to result in virile offspring, would be too divergent, in all probability, to fit into their environment successfully. At all events the possibility of such crosses would constitute a disturbing influence that would rob the scheme

A Brazilian Solanum

This is a relative of the potato and tomato that came originally from Brazil. The fruit somewhat resembles the tomato, although of a quite different species. This picture shows the fruit of the new Solanum in a transition stage, after Mr. Burbank had worked on it for a few generations, but when it was by no means perfected.

of organic nature of a good deal of its orderly character.

And so it appears, so far as may be judged from my experiments, that even when hybrids between these divergent forms are produced, the offspring are sterile, and the results of the hybridization are not perpetuated.

Such, then, is the barrier that nature erects in the interest of race preservation, between species that have widely diverged.

But, on the other hand, we have seen many illustrations of the fact that when species a little more closely related are hybridized, the result may be not to produce sterility but to give added virility to the offspring.

We saw this illustrated, for example, when the walnut of the eastern United States was crossed with the black walnut of California. The hybrid progeny not only showed tremendous individual vitality, growing with great rapidity and to enormous size, but they produced an altogether extraordinary abundance of fertile fruit.

The hybrid variety thus produced—named, it will be recalled, the "Royal"—constitutes a new race that can more than hold its own against the parent forms.

And the reason for this, seemingly, was that the two species of walnut had not become sufficiently divergent to introduce a greater diversity of conflicting tendencies than is consonant with racial progress when the strains are brought together.

But it will be recalled that when the California black walnut was hybridized with the English walnut—producing the "Paradox"—the results in this regard were quite different. While the individual offspring showed great vitality, they were almost sterile, producing only a few stray nuts in contrast with the profusion of the Royal hybrids.

And we may infer from this result that the California walnut and its remote English cousin have diverged to a point lying just on the border line of the limits of desirable racial mingling.

These limits have not quite been crossed as they have been in the case of the dewberry and apple tree, and the strawberry and raspberry, but they are being approximated; and there is no probability that the hybrid offspring of the black walnut and the English walnut could maintain itself through successive generations as a new race in a state of nature. At all events, its fight would be a doubtful one.

The Application to the Human Species

It is more than likely, then, that the lessons taught by the unsuccessful experiments recorded in this chapter are quite as important as if they

The Perfected Solanum

A later stage of development of the new Brazilian Solanum shown on page 297. Mr. Burbank has now developed the fruit by selective breeding until it is of considerably increased size, and markedly improved in flavor. A few more lessons need to be given before the plant is marketable; but the new Solanum promises to be a valuable addition to the vegetable garden.

had led to seemingly more practical results. For they serve to emphasize a great fundamental truth of heredity, which has a more important bearing on the problems of racial development of all organic beings, including man himself. It has become more and more clear in recent years that the underlying principles of evolution apply in large measure to plants and animals alike, and that much may be learned about the proper breeding of mankind from a direct study of the breeding of the lower organisms.

And as regards the particular case under consideration, it is scarcely to be doubted that we may draw important lessons from the obvious results of the hybridizing of plants to apply to the commingling of human races.

It is commonly held that the various existing races of man constitute a single species. But this classification was made under the influence of the old idea that sterility of offspring is a valid test of specific difference. No one nowadays holds that view, with regard to plants at any rate, and the view is probably no more valid in its application to a great number of animals, including man himself.

But, in any event, the question as to whether mankind constitutes a single species or several species is a matter of definition of no real importance. It is beyond question that the human family comprises widely divergent races, and it is scarcely open to question that the divergencies in many cases are so pronounced as to make hybridization between these races inexpedient, even though it still is possible.

The student of history tells us that the great civilized races of the past were all mixed races. This was true of the Egyptians, the Babylonians, the Greeks, and the Romans. It is true of the chief nations of to-day.

But the races that intermingled to produce the great peoples have always been somewhat closely related. No good result has ever been achieved, for example, by the commingling of Mongolian and Aryan blood, or of Aryan with Negro. Such wide crosses must be expected to produce at least a measure of infecundity, and a commingling of racial tendencies too divergent to be advantageously blended.

The case is comparable to that of the Paradox walnut, even though it be not quite so extreme as the case of the hybrid strawberries and dewberries.

But what chiefly concerns us now is not the past history of mankind, but the present and future history; and in particular the history of mankind here in America. There is taking place

Aid from the Butterfly

This picture shows the butterfly at work on the Prince's Feather or Cockscomb flower. The butterfly plays by no means so important a part as the bee in plant fertilization, yet it constantly transports pollen, and there are many types of tubular flowers that depend entirely on butterflies or moths for cross-fertilization. We think of the butterfly as leading an absolutely aimless life, but it is a very useful citizen in the flower garden.

in our day what is doubtless the greatest migration in all history. The races of Europe are flooding into America, and there is a more pronounced commingling of racial strains now taking place on our soil, than perhaps ever occurred in any one place, or in any single epoch, in the history of the world.

America owes its present greatness in considerable measure to the mingling of moderately divergent strains in the past; but this fact should not blind us to the menace that lies in the mingling of races that are too divergent to blend advantageously.

And it is at least an open question whether certain of the Latins, the varied races of Slavs, and the vast hordes of Semites that have come to us in recent years can mingle their racial strains with the Anglo-Saxon stock without disadvantage to the ultimate progeny.

It is this thought that I would put forward as the most important suggestion that arises from the study of the hybridizing experiments in which I unsuccessfully attempted to blend the hereditary tendencies of certain races of plants that were too widely divergent.

[End of Volume II]

List of Direct Color Photograph Prints in Volume II

Walnut