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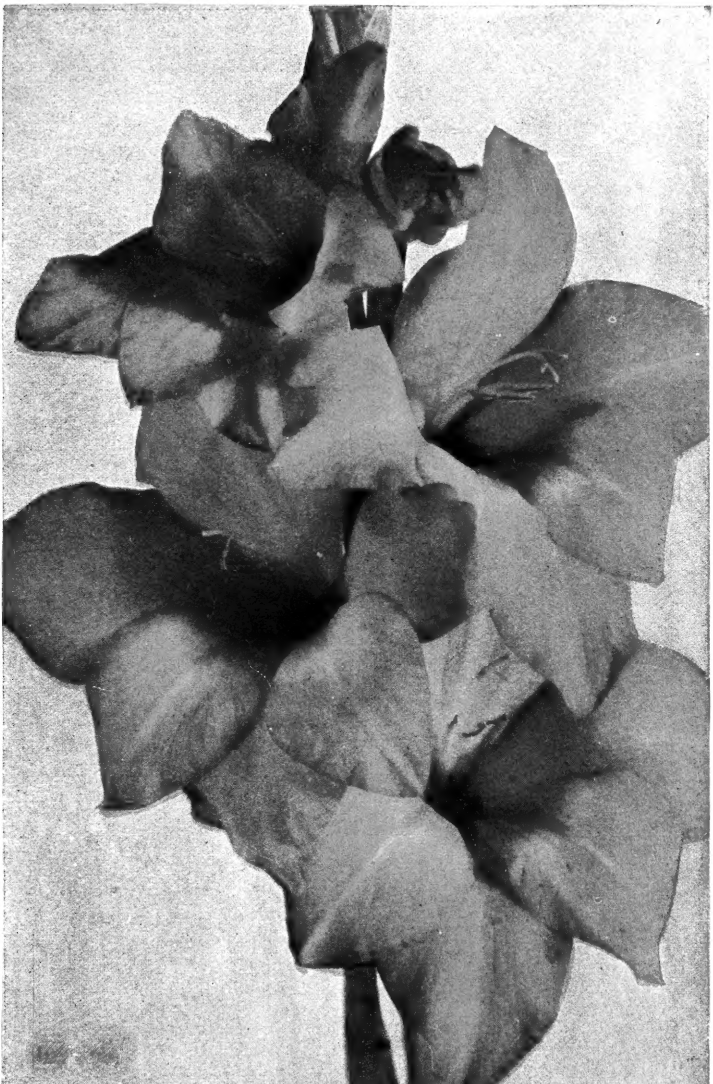

LARGE SIZE AND COMPACT GROWTH

A quality sought by Mr. Burbank in the development of the gladiolus was the habit of compact growth on the stem, so that the flowers should be solidly massed, instead of being scattered along the stem. The brilliant blossoms pictured here indicate striking success in the matter of compact growth, as well as in the increased size and symmetrical form of the flowers themselves.

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HOW PLANTS ARE TRAINED
TO WORK FOR MAN

BY LUTHER BURBANK Sc.D

FLOWERS

VOLUME VII

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EIGHT VOLUMES · ILLUSTRATED
PREFATORY NOTE BY DAVID STARR JORDAN

P. F. COLLIER & SON COMPANY
NEW YORK

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TEACHING THE GLADIOLUS NEW HABITS

The Mutability of Species

THE history of the growth of ideas shows some curious paradoxes. As a minor illustration, it may be recalled that an English clergyman was doing his best—and a very good best it was—to build up evidence of the mutability of natural species at a time when it was rankest heresy to suggest that species are mutable.

The clergyman in question was the Honorable and Reverend Dr. William Herbert, Dean of Manchester. His work was carried out in the early decades of the nineteenth century. He was a horticulturist of great skill, and he labored assiduously with many plants. And among those with which he attained conspicuous and striking results that seemed to belie the botanical beliefs of the period, was the plant now familiar in every garden as the gladiolus.

The time when the important work of this clerical amateur was carried out was one in which such men as Erasmus Darwin, the poet Goethe, and the French biologist Lamarck were advocating the idea of the mutability of species. And no doubt the Rev. Herbert had some of their theories in mind as he went about his plant experiments in the gardens of the Manchester Deanery.

Yet in the main he was probably quite unconscious of the full significance of the experiments that he was performing.

The particular experiments that are of interest to us in the present connection are those in which he hybridized one species of gladiolus with another, and in so doing not only produced new races of gladiolus, but proved to his own satisfaction that these new races were altogether fertile.

Almost half a century later Charles Darwin in his "Origin of Species" had occasion to quote the opinion of the Rev. Herbert, based on his experiences with this flower and several others, to the effect that hybrids are not necessarily sterile —a point that was still ardently in debate. He even cites Herbert as having claimed that the hybrids gained in fertility over the original species—a fact which Herbert himself regarded as being "a strange truth," but regarding which Darwin, writing with fuller knowledge, asserts that it was by no means so strange as it would appear.

To be sure, nothing revolutionary came directly from the reverend horticulturist's experiments. He produced interesting new varieties of flowers, but the theoretical bearings of his work were doubtless quite ignored by his fellow clergymen and, indeed, as I have already suggested, were probably only vaguely realized by himself.

Yet as we look back on this work now, from the new point of vantage that Darwin gave us, we can see that the work of this amateur horticulturist must have had its share in disturbing the ideas of at least some of the persons to whose attention it came, and in preparing the way for the new view of the flexibility of species that now seems so much a matter of course that we can hardly realize how revolutionary it seemed to our forbears of two generations ago.

A demonstration made with a plant that grows in everybody's garden has force that comes home to us more cogently than records of any number of observations of animals and plants of tropical forests and South Sea archipelagoes. And a number of new species of plants, gladioli among others, that the Dean of Manchester created by hybridizing old ones made their way into the gardens of Europe, and gave their message, we may be sure, here and there to a receptive mind in substantiation of the disputed evolutionary doctrine, which, even before the publication of Darwin's "Origin of Species," was exciting the interest of the thoughtful.

Other Gladiolus Hybrids

Before the gladiolus made its full conquest of the popular gardens, however, it was further improved by other gardeners, both in England and in continental Europe.

The species that the Rev. Herbert had crossed were the showy *Gladiolus cardinalis* and the smaller but more free-flowering *Gladiolus blandus.* Subsequently he crossed a number of other species, and produced races of great beauty and fertility. But a race produced by Mr. Colville at Chelsea in 1823, by fertilizing the form known as *Gladiolus cristus* with the pollen of *Gladiolus cardinalis* gained additional popularity.

It was not until 1837, however, that the form was originated which was to make actual conquest of gardens throughout Europe, and presently to attain corresponding popularity even in America. This new form which became the parent from which most modern varieties of gladiolus have been developed was raised in 1839 by M. Bodinghaus, gardener to the Duc d'Arenberg of Enghien. Like the other hybridizers, he used *Gladiolus cardinalis* for one parent form, the other parent being a species known as *Gladiolus psittacinus.*

We have seen that the *cardinalis* was used by the earlier hybridizers. It appears that the *psittacinus* was also used in hybridizing experiments by the Dean of Manchester. But either he did not make the precise cross that was now made by the Belgian gardener, or the strains he used were somewhat variant; for the hybrid now produced had qualities that gave it a new appeal to flower lovers in general, and in particular made it a flower of such easy cultivation and such striking appearance as to make a strong bid for popularity among amateurs.

It gained such vogue as to be thought of everywhere not only as a distinct species but as representing a type form of the race of gladioli. It was named *gandavensis,* from Gand (Ghent), the place of its origin.

It is believed, however, that the form of gladiolus that came to be known everywhere as the *gandavensis* has in its racial strains the blood of many other species beside the original parents. It is almost certain, for example, that the strain

A NEW GIANT GLADIOLUS

This is a variety selected for size of the individual flower, rather than for arrangement of flowers on the stalk. It illustrates the accentuation of size to about its present limit. (One-half life size.)

of *G. oppositiflorus* accounts for the modifications of form and for the introduction of a tendency to produce white flowers; and that strains of *G. blandus* and *G. ramosus* have also been introduced.

In a word, the form of gladiolus that came to be familiar everywhere under the name *gandavensis* is not merely a hybrid, but a hybrid that probably carries the racial strains of at least four or five species, and possibly of many more than that.

All of which is essential to an understanding of the later developments of the race of gladioli.

For when we come to investigate the pedigrees of the chief races of gladiolus that are now found in our gardens, we learn that, practically without exception, they are hybrids that carry the *gandavensis* strain among others, and hence are multiple hybrids, the precise lineage of which is too intricate for tracing.

It is this fact that accounts for the wide range of variation as to form and color that characterizes the gladioli of our gardens. For the hybrid races have practically supplanted the original species everywhere.

The same thing is of course largely true of most other cultivated flowers, and it is altogether true of the cultivated fruits and vegetables. As regards a large proportion of these, the cultivated varieties have not only supplanted the original species, but no definite record remains of the original species themselves. The case of the gladiolus differs, and gains added interest, in that the original species were brought from southern Africa to Europe only a little more than a century ago. The development of the new hybrid races under cultivation, and the elimination of the parent forms by their improved descendants, has taken place in so comparatively short a time that its chief steps are matter of record, as we have seen.

So the story of the gladiolus has elements of educational interest for the plant developer that are quite lacking in many of the cultivated plants which attained relative perfection at an earlier period.

Early Work at Santa Rosa

There are a few species of gladiolus that are native to Europe and Asia, but the ones that were chiefly used by the early hybridizers came from South Africa, as already related.

Doubtless this fact was not without significance in determining the results of the work of the early cultivators. We have seen illustrated more than once the effect of transplanting a plant to new soils, and in particular of transporting it from one hemisphere to the other.

We cannot doubt, then, that the change in the seasons and in the soils and climatic conditions in general had a share in promoting the variability of the gladiolus when brought to Europe, although, as we have seen, the tangible stimulus to variation was given through the now familiar method of hybridization.

And, by the same token, we may suppose that when the gladiolus was finally brought to California, shifted thus halfway round the globe from its new home in Europe, there was an added stimulus given, urging the plant to still further modifications of habit, and supplying yet other elements of variation with which the plant developer might work.

At all events the gladioli in my gardens at Santa Rosa and Sebastopol have proved responsive and adaptable. And further modifications have been produced in the much modified flower that add greatly to the value of what was from the outset one of the most popular of ornamental plants.

I began work with the gladiolus about the year 1882, starting with the *gandavensis* hybrid, the origin of which has already been described.

At that time there was no great interest taken in America in growing gladiolus seedlings, but I was able to secure a large number of the best types of *gandavensis,* and also obtained bulbs of about a dozen of the natural species.

The material was obtained not alone from American growers and the cultivators of Europe, but also directly from South Africa.

From the outset experiments were begun on a comprehensive scale, raising the gladioli by the half acre and acre on my Sebastopol place. The first fault observed in the gladiolus was that the blooms would not stand our California sunshine.

Under the glare of the California sun, the blooms would wither in a single day, sometimes in a single hour.

Other serious defects were that the stalks were too slender, and the flowers too far apart on the stalk. Moreover, the flowers were small, they were illy arranged on the stalks, giving an untidy appearance to the plants; and often they were only half open when at their best.

The colors of many varieties, on the other hand, were fine, it being evident that selection had been made largely for color, by some at least of the earlier experimenters. My first object, then, was to remedy the defects just mentioned rather than to modify the color of the gladioli.

In particular I sought, while improving the stalks and the arrangement of flowers on the stalks, to make the petals of the individual blossoms stand out flat and in regular sequence.

The work progressed along the lines of hybridizing and selection with which the reader is already familiar, introducing strains of the long-neglected natural species to give added virility and stimulate still further variation, thus providing materials for selection.

Growing the plants by the acre, abundant material for choice was at hand and my usual method of choosing only a few of the very best representatives of the different forms that seemed worth developing, destroying the rest, was rigidly exercised.

In the course of a few years there were developed varieties which were introduced with new names, and which made their way everywhere, and were highly prized by gardeners throughout the United States.

Doubtless the most interesting development in this early period was the form named the California. This was a really magnificent semi-double variety which not only excelled in the form and size and color of the individual blossoms, but which had the added peculiarity of

ONE OF TEN THOUSAND VARIATIONS

The arrangement of color shades and color patterns in the newer gladioli is very remarkable and could never have been believed possible except by its actual demonstration in evidence. (*One-third life size.*)

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bearing the blossoms all around the stalk like a hyacinth, instead of merely on one side of the stalk as had been customary with all other varieties of gladiolus.

Even at the present time, although the varieties of gladiolus have been subject to rapid development within the past few years, I recall the California as one of the most beautiful flowers of the family.

Unfortunately this variety was lost, probably by freezing, along with the entire stock of other gladioli, by a Philadelphia dealer to whom it was sold.

My gladiolus colony progressed admirably, and the new forms attained a degree of virility that made it no more difficult to raise them than to raise potatoes; indeed, much less difficult, inasmuch as the gladiolus bulbs in California do not require to be dug or stored, but continue their growth throughout the year. The only object in digging them is to divide and separate them for multiplication.

The forms of the plants, and the manner of bearing, as well as the shape and arrangement of the blossoms, improved year by year, and the new varieties of gladiolus came to be well known to dealers throughout the country, and were still under process of development when an unexpected complication put an end, for the time being, to my further work with this plant.

War with the Gopher

The complication manifested itself in the discovery that entire rows of the gladiolus bulbs had been eaten by pocket gophers, which had tunneled their way into the grounds, and, boring beneath the gladiolus beds, had feasted on the bulbs, destroying large numbers of them (mostly during the dormant season) before I discovered the presence of the marauders.

The plants do not wither at once even when the bulbs are greatly injured, or in the dormant season totally destroyed. So long rows were destroyed before I knew the necessity of combating the enemy.

The attempts to exterminate the pests were at first so unsuccessful that I presently decided to give up the gladiolus colony altogether. I sold the entire lot to an amateur Canadian horticulturist, Mr. H. H. Groff, a banker, of Simcoe, Ontario, and for a good many years my experiments with the gladiolus were not renewed.

Meantime, every effort was made to exterminate the pestiferous gophers, whose depredations were of course not confined to the gladiolus, and through which I suffered an annual loss of certainly not less than a thousand dollars year after year.

Not alone with the gladiolus but with other bulbs it seemed that the animals took special delight in attacking the choicest plants. And the question of their destruction became finally a very urgent one.

Numerous methods of combating the pests were tested. A double box trap set in gopher holes was cumbersome and not very effective. An awkward iron trap was supposed to catch the gopher when he poked his nose against the trigger, but missed fire or failed to score a hit oftener than otherwise. One form of trap after another was tried and given up. Attempts to smoke out the animals proved ineffective, as the gopher instantly builds a wall to shut out the smoke.

Bisulphid of carbon, which gives off a poisonous, heavy gas, was tested with equal lack of success. About the only resource was the use of poison, commonly called strychnin, placed on a piece of apple, potato, or carrot, combined with the use of a wire trap, in the hope that if one failed the other might prove effective. But in spite of all these methods the gophers multiplied, mostly from neighboring fields, where their damage to ordinary farm crops was not so marked. A few years ago, however, a gopher gun was invented that practically solved the problem. This consisted of a trap so arranged that when the gopher pokes his nose against the trigger a charge of powder explodes beneath the animal, killing him instantly by concussion.

This device proved more effective than all others. Sometimes thirty-five or forty gophers were destroyed in a day about the borders of my gardens. And in a short time the gophers were so nearly exterminated that they ceased to be a serious pest.

When these old enemies of the bulbous plants were thus finally subjugated, after years of effort, I determined to take up again the cultivation of the gladiolus.

In the meantime, the gladiolus had been much under cultivation elsewhere, and its general and special qualities had been greatly improved.

But there remained plenty of modifications that could be made to advantage, and in starting a new series of experiments I had no difficulty in discovering faults to be remedied.

Recent Work with the Gladiolus

One of the modifications, to which reference has already been made, had to do with the arrangement of the flowers on the stalk. My success in developing a race having the flowers arranged on all sides of the stalks has already been referred to. In taking up a new series of experiments, the attempt was made to improve on the earlier varieties, by shortening the stems of the flowers, so that they were compelled to arrange themselves more compactly around it; by insuring regularity of placement; and by diversifying the plant arrangements in various ways.

Some forms were developed having two ranks of flowers, one on either side of the stem. Other races were developed with flowers in four ranks; yet others with flowers in a spiral. Meantime the individual blossoms were enlarged in size, and their stems shortened, so that, when grown in a spiral about the stem, they crowd one another, making practically a solid mass of petals.

The contrast in appearance of a stem of gladiolus flowers arranged on this new plant with the old form in which the blossoms grew only on one side of the stem, or at most on opposite sides, is very striking.

Attention was given also to the modifications of the form of the individual flowers. In one form, petals were developed that are broad and ruffled so that they overlap, and thus give the appearance of a double flower. In another form the tendency of the anthers to turn to petals was

AN UNUSUAL COLOR IN THE GLADIOLUS

This is a rather unusual color. Notice the flat, open flower—a quality prized in the gladiolus. (One-third life size.)

accentuated through selection until double varieties were produced; and in some cases the extra petals were added without affecting the stamens.

In yet another form, and one that I personally admire most, two flowers appear to be fused into one, so that twelve petals are presented instead of six. The variety was fixed so that the flowers on every stalk come in the same way, constituting a double flower of an unusual type.

Particular attention was also paid to the development of regularity of petal in the case of the double gladiolus flowers. Irregularity of petals may be attractive in such flowers as the rose and the carnation, but with the gladiolus the double blossoms are less beautiful than the single ones, unless the petals are very regular.

There was no great difficulty, however, in making the petals regular, as well as increasing their number by selection.

Studies in Color

In the newer series of experiments, especial heed was given, also, to the matter of color variation, seeking for clear and brilliant colors of varying shades. The blending of shades, and the arrangement of lines, dots, and edges of different color on the petals were all carefully taken into account.

There is opportunity for skill in the blending of different shades in a flower of such diversity of color as the gladiolus, far greater than the painter's skill in applying colors to the canvas.

One learns that there are certain combinations that will produce disagreeable colors, whereas others will result in new shades of exceptional brilliancy.

The characteristics of each flower to be selected for combination must be carefully studied.

If, for example, we cross a yellow gladiolus with a white one, we are likely to get a dingy white that is by no means agreeable, though not by any means necessarily so. The cross of a pale pink with a white form is likely to give us a still paler pink, which would not be regarded as an improvement. Again, from the blending of two nearly white strains, you may even get dark colors in unpredictable combinations.

By studying the combinations, however, and making rigid selection among the seedlings, it will be discovered that there are certain tendencies that tend to be dominant and that as a rule may be expected to repeat themselves in the hybrid offspring, overshadowing the less fixed colors. Still the races of gladioli are so blended, and their color factors so mixed, that one may confidently expect to find new and interesting combinations among any large lot of hybrid seedlings.

Indeed, it is not necessary to make new crosses in order to get interesting new types, since, as we have seen, all cultivated races of gladiolus are hybrids that carry many racial strains, and hence manifest the tendency to vary that we have seen everywhere manifested by hybrids in second and later generations.

It is of course possible to exert a powerful directive influence through selecting parents for crossing, and further direction may be given by selection among the seedlings for any given color or combination of colors. So new races with unique color combinations may be very readily developed, and, even if these are not at once fixed, they can of course be propagated indefinitely by bulb multiplication. Here, as with other plants, all forms grown from the offshoots of a bulb will reproduce the qualities of the parent form, and a new race may thus be multiplied indefinitely.

Notwithstanding the great diversity of colors of the different races of gladiolus, there have until recently been no good gladioli that could accurately be described as pure white.

Where so-called white varieties have appeared, they have a dinginess that suggests the presence of an underlying color; also there are spots, stripes, or featherings of other colors, especially on the lower petals. That the hereditary factors for color are really present in these so-called white flowers is demonstrated by the fact, already noted, that in crossing two of these we may produce varieties that bear colored flowers.

But the fact that these crosses of white gladioli produce flowers showing a great diversity of color, suggests obviously the possibility of selecting among these offspring, in the second generation, some that contain only the hereditary factors for whiteness, and by rigid selection I have produced a race of white gladioli which, when further perfected, will constitute an interesting acquisition. Already these are partially fixed. Other growers of gladioli have observed the same fact.

Already the white gladioli breed fairly true, and further selections, with reference to the perfection and fixation of the type, will give us a race of white gladioli that will meet the approval of the public. But here as elsewhere there is danger that in selecting for one quality other qualities will be neglected, so that the flowers are not kept up to their best standard.

Until quite lately there has been no blue color in gladioli, any more than in the poppy, except, perhaps, submerged in combination with some of the darker colors. And for this reason, it has been found by all growers of the plants far more difficult to produce a blue flower than any other color, and until quite recently nothing approaching the really blue gladiolus had been produced.

The first blue ones introduced were in reality more purple than blue. Nearly all hybrid varieties have shown lines of pale or smoky blue at times.

The first gladiolus that could really be called blue was the one sent out from Europe under the name of Madame Hulot. This had a small flower, and in other respects resembled the older gladioli—a dark purplish blue in color. By crossing this with white varieties of large size, pale blue with extra large fine flowers were produced. Two years ago one appeared, of very large size, and perfect in all respects with a true blue color.

The crossing of the gladiolus presents no difficulties. It is merely necessary to cover the three-parted stigmas with pollen of the desired

A SAMPLE GANDAVENSIS PRIMULINUS HYBRID

The gladiolus having this type of spike has departed rather strikingly from the traditions of its tribe as to arrangement of the flowers along the stem. But there is something strikingly attractive about the manner of clustering adopted by this variety, and we may feel sure that this specimen will be among those selected and allowed to go to seed, in the interests of future generations. (Not quite one-half life size.)

parent so thickly that bees and humming birds cannot interfere with the experiment.

In working on a large scale, it is convenient to place rows of different forms that one wishes to hybridize side by side, so that pollen may be readily transferred from one row to another, in walking along the rows each forenoon when the stigmas are receptive. Also this arrangement allows the hybridizing to be carried out by the humming birds which are always aids in the fertilization of these tubular flowers. Here, as in most other experiments, I have found that the results of the reciprocal cross are the same; it makes no difference which parent is the staminate and which the pistillate member. So the seed from the contiguous rows of gladioli thus hybridized may be saved in a single lot.

New crosses and rigid selection are giving larger flowers, brighter colors, more compact stalks, and a tendency to multiply more rapidly from the bulblets—and especially with greater freedom from disease. The propensity to revert toward the original type of the wild species—small flowers, long slender stalks, closed blooms, dull coloring, narrow leaves, and poor constitution—is being subordinated as the selection is carried through successive generations.

And while there will be no metamorphosis in the essential characteristics of this beautiful and popular flower, further modifications of detail that are of no small practical significance may confidently be expected.

We may well suppose that when the gladiolus was finally brought to California, having been shipped first from South Africa to Europe and then from Europe halfway round the globe, there was an added stimulus, urging the plant to still further modifications of habit, and supplying yet other elements of variation, such as form the basis of all plant development work.

THE CANNA AND THE CALLA

And Some Interesting Work with These So-Called Lilies

THE first canna of my own production is the one named the Tarrytown. This canna took the grand gold medal, at the Pan-American Exposition at Buffalo, as the best canna exhibited at that time. There were large numbers in competition.

In addition to receiving the gold medal, the Tarrytown was given special mention as being the most profusely blooming canna ever seen.

This canna is a rich brilliant crimson in color, and is rather dwarf in size, standing not higher than three feet. Instead of producing a single offshoot from each stalk or at most three or four, as a good many even of the better varieties of canna did at the time when this was produced, the Tarrytown grows from six to nine offshoots of the main stalk. Thus it makes a splendid and highly effective display.

The individual flowers are of good substance, enduring the sun well.

After the blossoms fade, the petals drop to the ground. This is a special feature for which careful selection has been made, as many cannas tend to hold shriveled blossoms, thus having an untidy appearance.

Origin of the New Canna

The Tarrytown canna was developed from the type known as the Crozy canna, hybridized with a native species of the Florida swamps known as *Canna flaccida,* a plant with extremely large flowers of pure lemon yellow.

The Crozy canna was a well-known horticultural variety, developed in somewhat recent years, which differs from the varieties that were previously in vogue in that its flowers are very large, notably attractive, and of varying colors. Until the cannas of the Crozy type were developed, this plant was prized chiefly for its foliage, the flowers being rather insignificant. But the Crozy canna has large flowers, to casual inspection similar to those of the gladiolus.

The Florida species (*C. flaccida*) that was used to hybridize with the Crozy, has very fine large petals, but the flowers are not lasting. But it blended well with the other type, and introduced an element of variability that facilitated selection and development along the lines similar to those characterizing the perfected Tarrytown; also the Burbank, Austria, and Italia, since introduced.

The Crozy canna is itself a hybrid, one of the parents being a form known as *Canna iridiflora,* a tall plant with long, dark green leaves, and with a long drooping panicle of rich crimson flowers. I have experimented with this form, but have never known it to produce seed.

The new cross that I effected between the Crozy hybrid and the native Florida species, brought together strains widely diversified. The tendency to variation was very obvious even in the first generation, as might have been expected considering that one of the parents was itself a hybrid.

From the same hybrid strain it was possible to select a number of plants showing individual peculiarities that seemed worthy of perpetuation.

The qualities developed in the Tarrytown have already been outlined. Another race developed simultaneously, through a different series of selections, differed very markedly, in particular as regards the character of the flower, which took on so characteristic a form, and colors of such elusive quality, as to merit the name of Orchid-

A SEEDLING CANNA

While the canna does not vary from seed nearly as much as the gladioli and dahlias, yet the variation is sufficient to make the growing of seedlings interesting.

flowered Canna. It chanced that experimenters in Italy produced simultaneously and quite independently a race of cannas having closely similar qualities.

The best of my cannas of this type was introduced under the name of The Burbank.

This plant rather closely resembles a variety known as the "Austria," which was introduced about the same time from Europe. The Burbank, however, is somewhat larger, and has thicker and more rubberlike foliage; and its flower is slightly less crimson in the throat.

Working with the Canna

The cross-fertilization of the canna should seemingly present no particular difficulties to anyone who studies the mechanism of the flower.

The stamens have a petallike appearance, and the pollen mass could not be transported by the bee or any other small insect. Large moths may carry it from one flower to another, but the usual pollenizer of the canna, in this country, is the humming bird.

The hand-pollenizer may readily enough detach the pollen mass, and transfer it to the stigma of another flower.

But it does not follow that hybridizing is easy. In fact, I found it exceedingly difficult, especially when attempting to cross the ordinary canna with the Florida species already mentioned. I worked for eight years with that purpose in view before succeeding. And even then the seedlings were greatly lacking in fecundity, producing very little seed, notwithstanding the fact that cannas in general usually produce seed abundantly in California.

The infecundity of the canna hybrids suggests that the species in question are almost at the limits of affinity. But the seeds produced, although few in number, were some of them fertile, and the hybrid progeny showed possibilities of development, as already suggested. Most of the later generations, however, are almost or quite sterile, refusing to seed.

The chief difficulty in growing seedlings of the canna is to insure the germination of the seed. The familiar name "Indian-shot plant" by which the canna was first known suggests the character of its seeds, which are not unlike small bullets in appearance and in hardness of texture. The old plan of germinating the seeds used to be to file off part of the thick shell, in order that the seed might absorb moisture. This works very well, but can hardly be applied on a large scale.

My own method has been to disinfect the canna seed with a solution of bluestone (sulphate of copper), and place them in coarse gravel, taking pains to pour water through the gravel at frequent intervals. Under these circumstances, the seed is less likely to decay through attacks of fungous pests than if planted in the soil. In the coarse, clean, sterilized gravel, a high percentage of the seed will come up in a few months. The porosity of the gravel, giving free access to air, is also an element that is advantageous to the seed of the canna.

Seed treated in this way will germinate at a relatively low temperature; but germination is facilitated if the heat is kept between sixty and seventy degrees.

As soon as the seedlings appear, they are transplanted thinly into boxes where they are allowed to stand until May, when they are planted in the field and cultivated like other crops.

A large proportion of the seedlings will prove worthless. The weeding out of the first year is done readily, but selection in the second year requires skill, to judge as to which plants are worthy of preservation. Beyond that, of course, the usual process of selection through several years will be carried out along the lines of the desired modification at which the experimenter is aiming.

The objects that the experimenter may advantageously bear in mind in developing new cannas include hardiness, the production of a double flower, and the production of a white flower, among others.

In California the canna may be left out-of-doors over winter; indeed it does much better when so treated than when the bulbs are lifted and stored. In the northeastern States, it is necessary to dig the roots and store them where they will not be subject to too low a temperature. It will be of advantage to develop the canna to a stage of hardiness that would enable it to be treated as an ordinary perennial, leaving the roots in the ground and only dividing them now and again for purposes of propagation. Still this might require more work than is worth giving to the task, inasmuch as the canna is already grown far to the north, and the work of digging and storing the bulbs is not excessive.

A double canna would certainly be a novelty and one that is worth working for. The same is true of a pure white canna. By hybridizing and careful selection, it should be possible to develop this novelty, judging from analogy with other flowers. Of course it is possible to increase the size of the flower, and to produce other color variations along the line of recent developments. Most important of all, the flower should be made more lasting. Just now white cannas of very good quality are appearing and every desirable quality in plant and flower are being brought forth from year to year.

Improved Callas (Richardias)

The manner of production of my fragrant calla was described in an earlier chapter.

It will be recalled that this anomaly was produced through selection from an individual found among a large company.

The question of odor and its variation in flowers was further discussed in a recent chapter. There appears to be, in point of fact, as wide a range of variation among flowers in the matter of odor as in regard to color. But inasmuch as most selective experiments have been made with reference to color and quite without regard to the matter of odor, the cultivated plants have naturally developed along the lines of color variation, and even those that were originally fragrant have in many cases lost their perfume.

Improving Essential Oils

In recent years, however, much more attention has been paid to this matter. In particular, the studies of the chemistry of essential oils, with reference to the production of artificial substi-

ANOTHER SEEDLING CANNA

This is a very pleasing variety of canna, the characteristics of which are well revealed in the picture opposite. The blossoms are individually of large size, and are borne in profusion.

tutes for the natural ones, has given clues that the plant developer is beginning to take up.

I have been requested, for example, to improve the clove and the cinnamon, as well as the coffee plant, in the production of races having a higher percentage of the various essential oils for which they are prized.

Coffee, as everyone knows, depends very largely on its aroma and fragrance, and it has been found that these may be greatly modified according to the soil in which the plant is grown. The fragrant qualities are often greatly intensified when the plant is grown on volcanic soil and at a high altitude. It is known that various spices differ markedly. In the same way the quality of alkaloids, such as caffeine and quinine, may vary in the same species under different conditions of soil and climate. There is a species of coffee that is practically without caffeine; but this has little aroma. It has been proposed to combine it with the Arabian coffee and it may be possible to produce a coffee without caffeine—which may or may not be popular.

Among garden plants that are prized for their aromatic quality, the thymes vary widely in the amount and quality of their essential oils.

The notable variation in the odor of the calla, which gave the scented variety, is duplicated in a good many species of plants. The individuals even of the wild species vary, some of them having a really delightful fragrance, and some none at all. In crossing the different individuals, you may accentuate the perfume, add one element of fragrance to another; or, on the other hand, you may make such a combination that the two aromas seem to neutralize each other, producing an odorless hybrid.

The plant developer who works with these anomalies in mind, paying heed to the fragrance of his flowers as well as to their other qualities, is almost certain to produce varieties that will be appreciated, for, as already suggested, the perfume of the flower and the flavors of foods are nowadays receiving more attention than formerly.

New Giant Callas

I have introduced four main varieties of calla in addition to the calla Fragrance.

This work began largely with raising seedlings for the trade, from the form of calla known as *Richardia albo-maculata,* a dwarf variety with spotted leaves that was at that time very popular.

The leaves of this plant bore attractive white or transparent markings on the bright green surface. The flower was white, with a brown tinge at the base, and in the original form was insignificant.

Among these almost numberless seedlings appeared, now and then, a golden variety, but this proved difficult to fix, although very handsome and attractive.

Presently I secured another variety of calla known as the Pride of the Congo, *Richardia hastata.* This is a much stronger grower than the other variety and has pale yellowish flowers larger than those of the *albo-maculata.* Many seedlings were raised from this variety on my Sebastopol farm, and developed by selection until it produced very large bulbs.

Then the two species were crossed, using our own hybridized golden variety of the *R. albo-maculata* and the highly developed varieties of *R. hastata.* The cross was made reciprocally as usual, and here as elsewhere it appeared to make no difference which was the staminate and which the pistillate parent.

The hybrids vary considerably as to bulb, plant, and flower—much more so than either parent species when raised from an uncrossed seed. And among the hybrids there were some plants that produced enormous bulbs, sometimes eight or ten inches in diameter and weighing from two to six pounds each. The plants that grew from these bulbs were of large size and bore blossoms that were of much brighter yellow than those of either parent.

This plant was introduced under the name of the Giant Calla, a name later changed to Lemon Giant.

Subsequently I obtained a number of other species of calla, including those known as *R. Elliottiana, R. Pentlandi, R. melanoleuca, R. Nelsonii,* and *R. Rehmanni.* These were all hybridized with one another, and with the species that previously was in hand.

Among these complex hybrids were plants that were very unique in form and foliage and flower. The blossoms varied in color not only in the different hybrid plants, but sometimes an individual blossom would be partly deep purple, partly deep yellow, and in part almost white. Sometimes the colors were mottled or striped, but usually the purple color appeared in the throat of the flower.

The purple is apparently a combined inheritance from the *Elliottiana, Rehmanni* and *melanoleuca;* and the *hastata* also has a faint touch of it. The yellow is heritage from *hastata* and *Elliottiana.*

These plants varied as much in size as in quality of flower. Some of them grew three and a half feet in height, others only eight or ten inches. In some cases the foliage and stalks were smooth and in others actually hairy, covered with soft excrescences of thornlike appearance. Some of the hybrids were very easy to raise, but most of them quite difficult.

Among the freak forms that appeared in this hybrid colony were plants bearing double and even triple flowers, and others in which the flowers and leaves were combined in the most curious manner. Of course the so-called flower of the calla is a modified leaf that has not altogether lost the leaflike form and manner of growth. So the reversion through which the flowers become still more leaflike in these mixed hybrids was perhaps not altogether surprising. But the particular manifestations of the tendency to reversion were most astonishing.

Other New Varieties

Among the hybrids that departed less markedly from the calla traditions were some that bore flowers of a splendid deep yellow, and that had all desirable qualities of easy multiplication and abundant blooming.

Some of these have a purple spot low down in the throat, others are a pure yellow, not dissimilar in appearance to my early varieties.

GIANT AND DWARF CALLAS

We have developed the flower of the calla in both directions, producing both giants and dwarfs. The one at the left in this picture is perhaps the smallest calla ever developed. Its spathe measures only two inches across, while the blossom of the new giant measures eight inches across.

But while the new hybrids outwardly resemble some of the early varieties developed by selection, they showed their inherent difference in that they are exceedingly easy to cultivate, whereas the earlier ones were subject to decay without apparent cause at any season of the year. The new hybrids are hardier, and can be raised much more readily. They will grow out-of-doors in any mild climate, and require scarcely more attention than so many potato plants. They are reasonably indifferent to the conditions of moisture and a moderate degree of cold does not in the least discourage them.

The contrast in this regard between the newer hybrids and the earlier yellow varieties is very striking. They furnish an illustration of the added vitality that may come through crossing and selection.

The original yellow calla is confined to a limited area in the subtropical regions of South Africa. Its pure-bred descendants, as we have seen, retain the sensitiveness of the parent. But the selected hybrids, while retaining the yellow color of the African plant, have acquired from their other parental strains a degree of hardiness that adapts them to our climate, and at the same time have received increments of vigor that nothing but hybridization appears to give.

THE LEMON GIANT CALLA

My calla experiments have had to do with a number of species which have been variously crossed. Here is an improved variety produced by hybridization and selection that was introduced under the name of the Lemon Giant. The peculiarly flecked leaves, together with the quality of the flower itself, gives it distinction.

Common Lilies

To a fair proportion of country folk, anything that is not obviously a pink or a rose is characterized as a lily.

In fact the diversity among the lilies and allied species is so great as almost to justify the wide implications given the name colloquially. A gigantic calla and a tiny trillium, for example, seem about as far removed from each other as two flowering plants can well be. And the most familiar forms of the tiger lily, which may perhaps be said to be the typical member of its tribe, assuredly bear small resemblance to either calla or trillium.

Nevertheless there is a large group of lilies that bear greater or less resemblance to the typical species, having characteristics of form, no less than of arrangement of stamens and pistils, that are quite unmistakable to anyone having the slightest botanical knowledge.

A large number of these may be hybridized readily, and I have personally worked with a great number of species. But while the results have in many cases been interesting, they have not been very spectacular, or very important, and it is not necessary here to go into details with regard to most of them. It will suffice to tell of two or three typical hybridizing experiments made chiefly with the native leopard lily (*Lilium pardalinum*) as the pistillate parent.

The extent of my experiments with the tribe may be gathered from the statement that at one time on the two Sebastopol farms I had fully five hundred thousand more or less distinct kinds of hybrid seedling lilies. About three-quarters of them were produced by pollenizing the native species just named with all the species from different parts of the world of which I could obtain specimens.

It was found that hybrids between the numerous species of lilies that are native to the Pacific Coast could be made with the greatest facility. Tens of thousands of seedling hybrids between the different indigenous species were produced. But, on the other hand, hybridization with the foreign lilies was found to be rather difficult, different species having seemingly diverged somewhat toward the limits of affinity.

One of the most successful crosses was that made between the species known as *Lilium Humboldtii* and *L. Parryi*. The former has a very large bold, thick petal, white, with large distinct spots, and it is fragrant. The other parent is a tall, slender variety, the flower being clear buttercup yellow, with very small spots or none.

The cross was made with some difficulty, and the result was a lily which some connoisseurs have considered one of the most beautiful ever developed. It grows about four feet in height, and its flower is open bell-shaped, with partially curved petals, brilliantly yellow in color, without a spot or dot, and having a delightful fragrance.

Another interesting cross was that between *L. pardalinum* and *L. parvum*. The hybrids of this cross sometimes produce hundreds of blossoms on a single stem, and several hundred clumps from a single bulb. Not only do they multiply with astonishing rapidity, but in size, color, and abundance of bloom they exceed either parent, although both parents are prolific bearers.

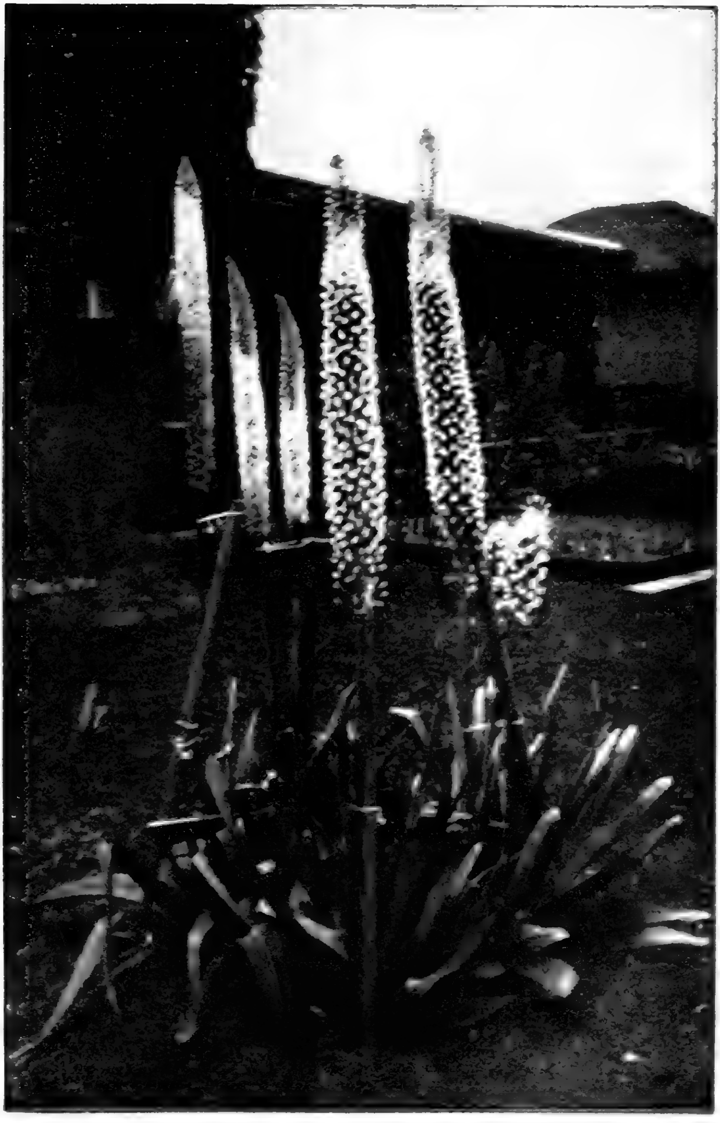
The crosses of the somewhat fragrant *L. Parryi* with *L. Washingtonianum* and *L. pardalinum* produce bulbs having similarly extraordinary powers of multiplication, although in this regard there was a most amazing variation. Certain individuals would produce a hundred bulbs while others of the same fraternity were producing only one or two.

Some of these seedlings would grow eight or ten feet in height, while here and there would be

THE SIBERIAN LILY

(*Eremurus*)

An improved variety of one of the most attractive flowers, the original of which grows wild on the Siberian deserts. These specimens were about six feet in height.



Among the most interesting of these crosses was one in which the so-called Lily of the Incas (*Alstrœmeria*—not a true lily, having no bulb), of South America, was crossed with the familiar California species (*L. pardalinum*), already so often referred to.

Of some of these hybrids I raised a large number, and they presented interesting variations.

Some of them, when they bloomed, seemed almost counterparts of the South American parent except that their petals recurved like those of the California lily. Some were spotted like the California parent, and some were quite without spots. As a rule, however, these hybrids, even though producing fairly abundant foliage, did not blossom at all, and at best they were small and insignificant, and within a year or two most of them had disappeared. They seemed to produce inferior bulbs that could not withstand the winter.

As further evidencing the lack of virility of these hybrids, it may be noted that all of them were dwarfs. In striking contrast to hybrids of the *pardalinum* with other native lilies, none of them grew more than a foot in height and many of them not over six inches.

These dwarfs were rendered all the more striking by the fact that the miniature lilies reproduced in many respects the characteristics of their South American parent.

Another interesting hybridization was that effected between the *pardalinum* and a species of the native *Trillium,* a plant familiar in our woods under the name of wakerobin.

The *Trillium* is, of course, a lily, but, like *Alstrœmeria,* it belongs to a different genus from the leopard lily, and its strikingly different appearance has already been referred to.

The hybrids produced by this strange union were dwarfs with broad, lilylike foliage, with blossoms that resembled those of the *Trillium*—having three very broad, flat, greenish-white or yellow petals, and three narrower petals, like sepals.

A plant that thus bore a close resemblance as to foliage and general appearance to the leopard lily, yet which had blossoms like those of the wakerobin (though somewhat larger and coarser) made a very striking and interesting exhibit.

The species of *Trillium* used in this cross was the common native *Trillium ovatum.*

The hybrids, although in themselves so interesting, proved lacking in vitality, and notwithstanding my efforts all died—not, however, before I had secured several photographs of these strange trillium-lily combinations.

Among all these experiments with the lilies there is perhaps no other result quite as interesting as this hybridization with the *Trillium.* Its results suggest the desirability of further experiments along similar lines.

There is an almost boundless opportunity for new series of investigations with members of this very extensive group. The plants may readily be cross-fertilized by the amateur, and interesting results must follow almost as a matter of course.

The plant developer who pays heed to the fragrance of his flowers as well as to their other qualities, is almost certain to produce varieties that will be appreciated. The perfume of the flower and the flavor of foods are nowadays receiving more attention than formerly.

THE PUREST WHITE IN NATURE

STRIKING COLOR CHANGES IN THE WATSONIA

BULBS are not usually measured by the cord. But I do not know how better to give an idea of my work with the *Watsonia* than to say that in recent years I have destroyed about eight cords of bulbs of this plant each season. A cord, it will be recalled, is 8 feet long, 4 feet wide, and 4 feet high.

If you will picture in your mind's eye eight cords of wood piled together, and recall that the *Watsonia* bulbs have corresponding bulk in the aggregate, and that each individual bulb is of the size of a small gladiolus bulb, you will gain a fairly clear conception of one of the least satisfactory aspects of the plant experimenter's work.

These discarded bulbs, it should be understood, would produce very beautiful flowers. It seems a pity to destroy them, when so many people would be glad to have them for cultivation. But past experience teaches me that I have no alternative in the matter. If these bulbs were permitted to go out they would presently be exploited by some one as "Burbank's Best Watsonias," or under some still more spectacular title, and my reputation as a producer of fine varieties would suffer, as it has many times in the past through similar deception.

So there is no recourse, after selecting the comparatively small numbers of bulbs that give greatest promise for the carrying on of the experiment, but to destroy all of the remainder, even though, as in the case of the Watsonias, these may number a quarter of a million bulbs of considerable intrinsic merit, representing an enormous amount of labor.

A Flower That Rivals the Gladiolus

The *Watsonia* has been somewhat recently introduced, and has made its way slowly. So it may not be superfluous to tell the general reader that this plant bears a close resemblance to the gladiolus. It is indigenous to South Africa, one species being found also in Madagascar, and is represented by a number of wild species, among which two or three have preeminent importance from the standpoint of the horticulturist.

Perhaps the similarity of the *Watsonia* to the familiar gladiolus has interfered with its rapid introduction. Moreover the new plant is somewhat less hardy than the old one, and although it thrives abundantly in the climate of California it cannot as yet be grown satisfactorily in the gardens of the northeastern United States.

But there is one quality of the *Watsonia,* in its perfected varieties, that puts it quite beyond rivalry of the gladiolus. It produces a beautiful snow-white flower. As we have elsewhere noted, there has been, until recently, no truly white gladiolus. But the white of the *Watsonia* has been characterized as the "whitest white" in nature.

In the quality of its whiteness, this flower is perhaps the only rival of the Shasta daisy. Each of these flowers is of snowy whiteness, undimmed by the slightest trace of pigment.

The original wild forms of *Watsonia,* to be sure, are not white. On the contrary, they are of various hues of red and pink. But there is apparently a spontaneous tendency to produce now and again a white variant, for at least two, and perhaps more, of these have been introduced from South Africa that were probably of inde-

SOME OF MY NEW SEEDLING WATSONIAS

I am particularly partial to flowers that have delicate hues. The Watsonias are peculiarly responsive, and I have produced varieties showing delicate tints almost rivaling those of the orchids. Here is a random cluster from my enormous Watsonia colony, but no color tints can be obtained to more than give a hint of the beauty of the flowers themselves.

pendent origin. The white forms that are most familiar under cultivation are so similar that they have been thought to be identical, the origin of one of them being somewhat in doubt.

The white *Watsonia* whose origin is clearly known is descended from a plant discovered about eighty miles from the Cape of Good Hope by Mr. H. W. Arderne, of Cape Town. He took the plant to his garden and in 1892 had a colony of the white flowers under cultivation. In due course they were introduced, and gained a measure of popularity among discriminating horticulturists, chiefly because of the exquisite whiteness of the flower.

Meantime, however, the original species has not been neglected, although comparatively little work had been done, in this country at any rate, in the cultivation of any of the Watsonias at the time my experiments commenced. Possibly the flowers would not have been prized but for the introduction of the white, as the others are rather dull and not particularly attractive in color.

Hybridizing the Watsonia

I have never been able to determine clearly whether the white variety named *W. Ardernei* in honor of its discoverer is identical with the variety introduced as *W. O'Brieni*. They are closely similar, but it seems not to be clearly established as to whether they come from the same stock, although the individuals from which the two races have developed were undoubtedly discovered independently.

On receiving the first bulb of the white *Watsonia* I planted it on a damp piece of sandy land at Sebastopol, but the bulbs did not thrive there, and it was two or three years before any of them bloomed. I learned later through experience that the bulbs do not require too much soil. They thrive especially in soil that contains a mass of leaves, and under proper conditions they put out numerous branching stalks, about four feet in height, which for months together are covered with beautiful snow-white flowers, which have, as already stated, much the general appearance of small gladioli.

The general conditions of soil under which the *Watsonia* thrives are similar to those required by the gladiolus.

As soon as a colony of white Watsonias was fairly established, I began making crossing experiments, using for the cross the reddish purple species and including, a few years later, also a pink variety of the *W. Ardernei* that was sent out by a Dutch florist. As usual in these experiments, one species after another was crossed until in the course of a few seasons we had crossbred forms of multiple ancestry.

There were strains of the white *Watsonia* in them all, but also strains of the purplish and pink species.

By 1904 I had a crossbred colony of Watsonias numbering about fifty thousand seedlings. This doubled in the succeeding season, and in recent years the colony has attained the proportion suggested by what has already been said about the elimination of bulbs by the cord.

Needless to say there is great variety among these complex crossbred flowers. All of them retain the essential characteristics of bulb and stalk and manner of growth of the Watsonias. But in their size of flower, and in various important characteristics, they show wide departure from either of the parent forms.

Perhaps the most striking individual develop ment is that of a pure white form of *Watsonia* that has double flowers. This double *Watsonia* is an unusual flower. The doubling has been brought about, not by the transformation of stamens, as in the case of a double rose or dahlia, but by growing a new circle of petals outside the old ones. This form of doubling, to be sure, is not altogether anomalous. It occasionally takes place in the case of the rose and the carnation, and I have known it to occur with the apple blossom. But it is not very common.

It is sometimes spoken of as supernumerary doubling, to distinguish it from the usual type in which each new petal takes the place of a stamen.

In addition to the double white *Watsonia,* the crossbred colony has presented single white ones that have very much larger and more regular open blossoms than the original forms. Also some that grow on much taller stems, and others on the other hand, that are dwarfed, and of more compact form. All of the newer ones show great improvement over the original forms. If possible, they surpass the original in snowy whiteness, and not only bloom much earlier than the type form, but they are the most persistent bloomers, putting forth flowers almost continuously throughout the whole season.

Strange Forms and Entrancing Colors

But even these snow-white members of the colony are surpassed in beauty by some of their associates that show the most remarkable combinations and blendings of colors.

The parent forms, as we have seen, are reddish purple and white, but these blended hybrids present such combinations of colors as I have never seen in any other tribe of flowers except the orchids. It would be impossible to describe with any degree of accuracy the varied hues that these amazing and delightful blossoms present.

There are combinations of violet and rosy pink, soft apricot yellows, salmon, nearly pure yellow, yellow shading into pink, deep, dark crimson, light crimson, and purplish tints of many shades. And these various tones and colors are so shaded and blended as to produce an effect which can be matched only among the far-famed orchids.

To produce races of flowers of such varied and entrancing hues from parent forms that had no exceptional distinction except for the whiteness of one variety, is to experience in full measure the best rewards that await the patient plant experimenter.

It chances also that these wonderful blossoms are not only individually delightful, but they are produced in such profusion as is not approached by the uncrossed races of Watsonias. And to cap the climax, these profusely borne and gorgeously colored blossoms are put forth throughout the season, early in life.

All in all, the new hybrid *Watsonia* must be given high rank among the aristocrats of the flower garden. They now lack nothing but an element of hardiness that will adapt them to grow in regions of the country where the climate is doubtful and the conditions are less favorable than those that prevail in California.

Somewhat later, the species *Watsonia coccinea* was introduced into the combination. It had smaller and more scattered flowers, long and tubular, and it was of doubtful value, and introduced with trepidation.

Some of the new hybrid forms presently developed long slender tubes, while the flowers are close to the main stalk. Some have star-shaped flowers with narrow pointed petals, others have wide rounded petals that give the flowers the appearance nearly of single dahlia blossoms. Still others are of a curious intermediate form—three of the petals being rounded, and three star-shaped.

Flowers of the last named type are quite anomalous. Petals of some of the old Watsonias were star-shaped, and others were rounded, but the combination of the two qualities is unique.

Among the hybrid seedlings there are some that are only seven or eight inches high, appearing with tufts of wide, dark green leaves at a time when others with slender leaves have shot up to a height of eighteen inches or two feet.

We have seen similar differences among other hybrid plants. They show at once the diversity of the racial strains within their germ plasm, and the possibility of segregating and recombining traits of different ancestors.

There is a corresponding diversity as to the bulbs, and in particular as to the degrees of rapidity with which they multiply. There are varieties that will produce a bushel of bulbs from a single one in a comparatively short time, whereas others multiply very tardily. It is rather curious to note that the bulbs that are the most rapid multipliers are usually the ones that produce the best flowers and bloom most abundantly.

In dividing the bulbs of the hybrid seedlings, it is observed that some spread out naturally into bulbs of even size and are easily pulled apart, like gladioli, thus multiplied with facility. Others grow together in clusters that must be wrenched apart, breaking the bulb seriously, or else cut with a knife. All these matters are taken into consideration in the selection through which the few are singled out for preservation and the many are destroyed.

It is my custom, having selected a certain number for preservation, to cut away nine-tenths of the seed pods in order to strengthen the bulb, thus stimulating the fullest development.

The Care of Seedlings

As the *Watsonia* is not generally known, it may be worth while to give a few specific directions as to the raising of seedlings of this interesting plant.

In general it should be said that, where the climate is suitable, the *Watsonia* may be raised as easily from the seed as the gladiolus, and the treatment required is altogether similar. My method is to plant the seed in shallow, well drained boxes of sandy soil, as soon as they are ripe in the fall. By March we have, in each box eighteen inches square, perhaps a thousand Watsonias about six inches in height, if other conditions are right. They thrive very well when planted as thickly as this in the boxes.

In the spring the choicest appearing plants are transplanted singly into rows. The ones that are not quite so choice are set out in the mass, by breaking up the soil into squares holding fifty to one hundred plants, all being planted in the open field, and by fall are ready to transplant into rows for testing.

A still more rapid method is to sprout the seed in moist sand at the proper season in the fall, just as the rains commence, sowing them quite thickly in drills eight inches apart and an inch deep in sandy soil, half the covering being sawdust. Scatter a few weeds over the surface to keep the winter winds and heavy rains from removing the sawdust. Early in the spring the young *Watsonia* seedlings come up as lustily as blue grass on a lawn.

Those that do not make a strong growth are allowed to stand thickly in the row another year, when they can be removed and planted.

For field culture, they should be planted four inches apart in rows four feet apart, being set quite deeply that they may resist the summer droughts.

Of course the more careful method first suggested is desirable if we are to raise plants of the finest quality. You also get results a year or two earlier by handling the plants individually. At the same time you insure the production of a plant from each seed, while when the plants are handled in a mass a good many of them no doubt fall by the wayside.

When treated according to the first method, many of the plants mature in the second year, and all of them in the third, so that they can be fully tested in that period. Moreover by the third year each bulb has developed quite a nest of bulbs about it, from each of which a new plant may be grown.

The results already attained with the *Watsonia* mark this plant as one that must take high place among the favorites of the flower garden. What chiefly remains to be done is to make the bulbs more hardy, so that they are adapted to different conditions of soil and climate. At present the flowers are chiefly grown in California and shipped to the eastern market. But in due course races will be developed that can be grown in the east, and the *Watsonia* will come to rival the gladiolus and in some respects to outrival it for all the uses to which that flower is adapted.

Moreover it will perhaps prove possible, through hybridizing the *Watsonia* with the gladiolus, to develop new races of plants combining the qualities of each in a way that cannot be definitely predicted. I have produced a great number, say four or five hundred, hybrids between *Gladiolus gandavensis* and the *Watsonia*, in most cases using the pollen of gladiolus (chiefly because it is more abundant and the *Watsonia* is more certain of seed), but sometimes making the reciprocal cross. Only three or four of these blossomed, largely, perhaps, because a great number of them were as tender as the gladiolus, and persisting to grow all winter were destroyed by the frost, although plants of the *Watsonia* withstood the season.

It should be explained that the gladiolus does not withstand the coldest part of our winter as well as the *Watsonia;* but fortunately the gladiolus does not generally make a winter growth, so it may be left in the ground with less danger.

Of the hybrids that blossomed, all died next year from gladiolus diseases.

It may be of interest to add that double white seedlings from the *Watsonia* have been produced here; also double flowers of other colors, pink, light and dark salmon, and white.

We have naturally had occasion, in recent chapters, to pay more attention to the matter of color than to any other single flower quality. For it might almost be said that flowers have been developed for color alone. A certain amount of attention has been given to modifying their forms, but this has always been subordinated to the question of modifying their color.

If attempts have been made to increase the size of the flower, and to multiply its petals, the central thought has been to produce a more striking color display. In exceptional cases, notably that of the orchid, anomalies of form add greatly to the interest with which a flower is regarded; but even with the orchids it is unquestionably the delicate beauty of the coloration, and not merely the grotesqueness of form, that gives the flower popularity.

From the standpoint of the plant experimenter the question of color in the flower is one that has perennial interest. In a very large number of cases new varieties are developed solely along the lines of color variation.

We have seen that there are almost endless modifications of color in the same flower, particularly in such variable races as roses and poppies and dahlias, and the case of the *Watsonia,* which has just come to our attention, illustrates the interest associated with the modification of color even when no other change is involved.

The white *Watsonia* that was discovered among its pink fellows was given a new botanical name, and went forth to conquer the world captioned as a new subspecies. Yet it differed in no obvious regard from myriads of its fellows except in the matter of color.

It was pure white, and all of its fellows were reddish purple. That fact gave the one *Watsonia* distinction among the millions and insured the propagation of its progeny and their migration to the utmost corners of the earth.

Evolution of Colored Flowers

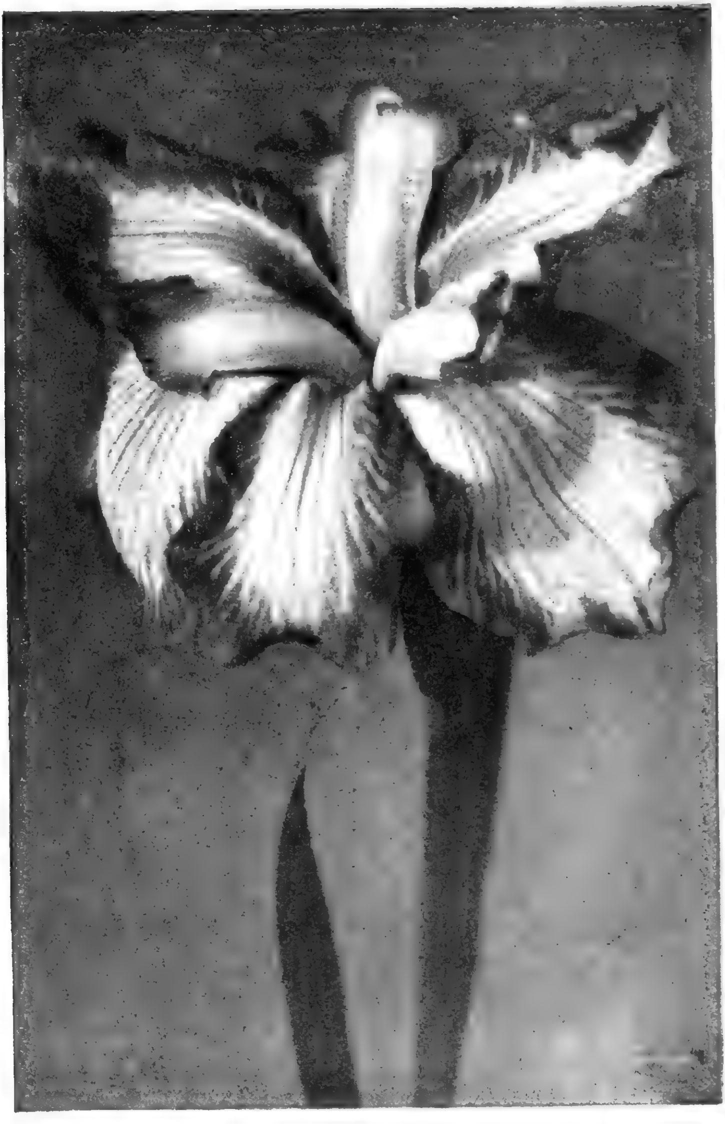
Something has been said in various preceding chapters as to the philosophy of color variation. The origin of the colored floral envelope is ascribed to the influence of insects. We have been made aware that the floral envelope was developed as an advertising device to attract insects, that their services may be engaged for the transfer of pollen that is so essential in keeping up the necessary adaptability and vitality of a race of plants.

We have been led to infer that the floral envelope is one of the most recent developments in plant evolution, inasmuch as the earlier forms of plant life had no such apparatus and their successors developed it only with the evolution of the insect tribe. And we have doubtless been correct in ascribing the ready variability of the floral envelope to the fact of its relative newness. The stalk and branches and leaves of the plant have persisted, more or less modified in form but essentially unchanged in functions, from the remotest periods, and hence have attained a fixed and determinate arrangement of their hereditary factors that is difficult to disturb.

The conspicuous advertising sign that we call a flower has been put forth so recently that it

A SPECTACULAR IRIS

Color variation is, of course, the most conspicuous characteristic that will appeal to the amateur in the case of the iris. There are purple iris and yellow ones and white ones in almost any garden, and these may be combined in endless ways. Here is a specimen that shows an interesting and spectacular color blending.



has not attained any such degree of stability. And, in particular, the color of the flower is an endowment that, as contrasted with the general structure of the plant, must be thought of as only a thing of yesterday. We are justified in believing that even among the old tribes of plants—those whose primeval forbears have left their remains in the geological strata—the flower is the one structure that has been most subject to variation. And we may doubt whether there is any flower whatever that has not changed its color more or less within comparatively recent times, geologically speaking.

Something has been said as to the probable relations of the different primary colors in their various associations in the floral envelope. We have seen that flowers of the same species may vary from deep red to delicate violet, and that it is the commonest thing for a species that is usually gaudily colored to have representatives that are pure white. And it is possible, by a careful survey of the field, to draw conclusions as to the probable sequence of development through which the variously colored flowers have been evolved.

In the first place, certain inferences may be drawn from what is known as to the hereditary responses of different flowers, in particular when hybridizing experiments are performed, that at least give clues to the story of the evolution of color.

Analogies drawn from the study of the spectrum are also of aid, in connection with these practical observations, in developing theories of the philosophy of flower coloration, which, if they cannot be said to be definite, have at least a large element of plausibility, and are full of interest.

The Physical Basis of Color

It has even been suggested that the earlier forms of vegetation were probably red in color where now the leaf structures in general are universally green; the basis for this belief being the observed manner of reaction between plants of green foliage and those of red foliage when hybridized, the fact that sea weeds are usually red, and the further fact that young vegetation, such as the buds of trees in the spring, is very generally red in color, the subsequent greenness being due to the development of chlorophyll granules.

Just why the cholorophyll granule is green is of course only matter for conjecture. But it is obvious that this is the ideal color for this purpose, otherwise it would not have been so universally adopted.

The presumption is that the plant finds it desirable to utilize the short rays of the upper part of the spectrum and the long rays of the lower part—those that stimulate chemical action chiefly, and those that are the greatest conveyers of heat, respectively—and that the intermediate rays producing the color green are not needed, hence are reflected or transmitted without influencing the plant.

A possible clew to the reason for this is found in the supposition that the plant needs the short light waves to enable it to carry out its chemical function of transforming water and carbon into sugar, and that this process is facilitated by having the tissues warmed by the long waves of the lower end of the spectrum.

It has been calculated that the sun beating on a leaf would raise its temperature to a point that would destroy the protoplasm and kill the leaf outright in a very short time were it not for the transpiration of water from the pores of the leaf, through which the temperature is equalized.

In spite of this danger the sunlight is known to be absolutely essential to the carrying on of life processes, but it is obviously desirable to limit the amount of heat as much as possible.

So the question of the heating effect of the sun must have a share in determining the color of the floral envelope.

A flower that blooms in the open and is exposed to the blazing rays of the sun may advantageously develop a glossy surface, just as a leaf does, in order to reflect the largest possible amount of light; and may in addition take on to advantage such transformation of its tissues as will make them reflect the long heat-bearing waves of the spectrum.

Such a flower, interpreted in ordinary language, is red in color—for of course that is the untechnical way of stating the facts that a given object reflects the long rays of light, and absorbs the others.

Contrariwise, it would be almost fatal for a blossom of ordinary texture to develop such consistency as to absorb the main bulk of the light waves, inasmuch as such a blossom would soon be heated to a dangerous temperature. That, doubtless, is why flowers that are even approximately black are the rarest of all blossoms.

On the other hand, a flower that reflects all the rays of light, and hence that appears white in color, is given protection against the heating influence of the sun even though it grows in the open. When we add that white is a conspicuous color the extreme abundance of white flowers is sufficiently accounted for.

It is true that flowers that bloom in the shadow, and particularly those that open in the twilight or at night, are almost universally white also, but this is sufficiently explained by natural selection, since white flowers are more conspicuous at night than those of any other color. Moreover, it must be recalled that white objects transmit heat less readily than dark ones, so white is not a bad color for a night-blooming flower, inasmuch as it conserves the internal heat even if it is not called upon to shut out heat from the sun's rays.

The Sequence of Color Development

All this is more or less axiomatic, but the further development of the theory of flower coloration involves a certain amount of assumption, and must be held only as a tentative theory.

Briefly stated, the essentials of the theory are that the original or earliest color of the flower was green in imitation of the leaf. All the older or primeval types of plants—cycads, pines, cypress, ferns, etc.—have green flowers or substitutes for them even to this day; in some cases slightly tinged with yellow. It is suggested that the color next developed was blue, the genesis of which involved but a slight modification of the molecular structure of the flower, inasmuch as the light waves that produce blue lie next to the green on one side in the spectrum.

The subsequent modifications of color were made in two directions progressively.

Some flowers were modified in the direction of the violet end of the spectrum, and others in the direction of the red end of the spectrum. The former were first light blue, then deep blue and indigo—represented among existing plants, let us say, by the larkspur and gentian—and ultimately violet. Flowers modified in the other direction were at first yellow, then orange, and finally red.

Evidence is lacking to answer the question as to which end of the spectrum was reached first—that is to say, whether the flowers of violet color or red were first evolved. But possibly the two may have been developed somewhat contemporaneously, and they would thus take their place in the hereditary scale more or less on an equality.

In any event, we may be fairly assured that there were blue flowers and yellow ones, and probably also indigo-colored flowers and orange ones in existence before there were flowers of pure violet or of deep red.

In other words, we may feel that the violet-colored flower and the red flower are the newest things in the way of color in the plant world.

The time of development of white flowers is more debatable. There is reason to suppose that the white flower owes its whiteness to a combination of the conditions which by themselves would be interpreted as greenish yellow and as blue respectively. It is known that these are the only colors that can be compounded to produce the color white. So it is perhaps the safest assumption that white flowers were evolved by the hybridizing of greenish yellow ones and blue ones, and that their origin antedates the development of red flowers or of violet ones. In other cases whiteness is due to air in the cells, and may have been a very recent development.

Nor is all this a matter of mere unsupported assumption. The inference that such was the sequence of evolution of the different colors seems logical, inasmuch as it presupposes the modification of molecular structure of the flower substance in such a way as to reflect successive rays of light in a graded series—or rather in two graded series, one involving shorter and shorter rays as in the flowers that develop from blue to violet; the other involving longer and longer rays in the series that developed from yellow through orange to red.

But an assumption based solely on this plausible analogy would not call for very serious consideration. The real strength of the theory lies in the support given it by the observed relations of the different flower colors when brought together through cross-pollination of the flowers themselves.

It is believed, on independent grounds, that the relations of dominance and recessiveness in Mendelian heredity *are determined exclusively, or at least in large part, by the newness or oldness, in an evolutionary sense,* of the respective elements that make up a pair of Mendelian factors—referring, it should be understood, to the *number of repetitions,* not to the mere lapse of time.

If this assumption is correct—and there is a large amount of evidence drawn from many fields to support it—then a guide is at hand with which to test the theory of color evolution.

Indeed, it is largely through the application of this guide that the theory of color evolution itself has been developed.

Making a practical application, it would appear that the color green, as manifested in a flower, is so remote an inheritance that it would be recessive to any and every other color; that blue would stand next in line of recessiveness; and that violet and red would be more or less on a par as colors of preeminent dominance.

White, according to theory, should be dominant to green and blue, but should itself be recessive or hypostatic when brought in combination with red or with violet. As a corroborative illustration, note that our blue poppies, crossed with white poppies, produce only white progeny.

It would also appear that the factors for yellow and for blue, which are really balanced or masked to produce the color white, might be segregated if a white flower were combined with another white flower or with a flower of a different color, white perhaps disappearing altogether and being represented only by its disunited elements.

Moreover, we have already seen that where various colors are segregated, two dominant colors such as red and yellow being brought together in the same unit system, the two may neutralize each other and fail of tangible representation; just as the colors gray and black are known to do in the color scheme of the coat of the mouse.

A LUXURIOUS TYPE

There is something peculiarly oriental and luxurious about the appearance of this particular variety of iris; the idea being carried out by the richness of coloration and the softly flowing contour of the petals. However, the oriental iris is generally of a somewhat different type, as will be seen in succeeding pictures.

The practical working out of the scheme is revealed in numerous cases that we have already examined.

Thus, union of our yellow poppy with a white one that produced a crimson progeny finds ready explanation when we reflect that yellow is commonly formed by the blending of the pigments red and green, and that white is probably due to the blending of yellow and blue. The combination of the yellow flower and the white one may thus be supposed to have resegregated the colors in such a way that yellow and blue were grouped to form white, which was in turn submerged as a recessive factor when coupled with red; the result being that the progeny were all outwardly red.

In a similar way may be explained the result of combining the orange daisy with the white daisy; and in general the multiplex presentation of reds and pinks and yellows and whites in the hybrids of poppies and roses and gladioli and dahlias.

The fact that blue so seldom appears is explained by the assumption that it was the first color to be developed, after green itself, and hence that it is recessive to all the other colors. When a blue is brought out as in the case of my blue poppy, it is unearthed, as it were, with difficulty, and represents the bringing forth of a quality that has been submerged from time immemorial.

Of course there are numerous flowers—although as we have seen they are relatively rare—that are blue in color. These are races that have either retained the ancestral color unmodified because it served them well in adaptation to their environment; or they are plants in which the recessive blue, which must occasionally appear in the course of hybridizations, was preserved and restored to prominence because it served its purpose better than the other colors, whatever they might be, that had supplanted it. As might be expected, deep or indigo blue flowers are more abundant than light or pure blue ones.

It is perhaps not without significance that blue flowers have usually a white counterpart—the bluebell furnishes a familiar example. Blue and white, according to the theory just presented, lie close together in the evolutionary scale. Either will be recessive to red or orange or violet; and it is only flowers from the germ plasm of which these dominant colors have been largely removed that are likely to develop blue or white races.

Yet the fact that the white flower carries a strain of yellow is an ever-present menace to its whiteness, as it may furnish the basis at any time for variation that will introduce yellow strains which stand a good chance of supplanting the blue and white ones.

Some further illustrations of the application of this theory of the evolution of color in flowers will appear in our subsequent studies. For the rest, the reader who is interested in speculations of this character will be able to make application for himself, and to test the theory as to its details, in particular if he enters the fascinating field of plant development.

Flowers offer the most inviting field for the amateur, even while they still hold their full attraction for the practiced experimenter, and one can hardly proceed far with flower experiments without becoming interested in the phenomena of color variation.

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HOW TO OBTAIN VARIATION AMONG FLOWERS

The Doubling of the Korean Balloon-Flower

IN illustrating the possibilities of flower development, the case of the Korean balloon-flower (*Platycodon*) will perhaps answer as well as another.

For some time I had been working with these flowers, to increase their beauty of form, size, clearness, and intensity of color, and the closer and more graceful placing of blossoms on the stalk. As to all of these qualities, the existing balloon-flowers left much to be desired.

The method of work was that which has already been outlined so fully in connection with other flowers. The essentials, as the reader is aware, are first the careful examination of the entire colony to discover the individual that is the very best of all as to the particular characters in question.

If the three or four different qualities, improvement of which is desired, are not combined to best advantage in any single individual, then it is sometimes necessary to select an individual for each quality, and to carry forward three or four lines of experiment at the same time.

It will be recalled that in developing a special variety of small sweet canning pea, with the qualities of uniform ripening, small seed, and of seeds of uniform number and equal size in the pod, I was enabled to find these qualities exhibited in such combination that the experiment went forward rapidly, so that in the course of six generations I had developed precisely the variety of pea desired.

But it will also be recalled that half a dozen other lines of experiment were carried forward at the same time, using the same group of peas, that led finally to the production of as many quite different varieties, characterized by large size of seed, by lozenge-shaped seeds, and the like. And these secondary experiments were carried out without in any way interfering with the primary one. It was merely that, in searching among the different vines, I could not fail to notice individual plants with interesting characteristics, and nothing more was required than to select these from the others and save their seed.

So in such a case as that of the balloon-flower, where it is desired to increase three or four quite different qualities—in this case size, beauty of form, manner of placement of blossoms, and intensity and clearness of color—it does not so very greatly matter whether in the early generations one finds the different qualities combined in a single individual, or whether, as is more likely, he finds one individual that is most graceful, another that has blossoms placed on the stalk in the best manner, and a third that shows to best advantage as to intensity and clearness of color.

It is much more probable, in practice, that the second alternative will be the one actually presented. Indeed, it is altogether unlikely, when new qualities, such as these, that have not hitherto attracted the attention of the cultivator of the plant, are in question, that one will find a single individual that surpasses all its fellows as to each quality, though this is sometimes the case.

In fact, with the balloon-flowers, it was necessary to save seed of three or four individuals and search among their progeny in turn the following season, and make additional selections that involved a number of individuals.

But when selection has been carried to a stage where we have one race of balloon-flowers presenting plants that are uniformly of graceful and attractive form, and another race that has the flowers arranged in a satisfactory way on the stalk, and a third race that produces flowers of a brilliant white color, the materials are in hand for an amplification of the experiment along lines with which the reader is already familiar, through which the desired combination of these traits in a single race may be effected with almost absolute certainty.

The Combination of Qualities

The method in question consists, of course, in cross-pollenizing the best individuals of the three new races. Of course, one cannot blend three strains in a single cross-pollenizing experiment. But one can cross-pollenize specimens of each one of the three with each of the others, making the cross reciprocal in all cases to make quite sure. Each of the new hybrid races will thus blend, in one way or another, the traits of two of the parent forms.

Selection being made to find the best types among these two cross-bred races, the ones selected will, of course, be interpollenized, and their offspring, representing the second generation from the three parent forms, will combine all the hereditary factors of their three specialized ancestors.

Among these second-generation hybrids there will be found, in all probability—if large numbers of specimens are grown—some individuals that will combine in superlative degree the qualities of gracefulness of plant of one grandparent with the satisfactory arrangement of flowers of the second grandparent and the clear whiteness of blossoms of the third grandparent.

It is, then, an obvious procedure to save the seed of this individual, and while we must expect wide variation among the plants grown from that seed, there will almost certainly be some among them that will reproduce the combined good qualities of the parent, and further selection along precisely the same line—called "line breeding"—will result in fixing of the type, so that we shall have the variety, hitherto existing only in our imagination, which we have all along been seeking to produce.

Moreover, not alone shall we have produced a type which combines all the best qualities of the different members of the original balloon-flowers, but this new race will almost certainly present these characters in markedly accentuated form. The perfected balloon-flower will be more graceful in form than the most graceful one of the original colony. It will have its blossoms much more artistically grouped on the stalk than any balloon-flower that has hitherto been seen, and the color of these blossoms will be clearer and more brilliant than those of any individual member of the original colony, whether blue, white, or intermediate, as may readily be demonstrated by comparison if the original colony has been preserved, and is now represented by unselected progeny.

Of course, in these experiments, the unselected members would usually have been destroyed, but the worker who experiments on a smaller scale may find it desirable to preserve the old colony, or some members of it, if for no other purpose than to find encouragement in making such a comparison as that just suggested.

The results, as I have said, are sure to be encouraging if you have carried out the experiment in the way just outlined. Nothing more is required than the use of your eyes and reasonable judgment in selecting the best specimens; care in the preservation of the seeds; cultivation of the seedlings in the way we have elsewhere fully described; and persistency in following up the experiment.

It has often been pointed out that in such experiments there may not be very much encouragement in the first generation or two. Some forms of plant, and in particular those that have not been very much under cultivation, or that are represented by only one or two species, may hold fixedly to their type and show at first only a slight range of variation. In such cases you must be content to go forward by very slow stages, making but the shortest step ahead with each generation for the first two or three years.

But even where progress is as slow as this in the beginning, the time will almost surely come when the effect of what I have several times referred to as the momentum of variation begins to be felt. Some season, to your surprise and delight, you will discover that the plants are varying much more widely than they have done hitherto.

Instead of having to examine your seedlings with the utmost care to determine which ones are largest and most vigorous; and then in turn to examine with equal care the blossoms—when they appear—to determine which are largest and most brilliant, you will find that some few seedlings will jump ahead of the others as if they belonged to another race, bringing to your mind the familiar tale of Jack's Beanstalk, or the less

SELECTED CHILEAN IRIS

Note how widely this flower differs in form and general appearance from the iris shown in other pictures. It belongs to a different species, growing upright three feet or more in height, and thriving in very dry soil, while the Japanese species thrives only in very moist soil.

familiar story of Darwin's Hero morning-glory, which appeared suddenly after several generations of selection.

When the seedlings which thus practically select themselves have come to blooming time, your delight will be enhanced as you discover that the blossoms they bear are markedly larger and more brilliant than any you have seen before.

Now all your disappointment and discouragement of the first day is forgotten. Now your enthusiasm is reanimated and accentuated. From this time forward you carry on the experiment with renewed zeal, and you feel confident at last that the coveted goal is well within sight.

Plants That Tend to Vary

Of course there are other plants that give encouragement from the very outset. Such is the case with almost any of the familiar cultivated plants, of which there are many species and varieties that have long been given attention by the horticulturist.

Suppose, for example, that you were to plant all the seeds taken from the seed pods of a single dahlia. Perhaps you have done this on occasion, not with any thought of making new experiments or developing a new variety, but merely in the hope of reproducing the characteristics of the best and most beautiful dahlia among the number in your garden. In that case you have doubtless been subjected to bitter disappointment. For when the carefully nurtured seedlings came finally to blooming time, instead of presenting flowers closely similar to those of the parent form, they have shown, in all probability, the widest range of variation—not one of them perhaps has been similar to the parent. Nor, perhaps, were any two precisely alike. Among them you could discover resemblances to all the other dahlias in your garden and, indeed, to a large proportion of those that you had seen pictured in the seed catalogues.

In a word, your dahlia seeds show that they contain the racial strains of a great variety of ancestors, and they present a variation that is truly disconcerting to the gardener whose sole desire was to produce a lot of dahlias of uniform character.

In one case, recorded by Darwin, an experimenter listed no fewer than eighteen different varieties of the dahlia grown in the first generation from the seed of a single plant, and of course there were all manner of intermediate forms. In the listed eighteen only six corresponded pretty closely to certain named or catalogued varieties. It would perhaps more truly present the record if we were to say that there were not eighteen different varieties merely, but as many varieties as there were individual plants.

But while such an experience as this is utterly disconcerting to any amateur whose only thought is to produce a bed of flowers of uniform color or character, the same experience would offer precisely the opportunity that the developer of new varieties is seeking. Now, it is not a case of hunting here and there throughout a company of seedlings for one that differs by a shade from the others. It is a case of selecting two or three or a dozen individual plants that present features that attract the experimenter; and selecting their seed to be planted the following year in individual plots, that the experiment may be carried forward, generation after generation, just as before so far as principles are concerned —but very differently as regards results, inasmuch as now there is the most striking departure in each successive generation from the characteristics of the parent form.

How wide the departure may be within a few generations is well manifested by the dahlias, since these plants, as we have already learned, have all been developed in the space of about a century from wild originals. Moreover, by no means are many generations represented as might be supposed, inasmuch as the dahlia is propagated usually from the tuber, and it is only now and again that an experimenter has taken the plant in hand to raise it from the seed and separate out new varieties.

That a plant which in its wild form is an ordinary sort of composite—not very different from the Black-eyed Susans and allied sunflowerlike plants that abound by every roadside—could be developed in a comparatively short series of generations into the extraordinary flower with solid heads, and presenting the gorgeous and variegated colors of the dahlia of to-day, is in itself an object lesson in the possibilities of plant development that is nothing less than inspiring.

Unexpected Results

Not only may plants be led along the line of some desired variation, but there is an element of chance in the enterprise that adds very greatly to its interest.

There is always a certain allurement about the happening of the unexpected. It is highly gratifying to select a plant for some desired quality and to have it respond to selection in such wise that a variety presenting this quality is finally produced. But it is doubly gratifying to see here and there, quite unexpectedly, the putting forth of a flower of an unpredicted color, or the development of a form of which one hitherto had no conception.

In a field of cultivated poppies, for example, where there were millions of specimens, all of substantially identical color, so that the field made a blazing sheet of yellow, I have come upon a single blossom of purest white.

To find this white blossom, isolated among the millions, is an experience that repays one for years of earnest effort and makes amends for almost any antecedent disappointment.

It was such a chance discovery as we have seen that gave the world the wonderful new race of white Watsonias. Quite possibly the white flower that Mr. Arderne found among the colony of reddish pink ones may have been the only one of its color among a million, or perhaps ten million, of its fellows for miles around. But this single atypical individual chanced to be discovered, and its progeny to-day are found by thousands, even by hundreds of thousands, in the gardens and greenhouses, not alone of its native home in South Africa, but of all parts of Europe and warmer regions of America.

The reader will recall that I have raised these white Watsonias by hundreds of thousands. Their strains were mingled in the quarter million bulbs of this species that I was obliged to destroy in a single season.

Such are the possibilities of multiplication of a plant. Such is the geometrical ratio at which the offspring of a single individual increase if given encouragement. Boundless, then, are the possibilities that lie before the plant developer who discovers a single specimen of a beautiful aberrant type.

What we wish to illustrate at the moment, however, is not the possibilities of multiplication of the plant, but the interest that attaches to the development of unexpected variations. And that the possibility of finding a new form in your flower garden almost any morning will give perpetual interest to your task, and will come to be a compelling incentive that will take you to the garden as steel is drawn to the magnet.

To illustrate the possibilities from the case directly in hand, let us recall the new race of balloon-flowers, the evolution of which we have just traced. This experiment began with the ideal of a balloon-flower of better form, more graceful placement of flowers, and individual blossoms larger and of more brilliant color. These ends were in due course attained, and the steps have been traced briefly through which the new race of perfected balloon-flowers was evolved.

Now it remains to add that when the experiment was approaching completion, and a new race of balloon-flowers in many ways satisfactory was actually in being, I discovered one day among the blossoms one that had a perfectly regular second row of petals, instead of the usual single row, or the irregular so-called double, which had sometimes appeared. Here was an unexpected variation, which was something not specially counted on or considered, but, needless to say, was hailed with delight, and marked for further education.

If we ask why this second row of petals appeared, the answer can be only a conjecture. Doubtless some condition of altered nutrition stimulated the plant to this abnormal production. It is customary to speak of such an anomaly as a "sport" or mutation. But doubtless these words beg the question. They name a condition, but do not in any way explain it.

It is an observed fact, however, that sudden variations analogous to this may be stimulated by a change of climate or a change of soil, as when a plant is brought from another hemisphere, or by a surplusage or a shortage of food. It is familiarly known that in a beehive the larva that would otherwise grow into an ordinary worker may be made to develop into a queen, that is to say, a mature female, by special feeding. In somewhat the same way a plant that has an excess of nourishment may tend to take on exceptional growth, and one manifestation of this might be a disturbance of the equilibrium of the floral envelope, with the production of an unusual number of petals.

It is known, on the other hand, that a shortage of food supplies or disadvantageous conditions of climate may hasten the maturing of a plant, and cause it to fruit earlier than it otherwise would do. And any disturbance of equilibrium of this sort may lead to anomalies in the precise character of the flower.

Possibly the reason why the petals of the flower are most likely to be altered as to number, and also as to color, is the fact that these are about the newest of all the plant structures. We have seen that the petals are not themselves essential to the fertilization of the plant—they are only advertisements to attract insects. They were developed late in the evolutionary history of the plant, and their variability is an additional evidence of their modernity. The fact that so many of our cultivated plants have become "double" is in itself sufficient proof of the tendency of the petals to be modified under conditions of change of climate and nutrition to which the cultivated plant is subjected.

But from our present standpoint, what perhaps is of greatest interest is the fact that when petals have once shown a tendency to such modification, this character is heritable, and the progeny of the plant will reveal some members at least that show the same characteristic.

Moreover, the "momentum of variation" to which I have so frequently referred will make itself felt in the tendency of these variants to take on still wider variation. In other words, the plant that has developed an extra petal or row of petals has acquired a tendency that will urge it to the production of still greater modifications of the floral envelope.

In the case of the balloon-flower, the plant that had developed a second row of petals, when its progeny were carefully examined, was found to have transmitted the anomaly to a certain number, and among the progeny of these there presently appeared one that had a third row of petals. So in the course of comparatively few generations there had been produced a race of balloon-flowers that had trebled the number of petals that hitherto had been the recognized complement for flowers of this race.

A JAPANESE IRIS

Our iris experiments, as mentioned in the text, have largely had to do with the Japanese iris. We raised great quantities of seedlings at Sebastopol a few years ago. The combinations of colors are beautiful beyond description, and they vary in all shades of the rainbow. Sometimes the double ones take on handsome and unusual shapes. These are typical specimens of a more usual form.

Multiplication of petals may result, as we have already noticed, from the transformation of stamens into petals, or it may come about from the springing into being of new petals *de novo,* rather than as modifications of any preexisting part of the flower. The latter appears to be the case with the new rows of petals of the balloon-flower.

At the present stage the flower has a triple corolla, constituting a very striking modification. The ultimate limits of its variation can be absolutely determined only by further series of experiments.

Stimulating Variation

The modification of the balloon-flower has somewhat exceptional interest, because there is only a single species of the genus *Platycodon,* to which it belongs, anywhere in the world.

In other words, this genus is what is called a monotype, and it is a well-recognized fact that flowers belonging to a genus having only a single species, and even to genera having half a dozen species, are relatively little subject to variation. Rightly considered, this is almost axiomatic; because the very fact that there are many species in a genus proves that the representatives of that genus *have been variable;* else they would not have developed so many different forms, since all members of a genus have sprung from the same ancestry within comparatively recent times.

The balloon-flower has, no doubt, been isolated under climatic conditions that have not greatly changed for a long period and hence it has maintained its specific identity, and the type has become thoroughly fixed. And this fact gives added interest to such an experiment as that just outlined, which shows how marked may be the developments that can be produced by selective breeding, even with a flower that tends very strongly to maintain fixity of type.

But no flower is so fixed that it does not vary to some extent.

There was no other color until last season, when a plant bearing large red blossoms appeared among a few thousand seedlings which had been grown from my long-selected varieties.

There is material at hand, then, through which cross-fertilization may be practiced, with the possibility of giving the flower still greater impetus to variation.

And indeed, even when these crosses have been made, there will still remain possibilities to invite the plant experimenter. For, although the balloon-flower stands in a genus by itself, there are of course other genera that are not very distantly related in the *Campanula* family, to which the flower belongs. The balloon-flower is often spoken of as the Chinese bellflower, and with entire propriety, inasmuch as its nearest relatives are the European and American bellflowers, of which there are several familiar species, the best known, perhaps, being the one called popularly the harebell or bluebell, and the Canterbury bell.

It is quite supposable that it might be possible to combine the balloon-flower with one or another of these European or American bellflowers.

And in that event it is not to be doubted that the hybrid race would show great new possibilities of variation and, by combining ancestral traits that have not been blended since remote geological periods, if at all, we should develop among the progeny of the balloon-flower races that would, in all probability, differ so radically from the parent form as scarcely to be recognizable as having any relationship whatever with the plant with which our experiment began.

All of this, of course, is taking liberties with the future. In the case of the balloon-flower, such hybridizations have not as yet been successfully carried out. But in suggesting the possible results of such potential hybridization, we are merely drawing analogies from almost numberless experiments with other races of flowers, and have every warrant for drawing such conclusions as those just suggested.

It may be added that there are yet other possibilities of stimulating variation by chemical treatment of the developing ovaries of the flower itself; or by subjecting the plant to unusual conditions of temperature; but experiments of this type, reference to which has been made in an earlier chapter, have not often fallen within the scope of my own work, and as yet have been carried out only tentatively by others. They are mentioned here only as suggesting that there are other possibilities so various and so complicated as to give full assurance that no single line of investigation will ever reach a stage where it loses interest because it has brought the investigator to the end of the road.

IMPROVEMENTS IN THE MUCH IMPROVED IRIS

And a Few Other Old Favorites

IF YOU are disposed to undertake a series of practical experiments along the lines suggested in the preceding chapter, it is by no means necessary for you to send to distant countries for the material.

Of course, the professional plant developer is always on the lookout for plants from all parts of the planet and even of other planets if available. But the amateur need not be deterred by the difficulty of securing such materials. He may go into his garden and begin experiments with the first flower he chances to find there.

Any old-fashioned flower garden, such as adorns the dooryards of millions of homes in America, will furnish abundant material for all the experiments that any amateur need care to undertake.

Let me name almost at random a few of the common garden flowers that offer interesting opportunities for development, and any one of which will serve quite as well as another for the commencement of your tests of the possibilities of plant development. Take, for example, the familiar iris, known sometimes as the rainbow plant. There are specimens of it, in one variety or another, growing in almost every garden. It makes its own way if given the slightest opportunity, and its unusual flower with the graceful recurved fringed petals has retained its popularity generation after generation, notwithstanding the coming of many new favorites.

My own work with the iris has had to do largely with a Japanese species known as *Iris lævigata.* On an acre of damp ground that I have at Sebastopol, great quantities of these flowers were raised a few years ago. The combination of colors was beautiful beyond description, varying in all shades of the rainbow. Among the seedlings were numbers that produced double flowers, and sometimes the double ones took on handsome and unusual shapes; in other cases the anomalies of form were grotesque and even monstrous, rather than beautiful.

Some of the seedlings produced almost ten times as many flowers as others, the individual blossoms being of equal size. Some were tall and lanky and could hardy support themselves when in bloom. Others were short and compact. The range of variation was from dwarfed forms of eight inches to giants of four feet or more.

And that the variation was due to heredity and not to any environmental conditions was shown by the fact that the dwarfs and giants might stand side by side in the same soil and subject to precisely the same conditions of moisture.

There was not much demand at that time for new varieties, so the entire lot of hybrid Japanese iris was ultimately sold as a mixture, without names or numbers, not taking the time to sort out and fix different types by selective breeding.

In addition to the Japanese form, I have raised a great number of other species, including one interesting form in which the seed pods turned out in a curious way and exposed the orange or scarlet seeds. This is a species known as *Iris fœtidissima.* This anomalous form was grown extensively to produce a race that would have seed pods and seeds that would have better form and open more fully.

It is not necessary to go into details as to the score or more of other species that I have grown, as they all reveal more or less similar tendencies to variation, and suggest over and over the same possibilities of development.

It does not matter very much, then, what particular variety of iris is growing in your garden. Probably there are plants that bear purple flowers, others with yellow ones, and yet others that are white. This obviously gives you opportunity for hybridizing, and there will be abundant interest in watching the results of the blending of different colors, or even of different species.

If, at the same time that you are crossing the iris of different colors, you save also seed from other plants, or from different flowers on the same plants, that are not crossed, you will be able to check the results of your experiment, and will find yourself launched at once into an investigation that offers fascinating possibilities. It should be explained, however, that the cross-pollenizing of the iris presents complications which will not be solved unless you make a very careful inspection of the flower.

The stigma of the flower has a little lip under the unique petaloid pistils, very different in appearance from the organs of most other flowers. If you examine it closely you will see that the little shell-like lip that projects is adjusted in just the right way to scrape pollen off the back of a bee as it enters the flower, or similarly from the head of a humming bird. The arrangement is such that the bee or humming bird will come in contact with the pollen of an individual flower only after it has passed the pistil, and the protecting sheath prevents the deposit of pollen as the insect or bird leaves the flower. Thus it is insured that self-fertilization will not take place.

While the flower is complex in this regard, nothing more is necessary than to study its mechanism attentively, pulling to pieces two or three blossoms to see just how the pollen must be deposited. After that you will experience no difficulty in cross-fertilizing the iris, and the results of your work are sure to be of interest.

Four-O'Clock and Columbine

The familiar four-o'clocks are all natives of America, but most of them had their original home in the subtropical and tropical portions of the two American continents. There is one, however, that is native to California, and various species made their way to the gardens even far to the north a century or more ago, and are now grown everywhere.

The most striking peculiarity of the four-o'clocks (*Mirabilis*) is their tendency to combine different colors in the same flower in peculiar patterns.

We have seen a great deal of color variation among flowers. We have seen numberless instances in which blossoms of the same species may be in one case red, in another pink, in a third yellow, and in a fourth white. We have seen also some instances of the mingling of different colors in the same flower, notably with some of the dahlias. But our attention has been yet called to no flower that mingles the colors in quite so anomalous a way as is characteristic with the four-o'clocks. For these blossoms, apparently unable to decide between different colors, have hit upon a compromise of arranging the colors in definite stripes, which give the tubular corollas a very curious and characteristic appearance.

In a lot of seedlings, supposedly of the same variety, the stripes may come in various widths of white, crimson, and yellow. Even when the seed is saved from a single plant, there will be great variation among the seedlings, in some the wide white stripes predominating, in others the crimson, and in yet others the yellow. Again, some of the flowers may come pure white, or yellow, or crimson, or pink, quite without stripes; or perhaps half of the blossoms on a given plant will be one color and half another.

It is obvious that a plant showing such wide variation does not necessarily call for hybridization to stimulate variation, that is in respect to color. The mingling of hereditary strains is already sufficiently complex in this regard and you will find quite sufficient occupation in attempting to sort out new races of a good color or combination of colors, and in fixing a dozen of them so that they will come reasonably true to type. If you succeed in accomplishing this, in the course of a few seasons, you will have performed an experiment that you will find full of interest, and your task will not have been carried out without giving you very suggestive sidelights on the problem of heredity.

It is, in any event, a very curious anomaly that a plant should so have assorted its hereditary factors that they adopt this compromise. And your investigation, which endeavors to determine how accurately the tendency to striping is dependent on particular combinations of hereditary factors, will not only prove interesting, but may lead to valuable revelations. The entire problem of the study of heredity of color, notwithstanding the attention that has been given it, still bristles with unanswered questions. Your experiments with the old-fashioned four-o'clock may serve to give you answers to some of them.

A somewhat simpler but perhaps no less interesting problem in color heredity may be taken up in connection with the equally familiar columbine.

SEEDLING JAPANESE IRIS

This is one of a multitude of variants among the seedlings of the Japanese iris, which is almost as variable as the dahlia.

There are thirty or more species of the genus *Aquilegia,* or columbine, and examples of one or two of the more common ones are perhaps to be found in your garden. At least you can get seeds from which to grow them of almost any seedsman.

The columbines have long attracted my attention because of their numerous species, and their wide range of color variation; also because of the curious shape of the flower and the tendency of the spurs to vary greatly in length, as well as in their tendency to open out in some cases, and in others to remain partially closed. There is, indeed, one old cultivated variety which has lost the spurs altogether.

Long ago I carried on some interesting experiments with this spurless kind of columbine, crossing it with many others, especially with one known as the *cœrulea,* which has very large flowers of beautiful shades of blue. The hybrids of this spurless form with the other species produced beautiful large flat clematislike flowers, some of them three or four inches in diameter.

Perhaps the most interesting feature of the experiment was that the hybrids were entirely spurless. This shows that the condition of spurlessness, which is an anomaly presumably of recent origin, inasmuch as the spurs are a characteristic feature of the flowers of the wild columbines, acts as a dominant factor in heredity. This, of course, is what should be expected if it be true that the newly developed characteristics of a plant are dominant over the older ones. But the case of the columbines furnishes another interesting corroboration of this interpretation of Mendelian heredity.

In the course of other experiments with the columbines numerous other species were brought into the combination through successive hybridizations, until my columbine colony carried the strains of more than a dozen recorded species. A most beautiful lot of hybrids resulted. Their various members revealed nearly all the colors of the rainbow. These were introduced to the trade as mixed varieties, as it did not seem to be worth while to fix the different types. On the contrary, the variety of blossoms seemed to be considered an advantage.

But even if it had been desired to fix these beautiful new types, it would have proved exceedingly difficult to do so. When you have two or more species of columbine in combination, the hereditary complications are comparable to those in the gourd family, to which we have had occasion to refer. It seems as if every member of a fraternity differs from all other members, and you cannot be at all sure as to what results you may attain by sowing seed from any individual plant.

But these complications result in part from the fact that the different columbines are so easily crossed by the bees. This is a case where there is no difficulty in effecting hybridization; the difficulty is to prevent crosses that are not desired. If the plants are shielded from the visits of the bees, and careful hand-pollenizing is effected, there is no great difficulty in combining the different forms in such a way as to get very definite results, and the hybrid forms may be fixed by careful selective breeding.

Of course, when you deal with a spurless form, if the individuals that you use are themselves hybrids of the first generation of a cross between a spurred and a spurless variety, their progeny, when they are crossed with a spurred variety, will be in effect second-generation hybrids and only half of them will be spurless. But this, again, merely illustrates the familiar segregation of characters and the reappearance of the recessive trait—in this case the spurred condition—in a rather definite proportion of the second-generation progeny.

Another anomaly among the columbines that offers good opportunity for experimental tests is furnished by the double varieties. I used to observe that if you crossed a double and a single one, you are about as likely to get a double as a single. Here, again, it would appear that the double condition of corolla acts as a Mendelian dominant factor, and that some of the strains were themselves mixed.

All in all, then, the columbine offers most interesting possibilities for the experimenter who likes to test for himself the principles of heredity. In the matter of color, there is the widest variation, some of the familiar forms being blue, others red, yellow or white. The curious spurs that characterize the flower, and the fact that one variety lacks them, furnish tangible features that may be tested, and the single versus the double corolla constitutes a third feature that is also susceptible to definite observation and record.

So the experimenter who will work with a small number, differing as to characteristics of color and spur and doubleness, has opportunity for watching the interplay of hereditary forces; observing the dominance of certain hereditary factors, and the recessiveness of their opposing factors; and finally the segregation of the different characters and their reassembling in new combinations in the second generation, that will test his knowledge of the principles of heredity to the utmost, and at the same time will give him definite ideas about the practicalities of plant development that will be at once interesting and valuable.

Meantime the experimenter may introduce problems of far greater complexity if he so desires by combining larger numbers of the plants somewhat at random, allowing them to be cross-fertilized by the bees. In this way he may secure, as I have done in some experiments, columbines of the most wonderful variety. In some of the mixed hybrid colonies the blending of hereditary factors was so complex that among ten thousand plants there would be perhaps not five hundred that could be classified as approximately identical with one another, or as conforming to a specific type.

In other words, there would be perhaps nine thousand five hundred individual plants, each of which might be said to constitute a distinct variety.

In the course of these experiments there were made perhaps ten thousand careful hand-pollinations between different specimens of these variant hybrids, and, needless to say, plants were secured with exceptional blossoms of many kinds.

A similar line of experiment is open to anyone who has the smallest plot of ground in which he can grow a few scores of columbines.

Campanula and Coreopsis

If you were to seek experiments of a still simpler character, you might do well to consider the beautiful campanula, known familiarly as the bluebells of Scotland.

These are hardy flowers, growing wild in great profusion, even far to the north. On a botanical trip to Canada many years ago I was delighted to see great fields of campanula as far north as Alberta. They are said to grow even in Siberia. So whatever the location of your garden, you will probably have no difficulty in raising bluebells. The plants, to be sure, are somewhat subject to the attacks of fungous pests and insects, but aside from this difficulty they are easily grown. It goes without saying that a flower that has become famous as the "bluebell" is generally blue in color. Yet it is by no means unusual to see specimens that are pure white. And it is this variation that gives opportunity for some simple experiments in crossing.

Nothing more is needed than to secure plants of the ordinary blue variety and others that bear white blossoms. The campanulas are easily crossed, and you will have opportunity to test the color variation in heredity in some of their simplest relations. There are, to be sure, many species of *Campanula,* and it is true that the garden varieties are likely to have been hybridized. I have, for example, raised seedlings from *C. rotundiflora,* white variety, without securing any white ones, all returning to the original blue color. It will be necessary, therefore, for you to test your varieties by raising plants of uncrossed seeds at the same time that you are making the cross-pollinations. But this complication will only add interest to the experiment.

The many tribes of *Coreopsis* give opportunity for experiments of equal interest. These plants are composites, and in hybridizing them it will be necessary to use the method detailed in our story of the dahlia, washing away the pollen before applying pollen from the other flower.

The different members of the family vary in color from deepest purplish crimson to light yellow and white. There are numerous species under cultivation, and there are wild ones growing as roadside weeds that are readily accessible The variability of the different races makes them an interesting race with which to work.

My own work with the tribe has included a good many species, the most important of which is the one known as the *Coreopsis lanceolata.* The experiments were undertaken to make the plants more compact in growth as well as to increase the size of the flowers and their abundance. There was no great difficulty in doubling the size of the flower, and in the course of four years, working with seed purchased in the common market, varieties were produced that were considered well worthy of introduction. These were distributed by several leading florists.

The developed varieties had exceptional value because of the large size of the flowers and of the small center, also because of the strong stems, making it a good flower for cutting. A fault of most of the annual varieties is that they have small, weak stems.

As to all of these matters, the amateur can work by crossing and selection. The wide range of color variation affords a ready guide in crossing experiments, and the ease and certainty with which the plants can be grown from seed adds greatly to their utility from the standpoint of the amateur.

Shooting Star and Salvia

A really fine plant that offers opportunity for improvement, yet which has been little worked with, is the Shooting Star, sometimes called American cowslip, a member of the primrose family, classified under the genus *Dodecatheon*. There are sixteen or eighteen species described in botanical literature, yet so great an authority as Asa Gray thought that all the *Dodecatheon* in the world should be classified as one species. There are remarkable variations in size and color, however, yet the varieties are sufficiently fixed to offer good opportunity for experiment, and at the same time are closely enough related so that they may readily be crossed.

The flowers of the various types show the widest variation—dark purple, crimson, rose, white, spotted, cream color, and yellow. There is opportunity for selecting individual colors and their fixing through selection; and, on the other hand, for the combination of colors to produce new shades.

The plants are handsome, and furnish admirable material with which to work, not merely by way of gaining experience, but also with the possibility of producing worthy new varieties.

Salvias

The Salvias are members of the mint family. There are many species, showing a wide range of variation. The commonest one is known for its brilliant red flowers borne in such profusion as to make splendid masses to group along walls or

A NEW EVENING PRIMROSE —THE AMERICA

This is a new variety which originated on my place some fifteen years ago and which is now widely grown. The flowers are far larger than any Œnothera ever before seen. A single petal of America will cover the whole flower of any other kind. These gigantic flowers look like pocket handkerchiefs thickly strewn over the foliage.

as borders. There are other salvias, however, that have charming light blue flowers. The plant in the ordinary gardens is grown, of course, only for its flowers, yet there is a species, known as *Salvia sonomensis,* or *Salvia ramona,* that is abundant on some of the hillsides in California, and that is to all intents and purposes identical with the cultivated sage. Its foliage has the exact flavor of that of the cultivated plant. I have at times thought of growing it to see if there could not be developed from it a sage that would be more valuable for seasoning than the one under cultivation. The common sage runs into numerous varieties, some woolly-leafed, some golden-leafed, and some with tricolored leaves.

It is possible that by crossing this plant with the wild variety, great improvement would be made in the unique quality for which its leaves are prized. From the present standpoint, of course, our interest in the salvias concerns their flowers. I have done much experimenting with various members of the family, both in the way of selection and of combination. The plants are variable, even within the same species, and the various forms run more or less together, so that it is difficult differentiating them botanically. But the contract between the species bearing blue flowers and the familiar garden plant with its scarlet blossoms is striking enough to challenge the attention even of the least observant.

The fact that the various species can readily be combined, while at the same time they show such variation as to color of blossoms, gives them obvious interest from the standpoint of the amateur plant experimenter. It should be noted, also, that there are some salvias with white leaves, one of these having foliage so thoroughly covered with a white thick woollike growth that the leaves make excellent penwipers. The experimenter who works with one of these varieties could develop interesting modifications of leaf through selection, and, of course, crossing methods could be utilized to accentuate the variation.

Another plant that is exceptionally interesting because of the work that has been done with it in recent years is the familiar evening primrose (*Œnothera*).

Mention has been made in another place of the work of Professor DeVries, which furnishes the foundation for his celebrated theory of mutation. It will be recalled that Professor DeVries found specimens of evening primrose that departed so widely from the form of their parent as to seem to constitute new species. The question whether these mutations were of unexplained origin, or whether they were really due to hybridization, is still perhaps an open one. But, in any event, the use made of them by Professor DeVries called particular attention to this plant, and has given it a place quite apart among flowers of field and garden.

There are many species of evening primrose, and the tendency to vary among them is marked.

I have experimented with the primroses, crossing them quite extensively. One form received from the mountains of Chile has given some interesting results through selection, in that it now produces blossoms, a single petal of which would cover the entire blossom of any of the other primroses under cultivation. The flower itself is sometimes six inches or more in diameter. A bed of these plants reminds one of a lot of handkerchiefs spread out on a lawn, as the blossoms are somewhat square with rounded corners. A new crop is produced each morning throughout the entire summer.

The plant itself is somewhat trailing, and about two feet to two and one-half feet in diameter. It is a perennial, though it commences to bloom quite early in the season.

This large-flowered variety has been produced by most rigid selection for size, form, and whiteness and substance of flower, and it far surpasses all other members of the genus in size and beauty.

This Chilean race has been crossed with the common *Œnothera acaulis*, or *Taraxacifolia*, and produced a large number of intermediates, from the best of which selection has been made. These hybrids seem to come absolutely true in the second generation, so far as foliage is concerned, being in all cases intermediate between the two species. This is perhaps what would have been expected in a member of this race, in view of the observations of Professor DeVries. The plant seems to have an exceptional propensity to form new fixed types.

This, of course, is precisely the characteristic that gives the plant interest from the standpoint of the amateur experimenter. So a plot may very well be set aside in the flower garden for some evening primroses of two or three species. Crossing will sometimes be effected by the insects, if the experimenter does not care to take the trouble to hand-pollenize the plants, and the production of some interesting new forms may be expected.

Only two other common plants from among the almost numberless ones that might be selected are named as offering advantageous material for selection by the amateur experimenter. But these are about the commonest of all, and in some respects among the most beautiful and interesting—the goldenrod, and the aster. These plants are almost universally associated when growing wild in the field, and their blossoms form so beautiful a contrast that the two may very well be transplanted to the garden together.

I have experimented extensively with the goldenrods, as well as with a collection of the native asters. And while the two plants are so very different, the fact that they blossom together late in the fall and harmonize so beautifully in the landscape, makes it worth while to work on the two in combination.

The goldenrods are of so many species and so variable that they tax the skill of the botanist. To differentiate between them accurately is a task lying far beyond the skill of most amateurs But, for that matter, it is my observation that the different species hybridize so freely when growing wild that the specific lines are thoroughly broken down.

Any botanist who pretends to fix hard and fast lines beween the different species of goldenrods, and does not take account of the hybrids, which are even more numerous in many localities than the parent forms, will not gain a very adequate idea of the goldenrods as they actually grow.

Any species of goldenrod will serve the purpose of the experimenter. But, of course, it is desirable to have a number of species, and it is obviously worth while to make careful selection in deciding which ones to transplant to your garden. I have spent many days on a few acres of ground, searching among the multitudes of goldenrods and asters for the most beautiful individual specimens. From these selected seed was collected, or the roots themselves dug, to furnish the basis for further experiment.

Some of the wild forms seem almost perfect, yet when taken under cultivation and carefully selected they even prove susceptible of betterment.

The hybrids, in my experience, are not as variable as might be expected. One can seldom be sure, in working with the goldenrods, that one is working with pure species.

But such complications, of course, give added interest to the work of the plant developer after he has the fundamentals of the method fairly in hand. And I think of few problems that would be more interesting than to attempt to untangle some of the hereditary complications among the goldenrods. The fixing of types by selection; the improving of the best existing ones; and the development of new types by crossing—these are all methods that offer opportunity for fascinating experiments.

THE TIGRIDIA AND SOME INTERESTING HYBRIDS

New Charms in Far-Away Flowers

ABOUT a quarter of a century ago I commenced cultivating and crossing all the Tigridias, or Tiger Flowers, that were then offered by any seedsman or nurseryman anywhere in the world.

I also secured all the species of the allied genus *Ferraria* that I could obtain and cultivated them for the purpose of crossing them with the tiger flowers. The Tigridias are natives of subtropical and tropical America, ranging from Mexico to Peru and Chile. The Ferrarias are from the Cape of Good Hope, and are represented by a number of species.

Both tribes belong to the Iris family, and the two forms are so closely related that by some botanists they are regarded as properly falling within the same genus.

My own experiments, which show the ready hybridization of the various Tigridias and Ferrarias, suggest this close relation. Yet the fact that they are indigenous to different continents shows that they have been separated for a very long period of time, although of common ancestry.

The students of geological botany tell us that there must have been a great mass of land in the Southern Hemisphere at one time on which races of plants developed and subsequently were isolated on the land masses that are now known respectively as South America, Africa, Australasia and New Zealand. At that remote period the Tigridias and Ferrarias were doubtless of one stock, and the fact that their descendants of today retain such elements of affinity as to puzzle the botanists and to serve well the purposes of the hybridizer gives another illustration of the wonderful pertinacity with which the characteristics of a plant are sometimes transmitted through almost numberless generations without radical transformation.

It is little wonder that the earlier biologists, before the coming of Darwin, when confronted with such observed cases of affinity between races that must have been separated for countless thousands of years, were strong in their faith in the fixity of species.

Yet the facts of variation, even within a few generations, are too obvious to escape attention.

And the compromise has been found, as everyone knows nowadays, in a recognition of the fact that time is long, and the further fact that natural selection may be instrumental in maintaining the fixity of a race, provided the environing conditions are unchanged, just as it may sometimes be instrumental in somewhat rapidly changing the form of a race when the environing conditions have altered.

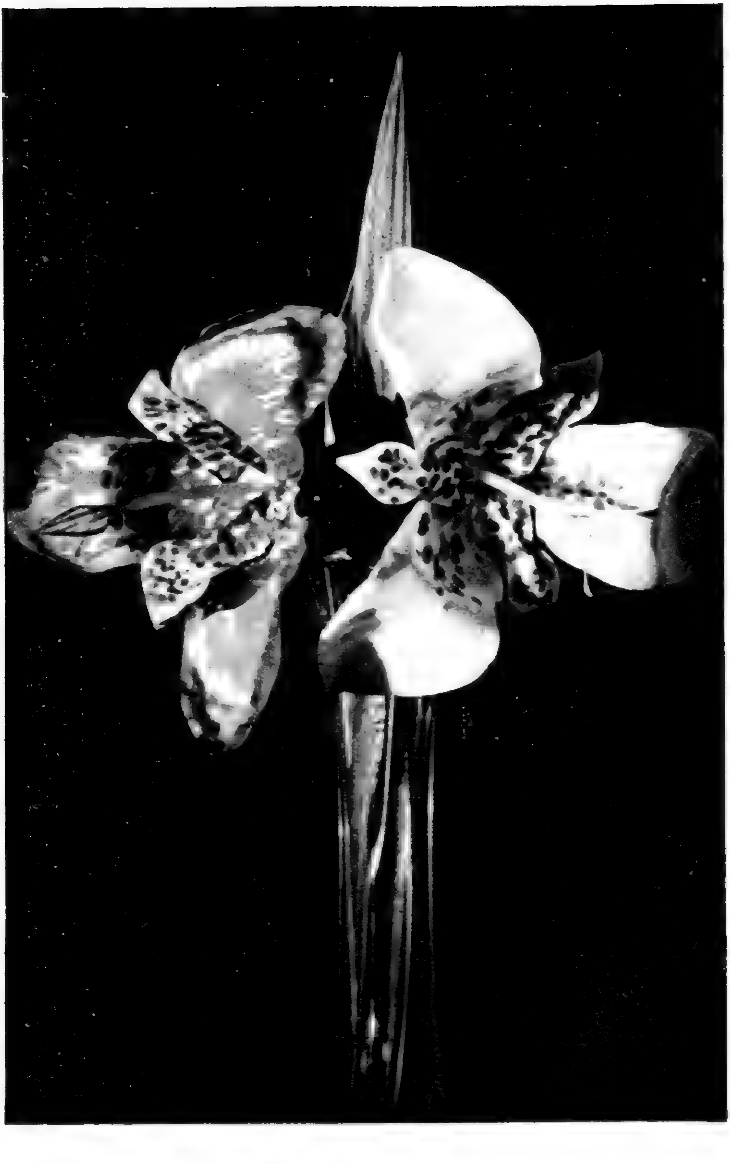
From the outset I found that the various tiger flowers throve in my grounds, particularly in the sandy land at Sebastopol, and in sandy beds especially prepared for them at Santa Rosa.

As before said, I began at once crossing and hybridizing the various species and varieties, and of course carried out selection among the seedlings and made new crossings, according to my usual custom. The type species with which the experiments began was the *Tigridia pavonia,* of which there are numerous varieties. Another form known as the *conchiflora* or Shell Flower was utilized, and subsequently the *T. buccifera,* a form more recently introduced from Mexico.

An especial effort was made to introduce also into the combination the strains of a plant of yet another genus, the *Herbertia platensis.* This is a tall-growing plant bearing close resemblance to the Tigridias, and by some botanists classified

HYBRID TIGRIDIAS

The word "tigridia," or tiger flower, would suggest a striped flower, whereas this flower is spotted. The word "leopard" or "panther" would have been more appropriate, and the term "jaguar flower" would have been still more significant, inasmuch as the tigridias come from South America, the home of the jaguar. The specimens here shown are hybrids of a very interesting type.



with them. It has pale blue flowers marked with yellow, and the specimens are of a slightly different structure from those of the *Tigridia,* though the bulb and general growth of the plant are similar.

It was particularly desired to introduce strains of the *Herbertia,* because this is a very strong-growing plant, and its vigor and health would be of great service in giving hardiness, the one thing that the Tigridias more especially lack. In particular, the bulbs of the tiger plant are difficult to keep over winter, and especially subject to decay from exposure to air and to the attacks of aphids when stored.

But I was never able to effect hybridization between any of the Tigridias, either pure bred or hybrid, and the *Herbertia.* The experiment was made over and over, and in every case it was without result.

Meantime, however, there was no difficulty whatever in crossing the ordinary cultivated strains of tiger flowers among themselves and with some of their South African relatives. And the results of such hybridizings were manifest almost from the outset.

One of the most striking modifications shown gained greatly in vigor of growth, in hardiness, and in resistance to disease.

The colors of the new flowers are all conspicuously brightened. The striping is usually crimson on white, crimson on yellow, or yellow on crimson. In addition to presenting these stripes, which are quite unlike any marking of the other Tigridias, the hybrid flowers generally retain the dotting at the center that characterizes the tribe in its original form. But these dottings are greatly increased in size. In some instances, on the other hand, the dottings are partially or entirely eliminated.

The original types of these very striking new forms of tiger flower were readily fixed so that they breed quite true from the seed.

The hybrid plants thus perfected exceed greatly the size of any plants that could have been developed by mere selection without crossing.

The new tiger plants, although still lacking something of hardiness, were greatly improved in this regard over their ancestors, as most of the old Tigridias are quite subject to insects and disease. The hybrid forms are much more resistant. There is also a greater power on the part of the new plants to stand sunshine. The old Tigridias sometimes withered under the influence of the sun. This might not at first thought be expected of a tropical plant, but it should be recalled that the growth of vegetation in tropical regions is so luxuriant that low-growing plants of this order are not usually subject to the direct rays of the sun throughout the day.

The bulbs of the tiger plant are elongated and tunicated, and multiply by division somewhat after the manner of the hyacinths, tulips, and the allied races in general. It goes without saying that the bulbs of the new tiger plants were improved in proportion to the stalks and flowers.

The bulbs of the new hybrid Tigridias were doubled in bulk, and in some cases quadrupled, as contrasted with the parent forms. Like the somewhat similar bulbs of the gladiolus, they may best be kept in the ground over winter here in California, instead of being taken up and stored as is necessary in colder climates.

The development of the bulbs of the Tigridias has not been at all a matter of accident. At all stages of the experiment in hybridizing and selection, I have paid the most careful attention to the condition of the bulbs, selecting always those that were largest, firmest and soundest. And the reason for this was not merely that such bulbs usually produce the best flowers, but also

ANOTHER HYBRID TIGRIDIA

None of the tiger flowers are striped, which seems to make their name inappropriate, as already suggested; nevertheless, there does seem to be something tigerlike about this richly caparisoned and oriental-seeming flower. It is rather curious to reflect that the spots on the flower are intended to make it conspicuous, whereas the striped coat of its namesake is calculated to make the animal invisible in the jungle.

that it is worth while to improve the size and quality of the bulbs quite on their own account.

The particular reason for this is that the bulbs of the *Tigridia* are edible. When cooked like potatoes, or made into a stew, they constitute a really delicious vegetable.

To my taste the bulb of the Tigridia is at least the equal of any vegetable under cultivation. It is also highly nutritious. I am not sure that it has an equal among the vegetables of our gardens in its combination of nutritiousness and appetizing flavor.

These very qualities lead to its destruction by all kinds of animal and insect life, like the *Lilium Brownii,* which has no bitter principle, containing sweet and nutritious matter, and which also is attacked and appropriated by insects and other creatures.

As yet the *Tigridia* is too tender to gain a place in the vegetable garden on a footing with the potato and allied bearers of bulbs and tubers. But when, through further breeding experiments, it has been rendered more amenable to general cultivation, its bulb being at the same time still further increased in size, it may come to be valued for its edible bulb quite as highly as for its beautiful and spectacular flower.

Multiplication by Bulb Division

The habit of storing nutritious matter in its bulb, and the further habit of producing collateral bulbs from which new stalks will grow, so that the plant multiplies indefinitely in this way, is characteristic, as everyone knows, of a large number of plant families, many of which have come within the scope of our studies.

The phenomenon of bulb division, indeed, is so familiar to everyone who has experimented in the vegetable or flower garden as to take its place among those familiar matters of fact that call for no comment.

Yet if we consider the matter thoughtfully it will be clear that this habit of putting forth offsets from a bulb as the basis for the development of new plants is an altogether extraordinary phenomenon—quite as mysterious, indeed, as the production of the seeds that bear the complex hereditary factors and transmit the qualities of a race of plants from one generation to another.

There is no fundamental difference between the production of new plants by bulb division and their production by seed, except that in the latter case there is opportunity for the union of two different racial strains, one borne by the pollen and the other by the ovule. This, to be sure, is a difference that has all-important practical bearings, inasmuch as the union of two different hereditary strains gives opportunity for the blending of hereditary factors and their recombination, thus compelling variations that furnish the basis for natural or artificial selection, through which new races are developed.

All this needs no explanation here, as our earlier studies have made it perfectly familiar. But we may now emphasize the fact that the bulb that produces a new plant carries the hereditary factors of the parent plant substantially as they are borne by the ovule or the pollen grain that the same plant puts forth on its aerial stalks, and exactly as the bulb of any plant—in fact, the bulb of any plant is only a fat underground bud.

If the ovule could develop without being fertilized, or if the pollen could grow into a plant, the result in either case, we may reasonably assume, would be a reproduction of the plant similar to the parent form, just as the aphids and the bees when parthenogenetically produced, and in a few instances of plants, for example, the violet. Yet there are slight differences even between the different pollen grains and between the different ovules of the same

SEEDLING TIGRIDIAS

The wild species of tigridias, of course, breed true from the seed. But, equally, of course, the hybrid forms cannot be expected to do so. So there are fascinating possibilities of variation among the progeny of any hybrid. Yet even the most widely varying specimen is at once recognizable as a tigridia. (Reduced one-half.)

plant, as demonstrated by the fact that flowers, for example, of different colors may be borne on plants grown from a single seed pod.

So if we are to present the matter quite in its true light we should say that the *aggregate* pollen product and ovule product of a plant must be considered as representing the personality—that is to say, the hereditary complex—of the plant.

No single pollen grain and no single ovule contains representatives of all the types of hereditary factors that are present in the heredity of the plant as a whole.

Stated otherwise, the pollen grains and ovules are very specialized and concentrated portions of matter, each of which contains a similar equipment of the *most fundamental* of the hereditary factors, but each of which contains a somewhat different assortment of the *less fundamental* ones.

All the plants that grow from the seed of a *Tigridia,* for example, will be unequivocally Tigridias in stem and leaf. But there will be minor differences among them as to details of size, as to freedom of flowering, as to precise size of flower, and as to the exact distribution of the color markings.

As a matter of course, when the seeds are the product of cross-pollenizing, the offspring, representing now two parents, will show a still wider diversity of hereditary traits.

Meantime, turning attention again to the bulb, we find that this structure represents the parent form with much greater fidelity. As nearly as there can be identity between two different living things, the plant that grows from any offset of the bulb of any given *Tigridia* will be identical with the parent form.

A certain amount of diversity there must always be, because no two living organisms are absolutely identical.

But for all practical purposes it may be said that the different plants grown from offshoots of an original bulb are identical. The process of bulb division can be repeated a thousand or a million times, until the original bulb has been so multiplied that its descendants people the earth. But from first to last, one bulb will be substantially like another, and all the myriads of plants that have thus arisen may be said to constitute a single personality.

All this is such familiar matter of fact as to excite no comment.

Yet, rightly considered, it is a fact of the most mystifying kind and one that must excite wonderment on the part of anyone who gives it serious consideration.

That the multitudes of hereditary factors that exist in the germ plasm of so complex an organism as a flowering plant should be grouped in each successive bulb that develops as an offshoot of the original bulb of that plant in precisely the same combination, predetermining the production of a future plant identical with the original, is a fact that becomes increasingly mysterious the more carefully we consider it.

In particular, the mystery is great if we have kept in touch with modern ideas as to the segregation of the germ plasm and the body plasm of the living organism. There is a current notion, supported by high scientific authority, that the very earliest division of a fertilized egg cell, in the case of an animal or plant, results in the separation of the infinitesimal fleck of protoplasm into two different parts that are fundamentally different, one carrying the body plasm from which the structure of the new individual is to grow, and the other carrying the germ plasm that is to convey the potentialities of future offspring.

New studies in the biological laboratory have shown that this idea, that the first division of the egg cell results in such a segregation of body plasm and germ plasm, cannot be accepted. Nevertheless, it is obvious that in the case of all higher organisms, whether vegetable or animal, the germ plasm may be a thing apart. As finally segregated, for example, in the ovules and pollen grains, it constitutes a concentrated aggregate that transmits the hereditary factors from generation to generation in a sense independently of the bodily characteristics of the individual plant itself.

You may, for example, determine that a given flower and the seed that grows from it shall be of exceptional size and vigor by cutting off all other flowers so that the energy of the plant shall be concentrated on a single one. But in so doing you merely give added vigor to the new generation; you do not alter its fundamental hereditary characters. These are predetermined by the factors in the germ plasm that have been brought from earlier generations and of which the individual plant is only the carrier.

All this, then, suggests the isolation of the germ plasm; and the newest theories of heredity have tended in some cases to emphasize the idea that germ plasm and body plasm are things of a somewhat different order.

Yet the phenomena of reproduction by root division or by the putting out of new bulbs, furnish a striking demonstration that the germ plasm which predetermines the form of the future plant is present not alone in the pollen grain and the ovule, but also in the bulb.

Even from the single bud of a bulb, as we have seen illustrated in several cases, a new plant will grow that will duplicate absolutely—in the interpretation just given—the qualities of the parent plant. And when we were studying the fruit trees we saw that this is true of any aerial bud if grown even on a foreign branch.

Root bulb and aerial bud alike contain the essential germ plasm of the individual of which they are a part. They nurture potentialities of a new individual like the parent form.

Germ Plasm and Body Plasm

From all of which it follows plainly that the germ plasm of the plant cannot be thought of as isolated from the body plasm. It may well enough be segregated within the substances of any given cell. But that it is present in connection with the living cells of the plant everywhere, from its roots to its remotest stem, is clearly demonstrated by the everyday methods of propagation employed in orchard and garden.

Such being the case, it is difficult to avoid the conviction that the germ plasm that is part and parcel of every cell of the body plasm of the entire plant is more or less subject to the environ-

A BLUE TIGRIDIA

Here is a Burbank tigridia that has taken on a color variation that is very striking. It is a complex hybrid, further developed by careful selection. It represents the result of one of my most interesting series of experiments in breeding the tigridias.

ing influences that affect the body of the plant. And from this it would follow, at least as a reasonable inference, that environing influences that modify the structure of the plant body must have an effect in modifying also the germ plasm in a way to influence the character of the future plant that develops from that germ plasm.

And as much as this, it should be added, is admitted by all experimenters, even by those who deny the possibility of the transmission of acquired traits in the older interpretation of that phrase. That altered conditions of nutrition may modify the condition of the germ plasm in such a way as to modify the state of the offspring has been shown by experiments in many fields, both with animals and vegetables. Such being the case, the question of the transmissibility of acquired traits is reduced, as I have elsewhere stated, to a matter of definition.

Nevertheless, for practical purposes, it is unquestionably true that the germ plasm is enormously difficult to influence, and that under all ordinary circumstances it will convey its hereditary factors unchanged, or not appreciably changed, from one generation to another. In attempting to modify the forms of successive generations, the method that has hitherto proved successful, has been, not the modification of the individual germ plasm, but the bringing together of different germ plasms from diverse organisms through hybridization.

For such union of germ plasms there is obviously no opportunity in the case of the new plant grown from the bulb.

Hence the fixity of type of plants propagated in this way—a fixity that is often of the utmost practical importance, as in the propagation of a new race of vegetables or flowers, but which, by the same token, puts the plant thus propagated outside the field of the plant experimenter.

Complementary Modes of Propagation

Thus the two methods of propagation that are available for such a plant as the *Tigridia* and for countless others of its kind, are in a sense antagonistic or complementary in their influence on the history of the plant itself.

Propagation by bulbs insures spread of the race and also maintenance of the racial fixity.

Should environing conditions change, it is unlikely that plants thus propagated could change rapidly enough to adapt themselves to these conditions.

But at the same time that the plant is producing new bulbs it may also, year by year, produce seeds that are the result of cross-fertilization.

And this method of propagation is a perpetual bid for such variation as will make possible a relatively rapid change in adaptation to a changing environment.

That vast tribes of plants should have found it necessary to adopt both methods of propagation is in itself an evidence of the struggle for existence that is the basis of natural selection.

In another way, also, the bulb perhaps evidences the hardness of the struggle for existence, particularly in tropical climates. Everyone knows that vegetation is exceedingly luxuriant in the tropics, and it is a matter of observation that the habit of developing tubers and bulbs is especially common among the herbaceous plants of tropical and subtropical regions. Perhaps one explanation is that the storing of food supplies in the bulb enables the young plants to shoot up rapidly without waiting for the development of a large root system.

By so doing they may stand a chance of competing with the surrounding vegetation and thus have a far better chance of reaching maturity than if they had grown from tiny seeds.

It is probable, therefore, that the generality of bulbous plants that one would find in any given locality in their native haunts would have developed as offshoots of the bulb of an original plant or as inbred or close-bred. So the bulb has very fundamental importance in the plant economy. And it is interesting to reflect that it is correspondingly important from a human standpoint, inasmuch as bulbs as well as seeds furnish us our most important food products.

We have seen that many of the plants that are propagated solely from the bulb or tuber, of which the potato is the most familiar example, may give up the habit of seed production altogether under cultivation. But, on the other hand, it is observed that plants that produce comparatively small bulbs in the state of nature may be stimulated to the production of far larger bulbs and more abundant offshoots under cultivation.

Making application to the particular case of the *Tigridia,* it has already been recorded that I have found no difficulty in doubling or even quadrupling the bulk of the bulb of that plant, as well as greatly increasing the tendency to the multiplication of bulbs.

It will probably be found desirable to cultivate the plant further along these lines until it finds recognized place in the vegetable garden as the producer of a food of the finest quality, while at the same time retaining value as the bearer of beautiful flowers.

FOUR COMMON FLOWERS AND THEIR IMPROVEMENT

Results of Work on the Verbena, the Pink, the Petunia, and the Geranium

PERHAPS the most interesting Verbena ever produced was the one named the Mayflower. I use the past tense because I am not sure that any representative of the variety named Mayflower is now in existence. I have introduced the plant through a prominent horticulturist, but he apparently found it difficult to reproduce it with sufficient rapidity from cuttings and so attempted to propagate it more rapidly from seed.

Unfortunately the verbenas are so mixed, and the various races so little fixed, that they do not breed true from the seed. And so when I sent to the horticulturist for a sample of the fragrant Mayflower verbena a few years later, I received a plant that had but a reminiscence of the distinguishing quality of the original.

In the meantime, however, I had developed another race of fragrant verbenas, which was introduced in 1901. These are the two stocks from which a large number, at any rate, of the fragrant verbenas now under cultivation have been developed.

My first fragrant verbena, the Mayflower, was developed after I had worked for many years with this flower and had grown great quantities of the seed for distribution. The plant from which the fragrant race was developed was found among many thousands, most of which, as is usual with the cultivated varieties, have a rather disagreeable odor, if any.

I had noticed, however, that there were sometimes members of the verbena colony that had a very slight fragrance, especially in the evening, and so began a careful search among them to find a plant the flowers of which had the most pronounced perfume.

After a long search among the thousands, I found at last a plant that was distinctly fragrant, surpassing in this regard any of its associates.

This individual was of course carefully isolated and its seeds planted. In due course I had a number of seedlings among which some were found that produced flowers more fragrant than those of the parent. The selection was continued, according to my usual method, through successive generations, until at last a plant was found that was as fragrant as could possibly be wished. The plant in question was an exceedingly large verbena—in fact one of the largest ever grown. The flowers it bore were of a rich rosy pink in color, the exact counterpart of the color of the familiar trailing arbutus or mayflower of New England.

Curiously enough the fragrance of the new verbena was also precisely that of the arbutus in quality, although it was much more intense, as was readily admitted by all who tested the two flowers side by side.

It was for this reason that the new verbena was given the name of Mayflower.

Several perfumers who saw this verbena were agreed that it would be of unusual value for the production of a perfume. It was admitted by all that no verbena with a comparable odor had ever before been seen.

The subsequent history of the Mayflower has already been told. It was purchased by a dealer, and although plants grown from cuttings made from it may possibly be in existence, I do not know where they are and do not know how to trace them.

BURBANK VERBENAS

The reader is aware that we take the greatest possible interest in common flowers no less than rare ones. Our experiments with the verbena, for example, have been carried out on a large scale for thirty years. Here are some sample seedlings showing a wonderful range of color variations. Some of these are delightfully fragrant, having the exact fragrance of the trailing arbutus, but even more pronounced. These giant, fragrant verbenas are now grown all over the world.

Aside from its fragrance, the Mayflower was an interesting type of verbena, owing to its size and prolific blooming habit and the beauty of its flowers. But seedlings grown from the plant could not be depended upon to produce flowers that would reproduce the Mayflower fragrance. Indeed they could not be depended on to reproduce any particular characteristic of the parent plant.

Seedlings of the Mayflower produced plants bearing blossoms of almost every color—scarlet, crimson, pure white, yellow, deep cobalt blue, and purplish. But not one of the many thousands raised afterward had the delightful flavor of the Mayflower.

The Mayflower Accounted For

As might be inferred from its variability, the fragrant verbena was a very complicated hybrid. It was the outcome of hybridizing experiments in which I had utilized all the various races of the plant under cultivation. I had not only grown and crossed the ones that are offered in the seed catalogues, but also secured seeds from all four of the original species from which the cultivated verbenas have been developed, collected from wild plants in North and South America.

It is quite unnecessary, however, to hybridize the verbenas in order to secure variation, as all of those that are under cultivation are themselves hybrids, and the plant has been cultivated for a comparatively short period and none of the familiar forms breed true from the seed.

The ancestors of the cultivated verbena were semitropical American plants, and it is believed that there are four chief species that have been variously hybridized to produce all the forms now under cultivation. One of these, *V. chamædrifolia,* bears flowers of brilliant red, two others, *V. phlogiflora* and *V. incisa,* have flowers that are rosy or purple in color, and the fourth, *V. teucrioides,* are pure white.

The hybridized races show the breaking up of these colors, quite as might be expected, with the presentation of all the primary colors in many of their hues and gradations, although pure blues are not very well represented, and pure yellow is very exceptional.

But the point of greatest interest in the present connection is the fact that the white species of wild verbena, which is acknowledged to be one of the forms whose strains have been blended with the others to produce the cultivated verbena, has what is described as a jessamine fragrance.

The hybridizing experiments that ultimately gave us the garden verbena were carried out less than a century ago, but in the meantime the strains have been so blended that it would be impossible for the most part to trace the characteristics of any given form of cultivated verbena with certainty. But it is obvious that the hybridizers and those who further developed the plant by selection were chiefly influenced by form and color, as has been the case with so many other flowers, and paid little attention to the question of fragrance.

The verbena has been made to develop wonderfully symmetrical clusters, and its flowers have taken on the most gaudy hues. But in the main, as already pointed out, the odor even of the most beautiful specimens is disagreeable rather than attractive.

Yet one of the wild parents, as we have just noted, was fragrant; and our previous studies of heredity give us full assurance that the factors for fragrance must be retained in some at least of the hybrid progeny, and will now and again make themselves more or less manifest. That such is really the case, my fragrant verbena clearly enough demonstrates. To be sure, its fragrance is not that of the original. Some slight chemical modifications have taken place, doubtless through

MORE BURBANK HYBRID VERBENAS

Note the wide range of variation among these hybrid verbenas. Observe also that the centers, in some cases, have been filled up and made solid. The verbena is a plant with which any amateur may readily work, and this picture suggests interesting possibilities of developing new varieties.

the blending of the other chemicals that represent the odoriferous qualities of the other species, and it is only by rare exception that an individual appears having just the right combination to produce an attractive perfume.

But the point of interest is that when such an individual does appear, as in the case of the Mayflower, the anomaly is accounted for quite adequately by a knowledge of the existence of fragrant species among the ancestors of the hybrid.

Even if we had no knowledge of the existence of such an ancestor, we should still be justified in assuming that a fragrant verbena is really a case of atavism. It will be recalled that we invoked the existence of remote unknown fragrant ancestors in explanation of the appearance of our fragrant calla. But there is an element of added interest in the knowledge that in the case of the verbena the ancestor responsible for the quality of fragrance can be traced.

It would constitute a very interesting experiment in heredity, should some one care to undertake to hybridize a fragrant verbena with an odorless one and to trace carefully the hereditary influence of this quality—noting, for example, whether it acts as a preponent or as a recessive character, and whether it tends to reappear in the second generation in any fixed proportion of the progeny.

It will probably be found that the condition that leads to the production of perfume of a particular type is so complex and itself dependent upon so many factors that it is not inherited in any simple and readily traceable relation, and the practical results fully carry out this view.

One of the distant relatives of the fragrant verbena is a fine shrub known as *Aloysia citriodora.* Another, as different as possible in appearance, is a little trailing plant known as *Lippia repens.*

This little trailing plant is very valuable as a substitute for lawn grass. It requires less than one-tenth the water required by blue grass, and only a fraction of the care. It need be mown only once or twice in a season, and throughout the summer it will cover the lawn with a dense foliage, and bear a mass of small blossoms resembling those of white clover and fully as attractive to the bees.

Unfortunately the lippia is not very hardy, and when the temperature goes much below freezing it turns to a brownish color. It is not adapted to the cold climates of the northern United States.

An allied species is the mosslike *Verbena ericoides,* often called "Moss Verbena," which is an exceedingly pretty plant growing wild in the high Chilean mountains. In California it produces seed too abundantly and hence multiplies so rapidly that it becomes almost a weed. It is possible that new and interesting varieties of verbena may be produced by hybridizing the familiar cultivated ones with some of the many wild species that have not hitherto been brought into the combination.

Carnations, or Pinks

It is rather anomalous that a plant should bear at the same time two popular names suggestive of colors so different as pink and carnation and the anomaly is not lessened by the fact that the plant itself bears flowers not only of the colors suggested but also of the purest white.

Despite the paradox, however, the *Dianthus* fully justifies its popular names, for specimens are of the most vivid carnation and others are of the most beautiful pink. Meantime the white ones are just as beautiful.

Our studies of other flowers have made it seem commonplace enough that a plant should show such diversity. But the carnation as represented by one of my hybrid varieties, presents a color

ONE OF THE FRAGRANT ONES

We take particular delight in developing obscure qualities of flowers, and have developed fragrant varieties of many flowers that are ordinarily odorless, as the reader is aware. Our success in this regard with the verbena has been very striking, a great number of our fragrant verbenas having been introduced and widely cultivated.

anomaly that has not been shown by any other flower with which we have made acquaintance; nor, indeed, as far as I am aware, by any other flower whatever.

The anomalous plant in question is one that produces flowers that are snow-white in the morning when they first open, yet which at noon are bright pink, and which finally, toward evening, assume a deep crimson color. Each flower goes through this process during the first day, so that each morning one may see on the same plant carnations that are crimson, a few that are pink, and freshly opened ones of white, giving the plant a very striking and unique appearance.

It chances that the plant that bears this curious flower is a most astonishing bloomer, seeming indeed to have more blossoms than foliage. So its tricolor display is indeed a striking one.

The plant that bears these anomalous flowers is the hybrid offspring of a white carnation and of a deep crimson variety of *Dianthus Chinensis*.

The plant itself is about eight or ten inches high and of quite compact growth, in these regards closely resembling the Chinese parent. The foliage appears to be about an even combination of the characters of the parents. The flowers, as we have seen, combine the traits of the blossoms of the parent forms in a very anomalous way. Our earlier studies would lead us to expect that the combination of a crimson flower with a white one might produce crimson or white or pink. It would not surprise us to find hybrid plants of the same fraternity some of which bore the crimson flowers of one parent, others the white flowers of the other parent, and yet others pink flowers blending the two colors.

This would be what we expect of such hybrids, if not in the first generation, then in the succeeding generations. But that the color factors should be so blended that each in turn should be dominant in the same individual flower, the transition from one to the other being marked by the appearance of an intermediate color, is an anomaly for which our studies of color heredity have supplied no analogy.

We have considered it strange enough that different colors should be arranged in stripes on a flower as in the case of the four-o'clock or in the new hybrid tiger flowers. But the carnation that is white at first and then pink and then crimson seems to suggest an even more curious compromise among conflicting hereditary factors. It evidences anew the curious flexibility of color schemes as applied to the petals of flowers, and presents the evidence from an altogether new angle.

It may be of interest to recall, in connection with this curious manifestation of color heredity, that the carnation has been under cultivation from an early historical period. The name *Dianthus*, signifying divine power, is said to have been given it by Theophrastus three hundred years before Christ.

The flesh color of the original carnation was broken up into red and white more than three centuries ago. Since then multitudes of varieties have been developed. Yet there is a strong tendency in this flower to hold to uniformity of color as regards any individual flower. That is to say, carnations in general are likely to be uniformly scarlet or uniformly pink or uniformly white. There are variegated forms, to be sure, but these are exceptional.

This tendency of the flower to hold to one color or another may at least be recalled with interest in connection with the curious tendency of the tricolored hybrid to give recognition to the different colors of its parents in the same flower in successive periods of time.

I have produced no other variant of corresponding interest in this tribe, although I have had twenty-five or thirty species of *Dianthus* growing for the purpose of crossing, and have produced other variants of some importance.

In general, it may be said that the carnation, having been worked on by plant experimenters for two thousand years or more, presents a difficult problem for anyone who strives to develop new races of unusual value. It is like working against the traditions of the ages to attempt to modify the characteristics of such a plant in any new direction.

The Petunia

The experiment in which I hybridized the petunia with the tobacco plant, producing the anomaly that was described facetiously as "the petunia with the tobacco habit," will be recalled as having been described in an earlier chapter.

Doubtless this experiment constituted my most interesting earlier work with the petunia, although I have cultivated it largely and have sometimes tried to cross it with other species, notably with the allied plant known as *Salpiglossis.* This plant is regarded by botanists as very close to the petunia, but I have been unable to effect a cross with it.

It will be recalled, however, that the petunia and the tobacco were combined with difficulty, and it is very possible that a more extended series of experiments might result in hybridizing more satisfactorily with *Salpiglossis.*

An illustration of what can be accomplished by an amateur who devotes attention to a single plant is given by the work of Mrs. Sheppard, of Ventura, California, and her neighbor, Mrs. Gould. The former took up the cultivation of flowers for the healthful outdoor life on the recommendation of her physician, and the latter became interested in the work through observation of the results achieved by her neighbor.

On the advice of Mrs. Sheppard, Mrs. Gould took up the cultivation of the petunia as a specialty. The result has been that some of the finest strains of petunias that are known have been sent out of California. One of the largest and best of these strains is the form known as the Ruffled Giant.

A great amount of time and skill are required in raising the best petunia seed, and there is still opportunity for improvement. It is particularly necessary to use good taste in the selection and combination of the colors. It is found to be, on the whole, easier to produce large flowers than those having a blending of clear, pleasing colors. There are few common garden plants that give better opportunity for work of the amateur, particularly for one who has gained a certain amount of skill through previous experiment. The interesting character of the petunia-tobacco hybrid will be recalled. Doubtless by sufficient persistency other hybrids having equal or even greater interest could be produced.

Geranium and Pelargonium

Several years ago I brought all the geraniums that I could obtain from European and American florists and collected also some fine specimens of a variety from British America, *G. maculatum.* The last-named variety is exceedingly hardy, growing as far north as Alberta, where the thermometer sometimes falls 60 degrees below zero in winter. I thought it would be of interest to hybridize such wild species as this with the cultivated varieties.

The pressure of other work, however, prevented me from carrying out the experiments on an expansive scale. However, it is certain that the experiment of crossing the wild, hardy, and cultivated geraniums is well worth undertaking. The wild geranium is a much more promising plant to work upon than was the original violet from which all our beautiful pansies have been developed. Indeed, there are few other plants among our wildlings that offer better opportunities for development.

My more recent work with the geraniums has had to do more especially with the form known as the Pelargonium, a plant that is horticulturally distinguished from the geraniums, but which is obviously closely related.

An interesting story is told of the way in which the Pelargonium was introduced into cultivation. A physician, experiencing difficulty in obtaining plants from foreign countries and knowing that the seeds of many choice varieties often lie dormant in the soil, commissioned a sailor to bring him a barrel of soil from the Far East—I believe from Borneo.

When the soil was received and spread out and cultivated, numerous plants sprang from it, among others the one that became the parent of the now greatly prized race of Pelargoniums.

This illustrates a convenient way of securing new plants from foreign countries, as I have found it to be on many occasions. And however the Pelargonium was introduced, it has proved a plant worthy of the fullest recognition. It has obtained such popularity that the old-fashioned types of geraniums have in many places lost their vogue.

Hybridizing the geraniums is not at all difficult when one understands the process. It is only necessary to understand that the stigma of any given flower does not mature until after the pollen of the same flower has been scattered.

Bearing this in mind nothing more is necessary than to gather pollen and dust it on the stigmas of plants that have already shed their pollen. To make absolutely sure about guarding against the self-fertilization of the flower, it would of course be necessary to remove the stamens before ripening, though this would generally be labor lost.

Some of my experiments in hybridizing have been conducted with the idea of producing fragrant races of geraniums. The chief difficulty in this work is that most of the fragrant geraniums have been grown for such a length of time from cuttings that they have for the most part lost the power of producing seeds. This makes it obviously difficult to secure seeds from the plants that are precisely the ones it would be desirable to use for the purpose.

Nevertheless, I have produced a number of varieties having fragrance, of very attractive new qualities.

One of these fragrant varieties is developed from a compact-growing Australian form which produces an enormous amount of seed. This fragrant variety, which I have named Coconut Geranium, has a most pleasing fragrance and is unusually hardy and handsome in growth and foliage. Bearing as it does an abundance of pollen, it was used to pollinate the well-known Rose Geranium so much used in perfumery and which never bears seed. But by the use of the pollen of the Coconut Geranium seeds were produced on the Rose Geranium by which a whole new series of variously perfumed geraniums are now growing.

A line of work that I carried out at one time involved the crossing of the pelargoniums with variegated leaves with those having ordinary green leaves. Among these crossbreeds it appeared that the green-colored foliage was always, as was to be expected, prepotent or dominant over the white and yellow variations. The horseshoe variations were more readily transmitted, but there was a varying proportion of marked and plain leaves among these hybrids.

Also worked at one time in selecting the geraniums for the production of large flowers of dazzling brilliant scarlet color, and with a good measure of success.

It will thus appear that there is abundant opportunity for improving the geraniums even by working with the species ordinarily under cultivation. However, the best opportunity for work in this line will involve hybridizing experiments in which the exceedingly hardy wild species are utilized. It should be possible thus to produce new races of geraniums that have altogether exceptional qualities.

The wild species include some that are white in color as well as those that are pink or white striped with pink or with reddish veins. So there is opportunity to have a wide choice as to color variation. The cross might likely result also in giving the geraniums enhanced vigor so that new races of perpetual bloomers comparable to the best of the pelargoniums would be produced. Few plants among all the popular favorites have greater merits than the geraniums, and none, perhaps, offers better opportunities for interesting experiments that may be made by the amateur.

A plant which has been worked on by experimenters for two thousand years presents a difficult problem for anyone who strives to develop new races of unusual value. It is like working against the traditions of the ages to attempt to modify the characteristics of such a plant in a new direction, yet by adding new species to the ancient combinations the problem may be solved.

EVERLASTING FLOWERS AND SOME COMMON EXOTICS

THE AUSTRALIAN STAR FLOWER AND PLANTS FROM ORIENT AND TROPICS

NOT long ago I received a tentative order for ten million clusters of flowers in a single lot. The order came from a French milliner, who stated that unless he could get at least ten million blossoms he could not afford to handle them at all. I was too busy with other things to attempt to fill the order, but the fact that it was given is worthy of record as illustrating the more or less unexpected opportunities that sometimes happen to the plant experimenter.

The flower that the French milliner wished to use in such quantity was one of the species of *Compositæ* known commonly as Everlastings. These flowers have long been popular because they retain their form and color more or less clearly when dried, and thus make permanent bouquets. In recent years, however, the abundance of fresh cut flowers has caused them to be much less popular than they formerly were.

Now, however, it appears that a process has been perfected through which, by chemical treatment, certain of the dried everlasting flowers are given a degree of permanency and toughness of fiber that makes them suitable for use in trimming hats. Moreover, the grace and beauty of the new Australian star flower are qualities not possessed by any other everlasting. Hence the milliner's desire to secure them in quantity.

It was not convenient then to undertake to meet so comprehensive a request.

With the more familiar tribes of everlastings I have been well acquainted since boyhood, but it is only in recent years that I have given them serious attention. They are of many colors—red, pink, crimson, yellow, orange, and white Some of them that are annuals in the eastern States became perennials in California, even growing and blooming throughout the winter. The work commenced with a so-called double Rhodanthe, which varies from white to red in color.

The seeds that furnished the original stock were said to represent a double flower, but only a small proportion of the plants that grew from them bore flowers that were really double. That is to say, there was almost invariably a center devoid of petals. My work consisted in selecting to fill up the center, and make a flower that is altogether double.

The flowers vary much in size, and the colors are so variant as to supply good material for selection. But a difficulty arises in that the plants produce very little seed. The selective experiments have now extended over a number of years, and I have been able to increase the size of the flower, to improve it considerably in the matter of doubleness, and to isolate to a certain extent the different colors, although the plant as yet is not fixed in any of these regards sufficiently to justify its introduction. The improvement already shown, however, justifies the expectation that varieties of these everlastings could be developed that would show very marked improvement over all old types.

A Gomphrena has been under cultivation for many years. It is a low-growing plant, having globular, crimson flowers. The introduction of new native species from South America may be expected to have the usual stimulative effect, increasing the vitality of the plant and giving it greater adaptability, and even now a new orange color is appearing among the old crimson and white varieties.

AUSTRALIAN STAR FLOWER

This is the everlasting flower that a wholesale Paris milliner found so attractive that he asked me to raise ten million sprays of them for him. Having too many other matters requiring my attention, I could not undertake the contract, but the fact that the offer was made suggests the unexpected commercial possibilities that sometimes arise in connection with an experiment in plant development. Seeds of this plant were sent to me by one of my West Australian collectors. It was small and white. By selection it was made large and pink. It is an everlasting flower, now of rarest beauty.

The Australian star flower first mentioned in this chapter most resembles Rhodanthe, but is as distinct as a rose is from a carnation. The botanists have not been able to decide as to its specific name. With the possible exception of the Rhodanthe, this is without doubt the most beautiful of all the flowers called everlastings so far discovered or produced. The beautiful, star-shaped, white clusters of flowers, produced in the greatest abundance, are surpassingly beautiful.

All the everlastings are natives of desert countries and are mostly from the Cape of Good Hope and Australia. The "Australian Star Flower," seed of which one of my West Australian collectors, who first discovered it, sent me many years ago, came to me as a graceful white flower. After a few seasons' growth here, however, it began to show a tinge of pink here and there among the numerous plants then grown. No two botanists have agreed as to its scientific status.

This work with the Australian star flower has consisted of increasing the size of the blossom, making it semidouble, giving a clear, rosy pink color, and to some extent rendering it resistant to disease. This has been accomplished by the usual method of selection, the better specimens being selected, and finally the best one being saved for seed. Very great improvement was made considering that this was a wild plant never before under cultivation. The selected varieties do not as yet breed true from the seed, but all the new ones are wonderfully improved in form, size, grace, and with the greatly increased blooming qualities a real transformation has been effected in a flower which even in the wild state was beautiful.

The Tribe of Crinums

In an earlier chapter mention was made of hybridizing experiments in which certain members of the amaryllis tribe were crossed with certain of the crinums. It is desirable to make additional reference to some experiments in which the crinums themselves were variously developed and crossed with rather striking results. The hybrid crinums are a splendid group of bulbous flowering plants in which the bulbs are in many cases of enormous size, and the leaves are broad and long, making the plants very conspicuous.

Some of the leaves, indeed, are of gigantic size, and the stalk that bears the flowers may grow to a height of from four to six feet. The flowers themselves are of variant color, from white to rosy pink, and sometimes almost purple. They are borne in profusion, and their attractiveness is often enhanced by their fragrance.

The crinums originally came from the tropics, being indigenous to various parts of South America and the southern United States. Several species are hardy in California. In some cases these will withstand freezing, so that even if the leaves are destroyed by the frost the new growth will put forth in the spring, and they will bloom as abundantly as if they had been carefully housed over winter.

Like most other bulbous plants they thrive best in sandy soil.

Some of the crinums are evergreen under ordinary temperature; others are deciduous like most of their relatives of the amaryllis tribe.

The chief objection to the crinums for house culture is the enormous size of the bulb, and the tendency to produce a superabundance of foliage out of proportion to the number of flowers; although this criticism does not apply to all of them.

Fifteen years ago I had probably twenty species of crinums, most of them having been brought from the tropics. My object was to combine the good qualities of the tropical and subtropical species with those of the hardy ones.

A PLANT OF AUSTRALIAN STAR FLOWER

It will be seen that this is an extraordinarily prolific plant growing blossoms by the hundred. This is an improved strain selected from among thousands of others of the same species. A glance at this plant suggests that the project of supplying ten million star flowers for the use of a milliner is not as hopeless as it seems at first thought.

No difficulty was experienced in crossing the various species, and crossing was carried out in the usual way, different pairs of species being mated and then the hybrid forms in subsequent seasons remated, noting of course at all stages which combinations seemed to produce the best results. Complicated hybrids were finally produced that combined the strains of many species and the results were highly interesting.

In the course of a few years I had a strain of crossbred crinums presenting most of the desirable qualities of the different species in combination. The new plants, in spite of the strains of tropical species, are very hardy, withstanding the coldest weather of this region without injury. They have very large flowers, varying in color from white and pink to rosy crimson. The petals are broad, and the flowers in a large number of cases are fragrant.

The bulbs of some of these hybrids have taken on extraordinary growth. At four years of age some of them are from six to eight inches in diameter, and twelve to eighteen inches in length, weighing probably from ten to fifteen pounds, or even more. More recently specimens have appeared of even larger dimensions. Some of these enormous bulbs seldom make offsets, others produce from one to twelve or more offsets in a season, so that they can be multiplied quite rapidly.

The seedlings from these hybrids produce plants that as a rule show a combination of two or more of the species fairly well balanced. The seed parent of the larger number of my hybrids is the *Crinum americanum,* but in some cases the *Crinum amabile,* or the *Crinum asiaticum* was the seed parent. It is observed that a certain small percentage of the hybrids show a strong tendency to run toward the seed parent of whatever species. This can generally be detected by the foliage when the plants are quite small. I have not observed that any of the hybrids depart so strongly the other way toward the tropical species when used as the pollen parent.

In the second and third generations the variations are better balanced through selection, and become more fixed in desired qualities than at first, when grown from seed.

On the whole, it is perhaps a little easier to get valuable new varieties of crinums by crossing and selection than with most other bulbous plants, especially the lilies—although there are notable exceptions among the California lilies, some of which cross very readily.

Crinum seeds are very curious, in that they vary enormously in size, almost always, even in the same capsule. The pale-greenish bulb-like seeds with irregular corrugations may vary from the size of a pea to that of an English walnut. When placed in a graded sequence they present a curious contrast. Yet the plants grown from the smallest seeds are likely to be quite as large and of the same appearance and quality as those grown from the mammoth ones. The seeds of the crinum thus funish a unique link between seeds, buds, and bulbs, suggesting the properties of all these combined.

Another peculiarity of the seeds is that they contain so much nutriment and moisture that they may sprout and grow, making plants of considerable size, without access to any moisture except that contained within the seed itself. I have known them to sprout when laid on a shelf, or in envelopes, away from the light and entirely dry; also when sent to me by mail from Australia they sometimes started as seeds and arrived here in envelopes as small growing plants.

The crinums have been under cultivation for a long time, but there are many species that have not been experimented with, and the opportunity to introduce new forms from the tropics,

A HYBRID CRINUM

These enormous, fragrant flowers produced by a seven-pound bulb are one of the results of crossing several tropical species with our native Florida species. The flowers have the size, beauty, and fragrance of the tropical species with the hardiness of the natives.

together with the striking character of the plants themselves, gives them peculiar attractiveness for the experimenter. The possibility of making still wider combinations, as in the case of the cross with the amaryllis, and further selections, should of course not be lost sight of.

The Spectacular Ixia

Another tribe of interesting bulbous plants are represented by the genus *Ixia.* These, like so many other of the bulbous plants, are natives of the Cape of Good Hope, being closely related to the gladiolus, and resembling many other Cape bulbs, including the Watsonias. There are various species, but they have been so intercrossed that the experimenter need pay very little attention to specific names and distinctions. The bulbs are inexpensive, and are commonly grown several in a pot in the house in winter in the eastern States, but in California they grow outdoors, and there is no occasion to transplant them, except for propagation.

A single bulb will spread by putting out new bulbs, which in turn make offshoots in the same way, until a large and beautiful clump of plants is often developed. The *Ixia,* indeed, can never be seen at its best except when grown in this way.

The flower stems are thrown up in great abundance on long, slender, stiff, wiry stalks, and the graceful upright or drooping flowers are of every color except blue—crimson, yellow, and white being the characteristic colors.

The variety of *Ixia* known as the Wonder has double flowers that are exceptionally handsome. The group of ixias make so striking an appearance that they almost compete with the giant amaryllis on my grounds in May for first place in their appeal to the average visitor.

The two plants are utterly different, but each in its way is most individual and striking; the *Ixia* being characterized by gracefulness and fragile beauty, the other by its massiveness. The flowers of the *Ixia* are only about two inches in diameter; those of the others eight to ten inches, yet the massed effect of the *Ixia* is so striking that it competes in interest with the larger flower.

I have worked in a more or less desultory way on the *Ixia* for the past fifteen years. The varieties under cultivation are so varied as to their ancestry, and hence have so strong an inherent tendency to variation that it is not necessary to cross them. Even the double variety is probably at least half a century old. My work of improvement was for the increase in size and brilliancy of color of the flower; and, of course, here as always, attention is paid to gracefulness and abundance of blooming, and vigor and general health of the plant.

The improvements in all these regards have been quite striking, athough I have not considered any individual variety worthy of introduction under a special new name.

Notwithstanding the amount of work that has been done with them, the ixias will well repay the attention of the amateur who cares to work with them, especially in mild climates.

Oriental Poppies

In an earlier chapter an account was given of the blue poppy. An account has also been given of the development of the new colors in the flower usually called the California poppy, more properly known by the somewhat forbidding name of *Eschscholtzia.* Very little has been said, however, about the experiments with the well-known annual and perennial poppies, which have produced results of considerable interest.

The poppies in question are the opium poppy (*Papaver somniferum*) and oriental (*Papaver orientalis*).

The opium poppy is, as everyone knows, a commercial product of vast importance in the

Far East. It has been under cultivation in Europe to a greater or less extent for several centuries, and flowers have been greatly improved by the European growers, the varieties developed being of almost every shade of color, some flowers being single and others double.

From time to time charming varieties have been sent out in recent years, including an interesting single one known as the Miss Sherwood, a variety having blossoms with a white center and crimson edge, the petals being beautifully fringed.

There are other varieties of this poppy known as Pæonia and Carnation Flower poppies that are double and are exceedingly handsome in color.

The oriental poppy has very large flowers, always single and crimson with shadings of scarlet in color in a state of nature, and in almost all cultivated varieties—the color being unusually well fixed. The plant is a perennial with rough, hairy leaves, and stems. The flowers are borne on single stems, instead of branching from a main stalk as in the opium and most other poppies. The oriental species has probably not been under cultivation as long as the other, but some varieties have been developed, some of them semidouble, and the colors have been modified so that there are dull white, scarlet, and yellowish varieties, as well as the more usual crimson.

These varieties, however, seem not to be well fixed—they do not come true from the seed—and the best varieties so far produced quite generally appear to be lacking in vitality—possibly from overzealousness in selection by division, the only way of maintaining and multiplying any special variety.

My own experiments have more largely had to do with hybridizing the orientals and the opium poppies.

Rather curiously I found that the pollen of the opium poppy was ineffective when used on the oriental, yet when a reciprocal cross was effected, the pollen of the oriental being used on the opium poppy, seed was produced, and a great number of hybrids were soon under observation.

In the hybrid colony, comprising more than thirty thousand of these plants, there was as little variation in color as is usual with the oriental poppy. None of the hybrids were double, but they had several interesting qualities.

One striking peculiarity was that the hybrid poppies produced in some cases enormous seed

A HYBRID EVERBLOOMING POPPY

Here is a specimen of a cross between the opium poppy and the oriental poppy. The anomalous results of this combination, of great interest to students of heredity, are related in the text. (*About one-third natural size.*)

capsules, five or six times as large as the ordinary seed capsule of either parent species. Yet in other plants the seed capsule would be smaller than that of either parent. In still other cases twin capsules are produced uniformly, and with a certain number there was produced a mere rudiment of a capsule. But the most striking of all were the numerous plants that produced not even an intimation of a capsule, the flowering stem ending abruptly like the end of a lead pencil.

All in all the hybrids showing this extraordinary variation in the seed-bearing capsule—ranging from enormous enlargement of the capsule to its entire obliteration—make a very wonderful and interesting study in heredity.

It is of further interest to note that, although these hybrids were raised from seed of an annual poppy (hybridized, however, by a perennial), yet without exception every member of the entire company of thirty thousand is a perennial.

The flowers themselves vary greatly in size, some of them being seven or even eight inches in diameter, while the smallest are perhaps only four or five inches. Some are beautifully crimped, others have flat petals, there being the most striking variations in form.

Even the specimens that have unusually large, plump seed capsules may produce no thoroughly well-developed seeds. In a gallon of the seed pods, from which one might expect perhaps two quarts of plump seed, I usually obtain perhaps from one hundred to three hundred or four hundred grains mostly of shrunken ill-shaped seeds. Yet these shriveled seeds when sown produce good plants. Even seeds that seem so abortive that it is incredible they should germinate, may produce perfectly healthy seedlings.

Striking Variations in the Second Generation

The second-generation poppies produced from these seeds were among the most remarkable companies of plants that I have ever seen. All who saw them agreed that they were the most variable lot of plants of a single fraternity that they had ever observed.

The diversity was so great that it might be said that there were no two plants among the thousands that were even approximately identical. No two could be found in which differences could not readily be observed in the foliage.

Some of the peculiar forms of leaf were these: (1) Long, smooth strap-shaped leaves sometimes not more than half an inch wide and a foot or more in length; sometimes smooth and sometimes villous; dark green or light green. (2) Short and stubby leaves, trifoliolate, either villous or glaucous. (3) Leaves resembling those of the oriental poppy. (4) Leaves like those of the opium poppy. (5) Nondescript leaves, variously suggestive of the leaves of primrose, cherry, dock, wormwood, dandelion, and scores of others.

It is interesting to note that the blossoms of the second generation varied somewhat less than the leaves, although much more diversified than the blossoms of the first generation. Some were double and of various shades of the opium poppy. The range of color included almost black, deep crimson, purple, light crimson, salmon shades, pink, white, and various combinations of these colors. Yet on the whole color variation was not greater than that ordinarily found in the opium poppy.

The second-generation plants seemed not to have the vitality shown by those of the first generation. There were exceptions to this, however, individual plants manifesting a vitality in excess of the average of the first-generation plants.

Most of the second-generation hybrids that produced double blossoms proved to be annuals

STILL ANOTHER HYBRID POPPY

The selected poppies sometimes attain very extraordinary size. This blossom measured almost a foot across. Few flowers afford greater interest for the amateur gardener than these spectacular hybrids, which are now grown in all countries where flowers are appreciated. (A little more than one-fourth natural size.)

or biennials, partaking thus of the characteristic of the parent from which they derived their doubleness of blossoms. This is perhaps what might have been expected. It is notable, however, that the quality of annual or biennial growth should have reappeared in these hybrids of the second generation, the first-generation hybrids having been, as already noted, all perennials.

But, on the other hand, some of the second-generation hybrids were perennials, and have continued to live and thrive, bearing large quantities of blossoms each season.

Thus the perennial and annual habit appeared, in the case of these two poppies, to be a pair of unit characters of which the perennial habit was dominant and the annual habit recessive; there being a characteristic segregation in the second generation.

As to habit of blooming, there was another interesting anomaly. The opium poppy, a strict annual, blossoms only for a short period—for a few weeks at most. The oriental poppy, although a perennial, also blooms but a short time. The first generation hybrid poppies bloom persistently. There is not a day in the year when some of these hybrids are not in bloom, spring, summer, autumn, or winter—

blossoms can always be gathered in quantity from them.

The hardiness of the hybrids has not been fully tested. I should not be surprised to find that they are largely as hardy as the oriental poppy, but the California climate does not subject them to a severe test.

The Third-Generation Hybrids

In the third generation a large number of the hybrids reverted toward one or the other of the original parents. But even those that resembled one of the parents or the other strikingly, retained also traits of the other parent.

All these unique hybrids present such interesting characteristics that it will be worth while to record that the opium poppy that was used as the original parent was of the Miss Sherwood variety, but that later other opium poppies of every shade and color that could be obtained were also used. Perhaps in all twenty-five or thirty selected varieties of opium poppies of various colors and different forms were used as seed parents. The progeny, however, as far as I could observe, varied little more than these from the Miss Sherwood crossing, and was not greatly influenced by the different type of opium poppy used. However, the variation was so great in any event that it would be difficult to judge as to this.

In general, the minor colorings and doublings of color seemed to have less effect in the heredity than the more fixed original foliage and flowers of the wild plants. The hybrids show doubleness and selected colors very slightly, except in a few cases in the second generation, when there was a tendency to return toward the original forms.

The size of the pollen and length of the pollen tubes may conceivably have something to do with the failure to effect hybridization when the oriental poppy was used as the pistillate parent, but this is only conjectural. Also, the opium poppy has been so long under cultivation, and has become so adaptable, that it probably is more pliable and more ready to receive strange pollen.

The relative sterility of the first-generation hybrids may be judged from the fact that almost five thousand seedlings produced ten or twelve gallons of capsules, but that there was only about a quarter of a teaspoonful of seed to each gallon of capsules.

As these seeds were shrunken and much smaller than ordinary poppy seeds, however, the actual number of seeds was proportionately large. Still the total number was only a fraction of what would have been the output of poppy plants of normal fertility.

All in all, this experiment of hybridizing the oriental and the opium poppies, with the production of relatively infertile hybrids showing Mendelian heredity as to some traits and a blending of characters as to others, and a further segregation and recombination of characters in the second generation, constitutes an unusually interesting experiment in heredity. I have made many other experiments in breeding the various poppies, but none perhaps that excelled this one in interest and importance. The best of these new hybrids have now been grown both by division and from seed for sixteen years and are unusually vigorous and have flowers of wonderful sizes and various colors, mostly crimson.

THE HYBRID LARKSPUR AND OTHER TRANSFORMATIONS

INTRODUCING A MISCELLANEOUS COMPANY

ALL the members of my hybrid larkspur colony are descended from a single individual.

That individual, in turn, was the select and peerless member of a company of some five thousand or more, all of them of equally aristocratic lineage, and each one of them worthy to show itself in any larkspur company. But the usual rigorous method of selection was also applied. The one individual that came nearest meeting all expectations was preserved. The rest were sent, with sundry thousands of other plants of diverse species, to the bonfire.

The selected individual, of course, became the progenitor of a new colony of larkspur. Some of these improved upon their ancestors, and many interesting varieties were isolated through selection.

The original parent form from which the one best larkspur was selected as the progenitor of new races was of the species known as *Delphinium hybridum,* or hybrid larkspur. As the name implies, this plant is itself of hybrid origin, but it has been cultivated a long time in Europe, being unusually popular in England, and ranks as a true species, or at least as a good horticultural variety.

There are numerous other species of larkspur, sixty or more altogether. Some are annuals and some perennials. Our native California species are among the most beautiful. One of these, named *nudicaule,* is a perennial growing along the sides of streams and in shady canons, although on occasion even mounting to the tops of high rocks. It bears flowers of a bright orange red, sometimes varying to yellowish, that are very showy. The plant is easily cultivated either from seed or by division, as indeed are nearly all perennial larkspurs.

Another species is *D. cardinale,* a large, strong plant growing in the southern part of California, the flowers of which are bright red and yellow, though quite different in general appearance from those of the one just named. Yet another larkspur that is of interest is *D.*

decorum, an extremely variable form growing usually on overflowed land.

The flowers of this wild species vary almost as much as do our hybridized and cultivated ones.

Growing side by side in a bed of wild larkspurs of this species may be found plants bearing flowers varying from deep blue, pale blue, dark rosy pink, pale pink and yellow, to almost pure white. The flowers of these are quite large and showy, but the colors, although so variant, are seldom brilliant. This is one of the species the seed of which requires time and patience to induce germination.

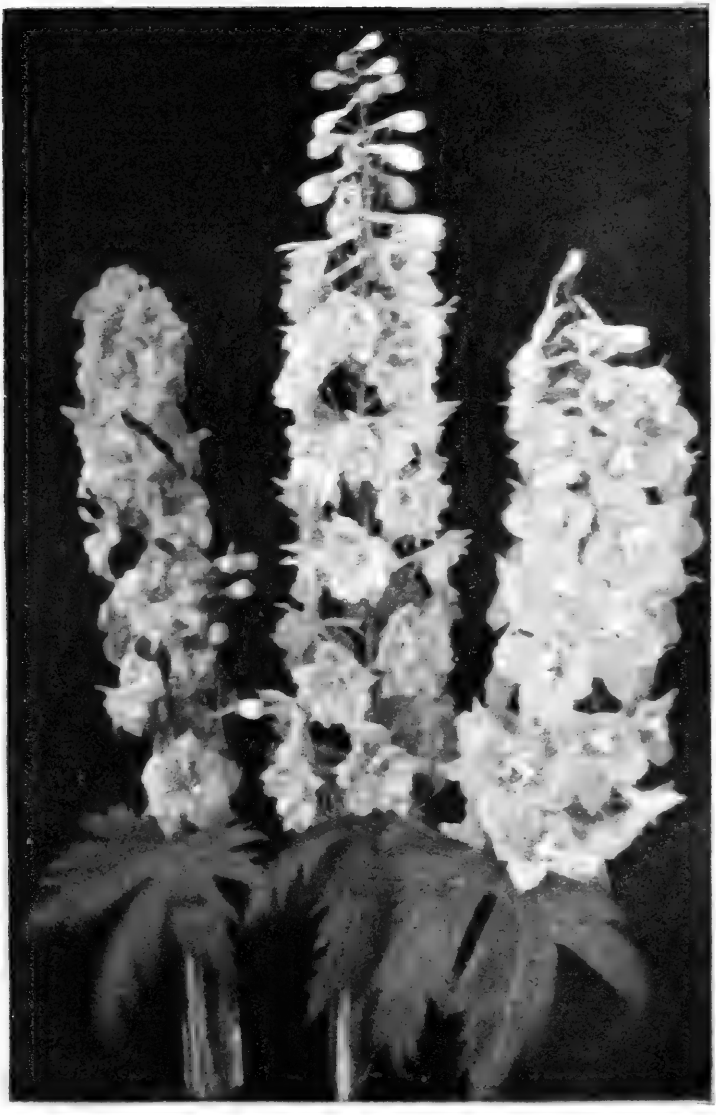
The larkspur known as *D. californica* is a giant species, often found in canons toward the coast. It towers to a great height, sometimes reaching seven or eight feet, but the flower is insignificant when compared with most other species, both in size and color. They are purplish blue or dingy white in color.

The combination of this species by crossing with some of our cultivated ones has not reresulted in producing anything of value.

There are several other native species of this State and some of them are mentioned in detail, chiefly to show the variation among them, suggesting the possibility of interesting developments when the various forms are combined. I

IMPROVED HYBRID LARKSPUR

Few of our flower productions are more popular than this improved hybrid larkspur. This picture suggests that the flowers amply justify their popularity. They are the product of hybridization, as their name suggests, combined with careful selective breeding.



have utilized them all more or less in experiments, and in addition have grown nearly all the larkspurs that are ever offered by seedsmen or florists. As already stated, my chief experiments began with the use of the hybrid larkspur as a seed parent, but of course the hybridizing experiments soon blended the strains of many of the other species, until the larkspur colony, like so many other flower groups, is of such conglomerate ancestry that the precise proportions of the different strains in any given race are not traceable.

Needless to say, selection has been carried forward along with the hybridizing experiments, these two methods always being complementary. Particular attention has been given to size of flower, vigor of plants, and resistance to insects and disease, as well as that of multiplication by division, at the same time that compactness of growth and brilliancy of color of flower have been carefully regarded.

One of the worst faults of the hybrid larkspur is that it tends to grow too tall, with a stalk that does not well support it, so that it requires to be staked. But my hybrid larkspurs have been so selected that they are compact in growth, and usually able to support themselves even in a moderate gale.

All the characteristic larkspur colors are represented among the new varieties, and in addition there are combinations of color that have never before been seen, I think, in the larkspur. Some of the individual flowers are considerably over two inches in diameter, and some of the largest are very double.

The color yellow is not common with the larkspur, its characteristic colors being red, blue, and white. There is one yellow species, a native of southern Asia. From this I have developed varieties with pale yellow flowers. The best of the selected varieties, as descended from the original one chosen among the first five thousand, is known as Burbank's hybrid, and has been given full recognition by seedsmen, florists, and gardeners. There is still opportunity for further development among the larkspurs, however, and improvements may be expected which, if not spectacular, have at least a fair measure of interest.

No plant is ever so fully developed that it does not hold possibilities of improvement.

A rare lemon yellow larkspur has been lately discovered near Bodega Bay, California. How this should have been so long overlooked is a mystery, even though it occupied only a small space in its native location.

An Almost Endless Variety

The great family of composites presents an almost endless variety of flowers, of which we have seen some striking examples, most notable among these being perhaps the daisies and the dahlias. But now and again a new form makes bid for popularity, and there is still an indefinite amount of material among our wild plants from which garden plants might be developed.

Yet the old favorites are not necessarily supplanted. Indeed, there are some of them that have perennial interest, holding their charm despite all competition.

One of these is the marigold, of which there are various species that find favor not only because of the ease with which they may be cultivated, but also because of the length of time during which they bloom, the abundance of blossoms, and their good keeping qualities after being picked.

The marigolds most commonly cultivated fall into two distinct groups, one spoken of as the African marigold and the other as the French marigold. In addition to these there are native species, among others a very interesting one sent me from Arizona, by Professor Lemon, whose name it bears. This native form is a

MORE HYBRID LARKSPURS

The hybrid larkspurs are very pleasing in form, and the compact clusters in which they grow are peculiarly attractive. But their other good qualities are enhanced by the wide range of color variation, of which a faint suggestion is given in this picture. The range of colors is striking, and all of the colors are pleasing. (One-third life size.)

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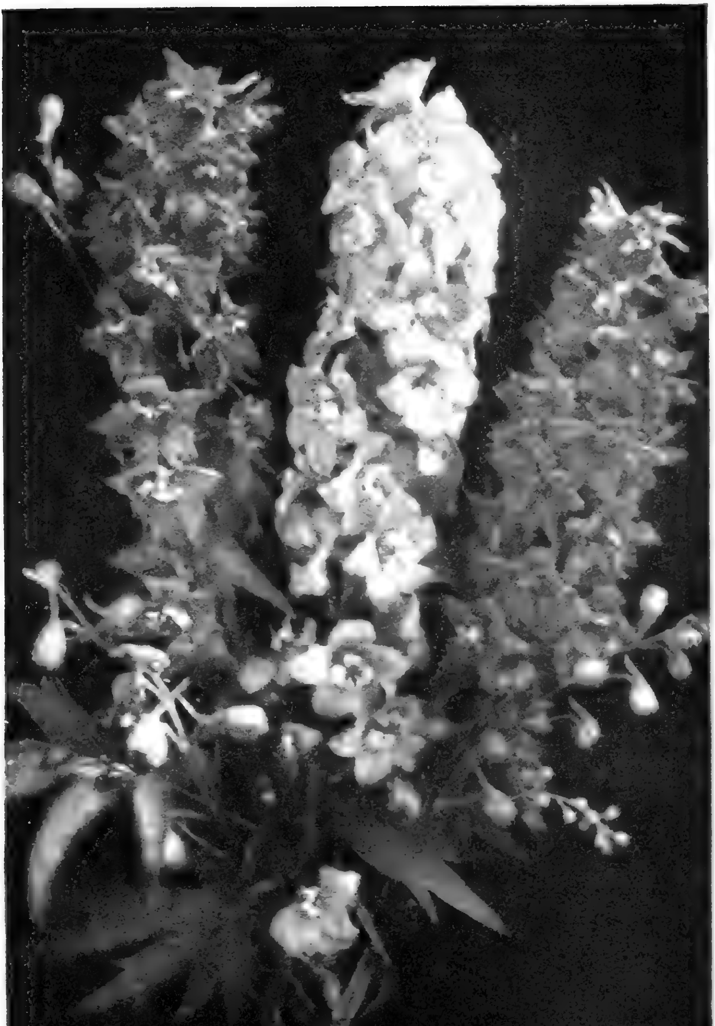


shrub about four feet in height, and in the fall it bears a mass of beautiful single golden flowers about the size of the French marigold.

This is one of the handsomest shrubs of this sort, and although I think it has not yet been introduced, it deserves a place in every garden, if—as has not yet been proved—it will stand the colder climate.

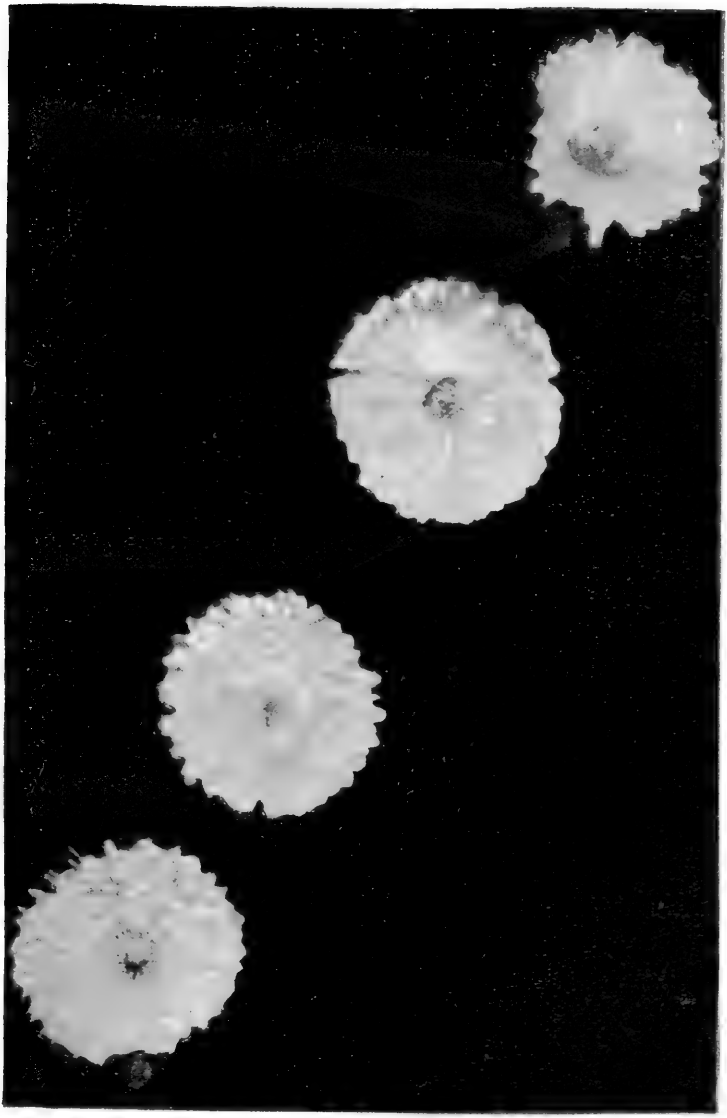
My experiments with the marigold were mostly conducted many years ago, chiefly along the lines of crossing the French and African races and this new Arizona perennial species. In addition to their practical horticultural results, the experiments gave some interesting illustrations of hereditary influence.

In particular it was observed that when the double marigolds were crossed with the perennial single species, above mentioned, all the hybrids were single, as would naturally be expected, for most wild plants have their tendencies in all directions more fixed by endless uniform environment instead of the ever-changing environment of cultivated plants.

It is interesting to recall that precisely the opposite result was produced in hybridizing the poppies. In that case the union of an annual and a perennial poppy produced hybrids, all of which were perennials and for the same reason;

EDUCATING THE CALENDULA

Even the flower at the left has multiplied its petals many times; and the middle flower and the one at the right show successive stages of the filling up of the center with ray flowers.



It is, in fact, one of the most variable and pliable of plants—comparable in this regard to the dahlia.

Such being the case, it is not surprising that it has been found possible to develop new shades of color, as well as much larger and finer flowers than those of the original species. Forms with wider petals, and others with twisted petals and other variations of the corolla, have also been developed. Even a double cosmos has been produced. But the species is comparatively new in the flower garden, and offers therefore, rather exceptional opportunities for the experimenter.

The amateur who is looking for a plant that has not been carried to anything like its limits of variation may advantageously pay attention to this graceful, attractive, and rapid-growing composite.

The extreme heat and long days of the summer even in high altitudes in the United States makes possible the cultivation of a large number of flowers that were originally of tropical habitat. Among these no others are more familiar or have retained their popularity more steadily than the tribe of plants of the genus *Ipomœa,* which numbers among its representatives plants of such diversity as the morning-glory, the moonflower, the cypress vine, and the sweet potato.

A CALENDULA OF REAL DISTINCTION

This specimen is approaching the limits of variation in the direction toward which it has been specialized. Note the fringed character of the ray flowers, and their exceedingly symmetrical distribution, like shingles on a roof.

Another vinelike plant from South America that has made its way into every garden is the *Tropæolum,* commonly known as the nasturtium.

There are at least forty species of this tribe, mostly climbing natives of Peru and Chile. One of these, *T. tuberosum,* produces spicy roots that are highly prized as food and the seeds of the annual varieties are sometimes used in pickles and salads. The seeds of the form familiar in our gardens are often pickled and it is probable that table products of greater value could be developed from these plants if attention were paid to breeding them with that idea in mind.

Some of the nasturtiums are exceedingly tender to the slightest chill, but they may grow in the hottest and driest soil.

My work with the nasturtiums has been mostly with specimens sent from South America by my collectors, representing eight or nine species. Some of these have bulbs that sometimes remain dormant in the ground for two or three years, and then sprout and grow very fine vines.

The common nasturtium of our gardens, *T. majus,* is one of the most readily grown of our annuals and has been so long cultivated and so thoroughly crossed that the colors of the flowers are exceedingly variable. In recent years very good work has been done, particularly by California cultivators, in the improvement of the climbing nasturtiums, and in particular by crossing the ordinary form with the one known as *T. minus*.

Both the parent forms and the hybrids have run into numberless colors, clear lemon-yellow, flesh color, deep crimson, purple, scarlet, deep yellow and white, the colors being variously blended, and the foliage of the plant being sometimes most beautifully variegated. Even the form of the leaf has been changed, so that there now are ivy-leaved strains of nasturtiums.

The nasturtiums offer great interest for the amateur experimenter, as they are very readily hybridized, and as their range of variation, even without crossing, is so great as to afford the widest opportunity for selection. Indeed, crossing has been so fully carried out that for ordinary purposes selection will answer far better than further crossing. It is exceedingly difficult even to keep the colors of the various nasturtiums separate. The seed of a pure white variety quite commonly may produce various colors. And it is more difficult to fix these colors than is the case with most other flowers. But of course such difficulties only enhance the interest of a really earnest experimenter, and develop his enthusiasm.

Stamping Personality on a Flower

An illustration of the way in which the personality of the experimenter finds expression in the plants that he cultivates was furnished me a number of years ago by Mr. Peter Barr, a well-known horticulturist who specialized with the narcissus and daffodils.

On visiting my place a number of years ago, he related an experience that may be taken as typical, yet which the amateur who has not experimented extensively might regard as rather extraordinary. The story has been told in an earlier volume, but it may be briefly repeated here.

Mr. Barr stated that among the thousands of seedlings, the whole stock of which he purchased of two specialists in England, he could always tell at once, on seeing the blooms, which of the two specialists had developed any individual plant, even though the varieties had been mixed.

One of the breeders produced very large, coarse flowers, gigantic and broad, and lacking in delicacy of contour. The other produced seedlings of graceful and exquisite form.

And these contrasting characteristics of the different daffodils, Mr. Barr assured me, typified the personalities of the two breeders by whom they were developed. One of these was a person of little refinement, notwithstanding his love of flowers; the other was a cultivated banker of artistic temperament. The tastes and propensities of the two men made themselves felt in all the flowers they produced; which of course was inevitable, when we reflect that the plants were produced by selection, and that each man naturally selected the type that appealed to him.

The incident is here mentioned not as something exceptional, but as typical. Almost as a matter of course, one could draw correct inferences as to the personality of a plant developer from observation of the varieties that he has developed—provided always, of course, that his selections have been made along the line of his own tastes, and not to meet some specific commercial demand.

There should be for the amateur an added stimulus in the reflection that he is thus putting the stamp of his own personality upon the plants with which he experiments. The flowers of your own garden may thus come to have an individuality that represents you as fully as you are represented by your costume or by the books you gather on your shelves. And surely the possibility of developing a flower garden that has such individuality, differing from any and every other flower garden in the world, should give the pursuit of the amateur florist unique interest.

Some Interesting Natives

More than once the possibility has been suggested of introducing to the garden species of plants that grow in the wilds and that offer interesting possibilities of development. Two or three other tribes of these interesting wildlings may be here referred to. To name all that are worthy of consideration would take many volumes, for there are more than ten thousand species of flowers indigenous to the United States, and of these only something like fifteen hundred have at one time or another been placed under cultivation.

Two or three familiar ones may be named, in addition to those that have already been referred to, as offering exceptional attractions.

There are, for example, the Gilias, represented by many species. I have cultivated twenty or more wild ones at one time, selecting for brilliancy of color, for size of flower, for compactness of growth, or for some other desired quality.

On occasion I have carefully examined at least ten thousand different plants in order to select the individual with which to begin improvements.

THE VARIEGATED NEGUNDO

This variety of "Box Elder" is prized for the color of the leaves—and very justly so. It is the only hardy tree known which produces such beautifully variegated foliage, which retains its beauty all summer, even in our sunny climate. This was introduced from my place some thirty years ago.

The gilias vary greatly in color, so that they are very interesting flowers with which to work, and the colors may very readily be fixed in the course of four or five generations. So also may the qualities of compact growing, size of flower, and the like. The plants, therefore, are encouraging ones for the amateur who is anxious to get results.

The familiar milkweeds have been referred to in another connection with reference to the peculiar arrangement of their pollen masses, which are so adjusted as to entangle the feet of bees.

The amateur will find it peculiarly interesting to cross-pollenize these flowers. It will be advantageous to work with a magnifying lens of considerable power. The curious form of the flower and the unique arrangement of the pollen masses give the work of cross-fertilizing these plants a unique character, and these flowers are in general among the most puzzling of all flowers for the amateur.

There is possibility of developing, among the milkweeds, plants of commercial value. I have cultivated a number of unclassified South American species. For two or three years the work of selecting the best seedlings among a large number was carried on, until several races among several species were pretty sharply defined. The best of these are now being crossed, the object being to get varieties of more beautiful blossoms for garden culture, and also to secure varieties that will be of value in producing a fiber that has something of the quality of silk.

Even now tons of milkweed seed pods just before they are ready to open are dried in the Mississippi Valley and shipped to Japan, where they are used to make a kind of cloth, which is even more beautiful than the finest silk, but not as durable on account of the short fiber. In the Philippines there is a remotely related plant, the Kapok, which supplies a fiber much used for filling pillows and the like.

It is considered within the possibilities that a variety may be produced that will be of value for the production of rubber, as the juice of some species has excellent rubber qualities.

The native varieties of milkweed are generally exceedingly hardy and as they are perennials may be worked on season after season. There is great variation as to vigor of growth, size of leaves, compactness of plants, and color and form of leaves, as well as regarding the size, color, and abundance of blossoms. The seed pods, with their white, silklike fiber, also vary greatly. And there is corresponding variation as to the amount of latex or milk produced by the various individual plants.

All in all, then, there is scarcely another tribe of plants that shows a wider range of interesting qualities for observation of the experimenter.

Another wildling offering attractions of a different character is the so-called painted cup, or Indian's paintbrush, classified by the botanist as *Castilleia.*

The most familiar form of this plant is the one known for its brilliant scarlet color. But the tribe is exceedingly variable, and the different members present flowers that range from scarlet, crimson, orange, yellow, and purple to pure white. Some are variegated. Individual plants growing on the same cliff along the ocean shore may show the widest range of variation in the color of their blossoms. All colors are sometimes combined in the flowers of a single plant.

In other cases one will find a small patch of yellow flowers in one place, and in the neighborhood another patch of orange or white ones.

The only color that is missing is blue. It would thus be an interesting quest for some plant developer to see whether he could develop a blue painted cup, somewhat as I was able to develop a blue poppy. Even failing in this, the opportunity to study heredity of color, and to isolate races of painted cup of one color or another, and fix them so that they would come true from seed, would require a number of seasons.

The fact that the painted cup does not always prove easy of cultivation suggests that it is a plant worthy the attention not merely of the beginner but also of the amateur whc has gained experience, and who is willing to try his hand at difficult problems of plant development.

As before said, it would be possible to extend almost indefinitely this list of interesting flowers that invite development. But the ones named may serve by way of introduction, and the amateur may readily extend the list by looking about in almost any garden or by rambling almost anywhere along country roads or in neighboring fields.

The material lies everywhere about us, and despite the activities of large numbers of flower lovers, there are hundreds of species readily accessible that have never come under the hand of the cultivator, and which therefore have the attraction of entire novelty.

ORNAMENTAL PALMS AND CLIMBING VINES

VIEWS ON ARTISTIC TREATMENT

VISITORS from the East are often surprised to find palms growing thriftily at Santa Rosa and also in nearly all parts of the State. The average resident of northern latitudes associates the palm with tropical conditions. And while it is known to everyone that these trees grow in southern California, it seems a matter for wonderment that they should be found so far to the north as the region in which my experiment gardens are located.

In fact, isothermal lines make little or no difference in California, as the winds from the Pacific, deflected by the mountains, determine the climatic conditions, and produce quite unpredictable results. Thus it is that oranges are sold by the carload from northern California before they are even colored in the southern part of the State.

And again, the palm is a relatively hardy tree, in comparison, of course, with tropical plants in general. And whereas the date palm does not thoroughly perfect its fruit, for the most part, except in regions where the summer is very long and hot, this tree may withstand extremes of temperature that are widely removed from anything experienced in the tropics, and other palms generally perfect their fruit wherever they can be grown.

Indeed, so hardy are some of the palms that the question arises whether it may not be possible by selective breeding and adaptation to develop races of palms that will thrive even in the middle latitudes of the eastern United States, and far to the north of their present limits on the Pacific Coast. The fact that most of the palms now growing in California have been introduced within comparatively recent times, and that they have gradually made their way northward, is suggestive of the possibility of much wider extension of their habitat.

A difficulty in the attempt to carry out any project in selective breeding calculated to give the palm additional hardiness or any other quality is found primarily in the fact that this tree does not mature its fruit until from ten to twenty-five years of age. But in recent years an effort has been made by the Department of Agriculture and by several private individuals, to introduce races of date palms that will bear marketable fruit, and study of the palm that has been undertaken in this connection will doubtless lead to important results. Even now it has been demonstrated that just as good dates can be grown here as in the Sahara.

It appears that the palm, notwithstanding its relative fixity, is subject to considerable variation, and that this is particularly true of the date palm fruit, as might be expected considering that this tree has been under cultivation from prehistoric periods, and because it has been selected for the fruit alone.

The most delicate and delicious date fruits are not the ones that can be secured for export, so that these varieties can never be seen on the American market until they are grown here. All the best date palms, unlike most other palms, are grown from suckers which come up from about the roots of the tree.

To be sure, the Oriental peoples, for whom the date has supplied a most important food product from the earliest periods, have probably paid very little attention to selective breeding. Still the broad general fact that "like produces like" has been matter of common knowledge from remotest antiquity, and it can hardly be doubted that a certain amount of more or less intelligent selection of the trees that bear the best fruit, with attempts to raise seedlings from these trees and thus secure races of good fruit bearers, has been practiced generation after generation.

Moreover a certain amount of cross-pollenizing between allied races of palms has doubtless taken place without the agency of man, and so it is all but certain that the different palms under cultivation bear mixed racial strains, somewhat as do the different races of orchard fruits and cultivated plants of temperate climates.

It is quite to be expected, then, that the palms grown from the seed should show a good deal of variation.

That such is really the case is made obvious to anyone who attempts to raise them. The date palm, for example, may readily enough be grown from the seed, for the seeds germinate readily, though slowly. But the tests have shown that the progeny of a date palm bearing fruit of the best quality cannot be depended upon to transmit the characteristics of the parent with a high degree of certainty.

So it is necessary to grow the young trees from suckers if the strain of the parent is to be perpetuated accurately.

The experts of the Department of Pomology at Washington and several private individuals have imported rooted suckers, obtained from female trees known to produce fruit of excellent quality, distributing and planting them in various regions of the southwestern United States.

The trees that grew from these suckers have proved to be pistillate, as expected, and produced fruit equal to that of northern Africa. Considerable difficulty was first experienced in securing suckers from the *best* trees, even private individuals not being allowed to own them in the original country. As to the date palm, the progress already made in the improvement of the fruit indicates beyond the shadow of a doubt that still further improvement will be made in many directions. It is probable that the colony of fruit bearers thus introduced will spread indefinitely, until the date palm becomes an important economic tree in warmer portions of America, as it has already done in parts of California.

It is even more important with the palm than with other fruit-bearing trees that propagation should be carried out in this way, because when the plants are grown from the seed only half of them will be bearers of pistillate flowers.

The pollen-bearing trees will of course bear no fruit, and while there must be here and there one of these in the palm grove—one staminate to about twenty-five pistillate trees—it would be an obvious waste of space to give over half the ground to sterile trees. Yet there is no way of determining whether an individual tree is a male or a female until it comes to the age of blossoming; and the palm is a tree of slow growth that matures only after many years.

But trees grown from suckers will be of the same sex as the parent trees; hence the double utility of propagating by this method.

Palms for Ornament

From the standpoint of the present chapter, however, the fruit-bearing qualities of the palms are not so much in question as their ornamental character. Considered merely as ornamental trees, there are members of the genus *Phœnix,* to which the date palm belongs, that are more attractive than this famous fruit bearer. And in general the character of the form and foliage of a date palm is carried with sufficient certainty from parent to offspring by the seed to make it perfectly feasible to raise palms from the seed for ornamental purposes.

Even where the seeds are planted in rows, with the expectation of producing colonnades of palms, along roadsides or for borders, the palms may be grown from the seed without danger that they will vary sufficiently to interefere with the symmetry of the row, provided the seed are gathered from the same tree, or at any rate have come from the same general stock.

If, however, the seed be imported from different regions, there is probability of variation even among trees of the same species.

The usual method, in California, is to germinate the seed in a hothouse, growing the young plants in pots at first, and then removing them to boxes that they may be more readily transplanted, as they make hard, slender, wiry roots. They are as easily grown as kernels of corn, though requiring much longer periods of time. Occasionally, however, when quite small, they are planted in nursery rows, and it is sometimes desirable and safe to transplant them after they have obtained a growth of twenty or thirty feet in height, and a diameter of trunk of one or two feet.

In such a case, it is best to cut around the roots of the tree some time before removal, making a ball of earth that is to be removed with the tree. This treatment induces the palm to throw out new roots, giving added firmness, and making provision for the rapid absorption of moisture and nourishment after transplantation.

A box being constructed around the soil, the palm may be removed to any distance.

Sometimes a single palm thus transported is of such size as to require an entire flat car. But unless the precaution is taken to cut back the roots and allow them to stand for some time before removal, as just suggested, there is danger that the palm will die after transplantation, because the loss of its long roots makes quick adaptation to the new conditions impossible.

The *Phœnix canariensis* is a thoroughly hardy palm in this climate, and the handsomest of the hardy members of the tribe.

It is therefore the one most used for planting for ornament in California, though the *Chamærops excelsa* from Japan is as hardy and next most common. The Canary palm grows with great rapidity after the plant has the first five or six leaves, although like all other palms its early growth is slow. An ordinary specimen of this species, transplanted into good soil in this region when it has four or five leaves, will grow to a height of fifteen feet, with a corresponding spread of branches, and develop a trunk eighteen inches in diameter in six to ten years.

No other palm with which I am acquainted will make more than about one-half this growth in the same time and under the same circumstances.

There is considerable difference in appearance, however, and in rapidity of growth of different strains of palms of this species. Yet the seedlings are unusually true to type, so that long rows of the Canary palms may be grown from the seed with full assurance that they will not vary sufficiently to break up the general uniformity of the row.

Palms of the genus *Chamærops* are also very hardy. I have never known one of them to be injured by frost anywhere in California, even when quite young.

There are several species of this genus. I have grown them from the seed somewhat extensively, and have noted a wide variation among the different species, some making large trees while others are dwarfs, some of which, in this region, never attain a height of more than three or four feet. One exceedingly thorny species may be multiplied by division readily, as it throws up suckers abundantly around the old plant, unlike most other palms. Some accidental hybrids have appeared among the species of *Chamærops*.

Variation and Development

Notwithstanding the considerable variation among the different strains, there is almost no discoverable variation in seedlings of a species of this genus of palm when grown from seed of the same tree. The species most commonly grown in California is *C. excelsa.* This is a species that in China and in Japan is one of the most useful of trees, its foliage being used for thatch, the rigid leaf stalk for braces, and the woolly substance about its trunks for cordage and other purposes.

Moreover this is the palm from which fans are usually made, the undeveloped, immature leaves being used for this purpose.

The palms of this genus usually bear the staminate and pistillate flowers on different trees, but it is not unusual to find a few staminate blossoms on pistillate trees, or, contrariwise, a few pistillate blossoms on staminate trees.

If the attempt is to be made to hybridize the different species with the hope of developing hardier races, the matter of fertilization of the flowers becomes obviously important.

It will be worth while, then, to select the trees with reference to those that tend to mature their fruit while young.

But the work of developing a race of hardy palms will necessarily be a slow one, requiring the cooperative labors of successive generations of plant experimenters. And whereas it is probable that in the course of a century or two hardy palms will be developed, so that the question of selection of ornamental palms will be of interest even to residents of the middle and perhaps even of the northern regions of the United States, at the moment the matter can have practical interest only for a limited number of people, and we need not consider it more at length here.

It suffices to say that the methods of hybridizing and selection that have proved successful with other plants will doubtless be found to have full application to the palm; and to add that the actual work in this field has been begun only in a tentative way.

The method of hybridizing is simplicity itself —as simple as crossing two varieties of corn.

Meantime, however, the palm exists as an ornamental tree of the very greatest value in California, and the interest shown in it by tourists justifies the expectation that, in the near future, efforts of a comprehensive character may be made, probably under Government supervision, to develop races of palms that can be grown far to the north of the present limits of this tree in the eastern United States.

A drive along Grange Boulevard in Los Angeles, or from Palo Alto to Stanford University, for example, and inspection of its rows of palms, alternating with pepper trees, gives the visitor from the East a mental picture of the possibilities of this race of trees for ornamental purposes that should certainly stimulate a spirit of emulation. Interspersed among pines—their ancestors of prehistoric times—they will be particularly appropriate and look especially well.

The ornamental value of palms for roadsides and borders, and artistically placed here and there on the lawn, is admirably supplemented by a background of vines growing on walls or over rustic arbors or pergolas.

And of course there are numerous vines, as everyone is aware, that flourish abundantly in regions where the palm cannot be grown. So the picturesqueness of effect that can be gained by the use of vines sometimes better than in any other way is available for the residents of northern climates, even far toward the Arctic Circle, almost as fully as in the subtropical regions.

Among the vines that are so thrifty that they will grow in almost any soil, and so hardy as to resist the coldest winters, the various species of the genus *Ampelopsis* take foremost rank. Of these the Japanese Ivy, sometimes known as Boston Ivy (*A. Veitchii*) and its varieties, is probably the best known and the most extensively grown. For the purpose of covering brick and stone walls it is perhaps the most beautiful of all vines.

This vine has a close rival, however, in the native species familiar everywhere in the Middle and Eastern States as the Five-Leafed Ivy or Virginia Creeper (*A. virginica*). This vine, however, does not cling to flat, smooth surfaces as does the Asiatic species.

The strains of this vine differ materially in different localities, there being one in particular, named the *Engelmanni,* which clings to walls and trees better than the ordinary varieties. Vines of this variety are also far ahead of others in their rapidity of growth and in the beauty of their foliage, and especially in their autumn coloring. Some varieties hold their foliage nearly a month longer than others.

These variations should be borne in mind in selecting plants for the covering of walls or making of arbors. The wild *Ampelopsis* vines growing in Colorado are, in my opinion, much superior to those of the Eastern States.

I have raised thousands of seedlings of both species of *Ampelopsis* just named, and many specimens of other species known respectively as *A. heterophyla* and *A. arborea,* and have crossed some of them.

The Japanese Ivy and the Virginia Creeper have now been crossed, and it is expected that the combination will produce varieties of value, giving opportunity for the development of new races or ornamental vines to add to the comparatively limited number now available. The work is being carried forward on a large scale, and it is probable that the *Ampelopsis* and the grape may be brought into combination.

Meantime, I have more lately developed a new variety of Virginia Creeper through selection that has much larger foliage than the ordinary varieties, and that is also a much more rapid grower, with the habit of holding the foliage to a late period in the autumn. As the plant is readily propagated by cuttings, such a new race as this may be distributed indefinitely.

These vines are grown chiefly for their beauty of foliage alone, although the grapelike berries of the Virginia Creeper are not without some decorative value.

There are other vines that in some respects rival the *Ampelopsis* as climbers for the covering of walls and arbors, and that have the added merit of producing beautiful flowers. Notable among the vines that have this double attractiveness are the various species of *Clematis*.

There are several native species of the *Clematis*, and some of the species have been brought sufficiently under cultivation to develop a tendency to vary widely. Nearly all are rapid climbers, and produce beautiful flowers in great abundance. In addition some have feathery seed pods that are scarcely less attractive and interesting than the blossoms that precede them, making an artistic contrast with the foliage for a considerable period. So all in all the clematis must be ranked among the most beautiful of vines.

My own work with the members of this class of plants has been largely with the types that are known horticulturally as *Jackmanni lanuginosa*. These have large blue and white flowers, sometimes inclined to red and pink.

This type has been raised very extensively from the seed for many years, and, by selection, several varieties were produced that bore very handsome double flowers of peculiar form, varying in color from blue, pink, and ashy gray to pure white. Some of these new varieties also have exceedingly large broad petals with the flowers of unusually rounded outline, not unlike the form of a dahlia.

Several of the best of these were introduced through dealers. The clematis is somewhat subject to a disease usually ascribed to the same cause that destroys lilies and many other plants in cultivated soil. It is probably bacterial, and is associated with thrips, millipeds, and eelworms, which probably serve to disseminate the germs.

Subsequently I began a series of hybridizing experiments, using the *Clematis coccinea* as the original seed parent.

This species is herbaceous and has scarlet flask-shaped flowers, with the sepals slightly opened by the curling outward of their tips. The sepals are thick and fleshy, although not leathery, giving the flower almost the appearance of a fruit.

This species is not variable, about the only diversity noticeable being a slight variation in the size of the flowers. It produces seed freely, and to the pistils of *coccinea* was applied the pollen of various other species; among these being *C. crispa,* known as "Blue Bells," *C. Davidiana, C. Fremonti, C. ligusticifolia, C. Douglasi, C. verticillaris, C. occidentalis, C. Fortunei, C. Viticella,* and others, no attempt being made to keep the various crosses separate.

The hybrid progeny showed a very wide variation, especially as regards color of the flowers. There were blue, crimson, scarlet, and white flowers, and sometimes all of these colors appeared on a single plant.

There was also much variation within certain limits in the form and texture of the flowers, which in general were of a much larger size than those of the seed parent, and more spreading and widely open in form. Some of these had thick sepals and some had thin ones.

Perhaps the most striking peculiarity was that the interior of the sepals often had a frosted appearance, due to the presence of a filament network of papillæ. There is something of this appearance occasionally in flowers of *C. coccinea* and *C. crispa,* but it was greatly accentuated in many of the hybrids. In general habit and their herbaceous stems, the hybrids seem almost uniformly to follow the seed parent.

The flowers were produced in great abundance, and the colors were not only most beautiful but showed combinations never before seen in the clematis. The bell-shaped flowers are for the most part white on the inside, but exteriorly they are crimson, pink, orange, blue, or purple. The beautiful frosty throats give the flowers an appearance that is unique.

Among the hybrids a few of the most beautiful forms were selected and placed, without specific names, with a florist for introduction. Some of my earlier clematis introductions had been given names more or less suggestive of their peculiarities of flower, including "Ostrich Plume" and "Snow Drift." Another "Waverley," etc.

I have stated that the earlier varieties were subject to the clematis disease. In the later experiments the endeavor was made to produce varieties that would be immune to disease, as well as those that would show exceptional hardiness.

Several years ago, while on a trip in northern Canada, I found patches of clematis on half-woody slopes, growing in a region where the thermometer sometimes goes fifty or even sixty degrees below zero in the winter—regions where the deep wells do not thaw out altogether during the entire summer, always having a thick coat of ice about their walls.

The hardy clematis found in this region bears dark blue flowers that are fully three and a half inches in diameter, being about as large as those of the cultivated varieties known as the blue *Jackmanni,* the blossoms of which also resemble it in color. There are two or three wild species in the same region, namely *C. Fremonti* and *C. ligusticifolia,* plants that bear rather inconspicuous flowers of a greenish white color, but having long, feathery seed coverings that give them interest, and being in addition strong growers.

These have already been named among the species of clematis that were used in hybridizing experiments.

It was to be expected that plants having strains of such hardy species in their heredity would develop some varieties of great hardiness. And in this the expectations were not disappointed. A more extended series of experiments than I had planned to undertake would be necessary to fix the new varieties, and to make sure as to which of them are the hardiest.

There is still opportunity for fine work in this direction. The clematis is such a beautiful vine, and there are so many species available, and among these species such amazing variety of form of vine and flower, that the opportunity for extensive breeding experiments with this type is most inviting.

In raising the seedlings my practice was to sow the seed quite thickly in boxes in the greenhouse, as soon as it ripened in the fall, forcing the plants throughout the winter, and transplanting them in the open field in the early spring. The seedlings would quite often make vines from eighteen inches to two feet long the first season, but would rarely bloom the first year. In the second season they would almost invariably do so and the general character of their flowers could then be determined.

But the blossoms of the first season would not fully represent the possibilities of their mature production. For example, plants that first bear blossoms that are semidouble would in later seasons, when the vines had gained in strength, bear fully double flowers.

At the time when my first hybrid double clematis flowers were produced, there was, I think, but one other double one known anywhere in the world, this being a form produced in England. More recently, however, several good double varieties of this class have been introduced.

The clematis is a plant that improves with acquaintance. Existing varieties furnish vines that are beautiful in foliage, in flower, and in their picturesque display of seed pods. There is a great variation among the forms already under cultivation, but there is still abundant opportunity for improvement with these; and in addition wild species may be found that through hybridization will certainly introduce tendencies to still wider variation.

What plant could offer greater inducements to the experimenter?

Bignonia, Wistaria, and Bellflower

There are two or three other groups of vines that must be given at least passing notice.

One of the interesting forms with which I have done much work is the class of climbing shrubby plants of North and South America of the genus *Bignonia.* By crossing some of the bignonias with the *Tecoma,* a plant that grows wild in Virginia and Maryland, some interesting results were brought forth.

There was modification of color of flower, length of seed pods, and vigor of growth of the plants themselves. But no variety was secured that seemed worthy of special introduction.

An interesting feature of the hybridizing experiments with the bignonia is associated with the curious sensitiveness of the stigma of the flower to irritation. The two lips of the stigma stand open, like a set trap, and when pollen is supplied they close, traplike, grasping it instantly. Anyone who has never seen the lips of the stigma of the bignonia close when irritated by bees or artificial means would be greatly surprised.

It is necessary in applying the pollen to be somewhat dexterous, lest the lips of the stigma close and make the stigmatic surface inaccessible.

FLOWERS OF THE TECOMA

There are more than one hundred species of this genus, natives of temperate, tropical, and subtropical America, and also of Asia and Africa. Owing to the shape of the flowers, they are popularly known as trumpet vines. Some species, however, are upright shrubs or trees.

Nor may the lips be pried apart. They open spontaneously, however, after a time, but usually not until the patience of the operator has been exhausted. It is a curious and interesting experiment to irritate the stigmatic surface with a grass stem or twig, which will be grasped as the trap-like stigma closes, and held as a frog might hold a stick in its mouth. The same remarks apply also to the unrelated *Mimulus* or monkey flower.

Another ornamental vine that offers opportunities for the plant developer is the familiar and beautiful *Wistaria.*

There is a fair degree of variation among the different types of wistaria, some bearing blue flowers and others white ones. The plants of this genus are not only valuable as climbers, covering walls and arbors with vines that bear beautiful flowers, but they can also be trained to form tree-like bushes that are most attractive additions to the lawn. The Chinese wistaria is ordinarily a long vine, but may be trained to a bush five feet across and thrive fully as well. Under this mode of culture, a certain amount of energy that would ordinarily go to the production of the vine itself is saved and utilized for flower production, so that wistaria bushes thus trained become astonishing bearers of blossoms, like gigantic bouquets.

Nothing more is necessary in training the vine than to trim it to form a head, and then from time to time to cut out the straggling branches.

The wistarias are difficult to hybridize, because their flowers are papilionaceous, like those of the peas and beans. But, with a little care, hand-pollination may be effected, and some very striking variations should be obtained in the second generation from a cross, for example, between the American and Chinese wistarias.

A complex hybrid between these and the Japanese variety, *Wistaria multijuga,* which produces astonishingly long racemes of flowers, should give results of additional interest.

My own experiments with the wistarias have consisted of the growing of a great number of seedlings, both of the Chinese and American species, selecting among these for plants varying in form, and bearing blossoms of different size and colors. The results of these experiments show that the wistaria is quite an adaptable flower, and one that is certain to repay more extensive breeding experiments, in particular those that introduce the element of hybridization.

Only one other type of ornamental vine will be mentioned here, the *Lapageria,* or Chilean Bell-flower.

As an excuse for selecting this one among many tropical and subtropical forms, I may say that when I first saw the Chilean bellflower I thought it the most beautiful flower of any kind that I had ever seen. It has glorious, great, drooping, bell-shaped, rosy or white blossoms, which no lover of flowers could fail to admire. The foliage of the plant is smilaxlike, and somewhat deficient in quantity, but the wonderful flowers make amends for any defect of foliage.

Unfortunately the plants are very difficult to raise, needing peculiar soil and much attention. They are also sensitive to changes of temperature, and do not bloom at an early age. Moreover they must be kept moist at all times to insure good growth.

The possibilities of work with plants of this genus are shown in a remarkable cross said to have been made by Veitch, of England, between one of the Lapagerias and the *Philesia buxifolia,* the latter being the pollen plant. The hybrid which has been named *Philegeria Veitchii,* is of exceptional interest, inasmuch as the parents belong to different genera. In scientific interest it ranks with the blackberry-raspberry hybrids.

As illustrating the possibility of the production of interesting new forms, I may note that a collector in Chile sent me a few years ago several species of plants allied to the *Lapageria,* but unclassified as to species, that very much resemble the English Ivy and that show unusual habits of growth. One of these is said to bear excellent fruit.

At three years of age, when the first blossoms appeared, the strongest plants were about fifteen feet high. Among the thousands of seedlings, there is enough difference in the form of foliage, rapidity of growth, and other characteristics to show that the plant is susceptible of improvement even in the first generation of seedlings from wild stock.

Experiments in hybridizing these new plants with *Lapageria,* and further experiments in selection in the hope of securing a new vine that combines with other good qualities the property of fruit production, are contemplated.

The clematis is a plant that improves with acquaintance. There is a great variety among the forms already under cultivation, and through hybridization with wild species still greater variation may be induced.

LAWNS AND THEIR BEAUTIFICATION

Some Old and New Shrubs and Grasses

MOST people who see a good *Lippia* lawn are surprised to learn that it is not a grass. At a little distance this looks very much like any other lawn that is well covered with grass. But on closer inspection it appears that the lawn is carpeted with a plant that is obviously not a grass. It is in reality a species of verbena, very much more closely related to the familiar flower of that name than any other plant in cultivation.

This anomalous substitute for lawn grass is a plant which was briefly referred to in an earlier chapter as a relative of the verbena. It is known as *Lippia repens,* sometimes as *Lippia canescens.*

It is a plant indigenous to Chile, from which country I received the seed from which the new and greatly improved lawn plant was developed a number of years ago.

The value of the Lippias as lawn plants had been shown by Dr. Francheschi, of Santa Barbara, California, as long ago as 1900, he having introduced a common form of *Lippia repens* from southern Europe, where it had been grown as a lawn plant by division until it had lost its power of producing seed, thus making further improvement impossible.

The opportunity to improve the plant came when my collector in Chile sent seed of some of the wild species from the Andes. There was a good deal of variation among the plants raised from this seed, and the following season about ten thousand plants were raised, each one of which was given a little space in order that its individual peculiarities as to rapidity of growth, tendency to spread, and color of foliage might be studied.

From among these plants about half a dozen were saved, and the descendants of these constitute several varieties of *Lippia* that have marked peculiarities. A single cutting of one variety will spread on an ordinary soil over a circle about ten feet in diameter in a single season. This form would be very valuable for growing in sunny places, in certain localities along irrigating ditches, where the soil is subject to wash.

But I have more recently found two far better substitutes for this purpose. One is the *Mesembryanthemum æquilaterale,* which grows on our seacoasts. This produces an enormous amount of very heavy foliage, which is hardly moved even by a strong stream of water.

The other is the vine commonly called trailing myrtle (*Vinca major*). This forms a great mass of long white roots, and long slender vines with abundant evergreen foliage, which resists stream wash by shingling the whole surface so that the water cannot reach the soil. No plant surpasses it for this purpose.

Another variety of seedling lippia grows only half as fast, but has very fine dark green leaves and lies very close to the ground, making a most beautiful velvety lawn, while the older lippias made a very unsightly lawn, though better than none, for warm dry climates. Unfortunately none are hardy in the cold northern climates.

A third variety of lippia has pale-green leaves, is a slower and even more compact grower, and makes a lawn that contrasts charmingly in color with a lawn of the other lippias, or ordinary lawns of blue grass.

A fourth variety has long ropelike runners growing in all direction, but not filling up the spaces, and therefore not being suitable for lawns. Still another has hairy leaves that give it a peculiar frosty appearance, whereas the leaves of other varieties are most often glossy green.

The foliage of these selected new seedlings vary greatly in size, the leaves of some being several times as large as others. The half dozen types selected are being used for further development, and as might be expected they show still more variations in the second generation. A single plant of some of the rapid-growing varieties usually overgrows and covers up perhaps a dozen of the smaller lippias of the same age.

Add that the new plants, in addition to their rapid and compact growth, are adapted to dry soil, requiring not one-tenth the water that blue grass or other ordinary lawn grass requires, and keeping in good condition longer than any blue grass or clover lawn with a fraction of the care or the expense for watering, weeding, and mowing necessitated by the ordinary lawn and it is obvious that these developed varieties of lippias constitute an important acquisition.

Curiously enough the lippia lawn makes a better appearance where it is frequently trod upon and subjected to treatment that would injure an ordinary grass lawn, or destroy it altogether. The plants appear to pay no attention if a path is made directly over them; their appearance is actually improved thereby.

With some species occasional runners may grow above the main mass of foliage and become unsightly, but these are readily cut away, leaving a smooth velvety surface.

The real difficulty that stands in the way of the general introduction of the lippias as lawn plants of altogether exceptional quality, however, is their relative tenderness to frost. If selections should result in producing a hardy lippia, the plant will be welcomed everywhere, as it is already coming to be welcomed in the warmer regions as one that at least partly solves the problem of a lawn that will require practically no attention, and yet maintain its greenness even in long periods of summer drought. It must be added, however, that during the wintertime it turns brownish, and at that season it is not quite as ornamental as a blue-grass lawn.'

Until the lippia is further developed for hardiness, however, it could not be used except in the milder climates, and in the cold regions the blue grass and other allied grasses and the clovers must be depended on for making lawns.

Meantime one of these new lippias has been introduced, and named Dixie. This makes a most beautiful dark green, close-growing lawn.

SPANISH BROOM

This compact, upright, ornamental shrub is known to the botanist as Spartium junceum. It is a thrifty shrub, but unfortunately not very hardy. In any region where it can be grown, it should be prized as a garden ornament. The plant has been greatly improved here by selective breeding.

With all their tenacity in resisting storms, drought, and constant tramping, these lippias do not become weeds, as they produce no underground stolons. By simple plowing or spading they may be more readily removed than the ordinary lawn grass.

If left all summer without mowing, the lippia lawn makes a rich bee pasture resembling some of the low-growing clovers. If mown once or twice, it has the general appearance of a bluegrass lawn, being soft and yielding to the tread like a fine Axminster carpet. The lippias do not thrive well in the shade, being essentially sun lovers. The new lippia just described settles the lawn question for sunny places in warm climates, as well as the problem of very greatly lessening the wasting of land by erosion on river banks and hillsides.

Meantime other experiments are being carried on with various other plants which give promise of finally making good lawn plants. Among the most interesting is a species of trailing *Hypericum,* specific name unknown, from the mountains of eastern Chile.

Somewhat similar species of hypericum have lately been introduced to my gardens from Russia, Siberia, and central and northern Europe, which show a similar creeping habit, and no doubt will be hardy everywhere. These, even in the first generation from the wild native parent, show variation in rapidity and compactness of growth, and from all appearance a few years' work will give us a lawn plant for all climates, but probably a little more difficult to get started.

All the hypericums will stand a great amount of drought and ill treatment; are unusually hardy, stand tramping and mowing readily. No doubt in future there will be produced varieties that will be valuable as lawn plants for all climates.

Until the new plants have been perfected, however, the conventional lawn grass, with Kentucky blue grass at the head of the list, must be relied on in colder climates. It is not necessary to refer to the common lawn grasses here in detail, their general character and qualities being familiar to everyone, and there having been no marked development in recent years in the way of improving them.

It suffices to suggest that care should be taken in buying seed from reputable dealers that grass of good quality may be secured and the number of weeds minimized. Beyond that it is hardly to be expected that the interests of the amateur plant developer will extend. For the grasses do not offer opportunities for striking results in the way of improvement that make them appeal to the amateur. And, in any event, blue grass in its best varieties constitutes a lawn grass of really fine quality, and if properly cared for will produce a lawn of a very satisfactory character. Mixtures are seldom better, and not often as good as the pure Kentucky blue-grass lawn.

As to the matter of soil for the lawn, nothing specific need be said beyond the statement that the same sort of preparation is desirable that would be used in preparing soil for field or garden crops. Some details as to this will be given in the succeeding chapter.

It is well here to offer a few suggestive hints as to such preparation of the lawn which will insure a proper regulation of the supply of air and water, upon which the condition of the lawn so largely depends. What is true about drainage and irrigation will have equal application to land that is to be used for raising flowers or vegetables or small fruits. These suggestions are based very largely on my personal experience at Santa Rosa in preparing the ground for the experiment gardens on which plants of several thousand different species, and representing many families from all parts of the globe, are grown.

A Practical Drainage System

Hundreds of persons each season marvel at the exceedingly varied and prolific crops raised on the experiment farms—exclaiming, "What a delightful soil you have!"

Their surprise grows when they are assured that this productive land was originally almost valueless for growing plants. It was made fruitful by artificial drainage and irrigation. The application of the simplest principles of regulation of water supply resulted in transforming a relatively sterile soil into one of the most fertile areas of the earth's surface. The method by which this was accomplished may be outlined as offering a model that may be followed to advantage in draining similar land anywhere.

Probably half the low-lying soils in the United States could be made more productive by drainage. Even if the soil of your lawns and gardens is fairly productive, you may advantageously consider the advisability of introducing a system of drainage like that which we have employed at Santa Rosa with striking results.

The soil originally consisted of what is called adobe, a black claylike soil, said to be of volcanic origin, and this particular piece cracked so during the latter part of the dry season, that it was considered unsafe to pasture stock on it, as it endangered the legs of the animals, the cracks often being several inches in width and apparently bottomless. No crop had been grown here for years; and house lots a mile or more out sold for about the price I paid for the four acres.

Of course there is nothing novel about the statement that the drainage of land is important. The matter has been more or less understood since the earliest periods. Yet a very large part of the land of the United States that is given over to lawns and gardens is left to depend entirely on natural drainage, and fails to produce anything like the crops that might be grown on it, if a more rational provision had been made for adjusting the water supply.

In California the value of drainage has been shown in the results obtained even with wheat on fields drained and those not drained. Only one or two ditches across a field have made it possible to produce two or three times as large a crop as was grown in the same field before the ditches were made.

In a certain oat field in Wisconsin the yield per acre was doubled by drainage. The yield before drainage was only sixteen bushels, but after drainage it was increased to 32.3 bushels per acre.

A FRITILLARIA

The Fritillaria is found in many colors—brown, spotted, striped, green, yellow—and one beautiful California species is brilliant scarlet.

There are at least two bad effects to be expected from an oversupply of water. They are:

(1) An oversupply makes certain areas so soft that they cannot be cultivated at all or at least not until late in the spring.

(2) Air, which is essential to plant growth, cannot enter the soil supplied with a superabundance of water.

Air is as necessary to the roots of plants as water and it is upon this principle that all systems of cultivation and drainage are based.

The complicated chemical changes in the soil for the growth of the plant cannot take place unless there is sufficient of both air and water. Roots cannot exist where there is a superabundance of water in the soil.

There are several systems of drainage which will not be discussed here. I consider underdrainage with common drain tile is the best system for ordinary conditions, and it is with this system that I have had most experience. The discussion is given mostly from the viewpoint of results on my own grounds.

Small, well-burned drain tile was used on my Santa Rosa grounds carefully laid with a slope of one foot to forty feet and it has proven eminently satisfactory in every respect for twenty-five years. The soil is a heavy adobe and was almost worthless before it was drained.

The good results of the drainage were scarcely apparent the first year, but the benefits were multiplied each year until now the soil is easily cultivated and bears enormous crops, while before draining no crop of any kind could be raised.

This system consists of one main line of four-inch tile with laterals of two-inch tile every forty feet. The laterals gather the surplus water quickly after a heavy rain and the main tile carries it to a small stream near by.

The laterals do not need such a large capacity as most people think. It must be remembered that they work both day and night, and Sundays as well as week days and a very small tile will carry a great amount of water in the course of twenty-four hours.

It is a good plan to have the tiles flushed now and then, and if they are not too large they will be flushed during heavy rains when filled to capacity. This flushing serves to keep them clean and the flushing produced naturally when small tiles are used is sufficient reason for recommending the smaller sizes rather than larger ones which are more expensive and generally less efficient.

The general impression is that cracks should be left, and sand put in the cracks. The real way is to surround the joints with *clay;* then they are permanent. The *worst* thing to do is to put sand or gravel or straw about the cracks. A tile four feet deep will drain twice as wide an area as a tile two feet deep. About four feet is the best general depth where a lower outlet is at hand.

The strength of the entire system depends upon the weakest section. Therefore it is necessary in laying the tile to examine carefully each piece, and to see that they are well burned, but not sufficiently to make them impervious. The system must be laid upon the proper grade, for if the line sags, sediment will collect and retard the flow of water.

It is best to make a silt basin at the point where the branching tiles unite. This is formed by digging down a foot or two, and bricking or cementing up a barrellike receptacle, the entrance pipe from the main system being a little lower than the exit pipe, so that the silt may settle.

In the twenty-five years since the tile system was laid at Santa Rosa, the tile itself has never been exposed or in any way touched or examined. It continues to perform its function perfectly.

Drainage is really a science in itself, and there is not enough space here to give a full discussion of it. There are a number of good books upon the subject, however, and the names of these will be found in the chapter on reference literature.

Before the system is installed, some complete treatise on drainage should be thoroughly studied.

In some cases it is possible to secure the aid of a person who has had experience in laying drain tiles, and where this is possible it is the best plan.

Supplying Water

Irrigation is closely allied to drainage. The two systems are for a similar purpose—to regulate the amount of moisture in the soil for plant growth.

Irrigation is needed in locations where there is not sufficient rainfall to insure the growth of certain crops. In many places also where the rainfall is sufficient but not well distributed, irrigation will be profitable, especially in seasons of unusual drouth.

For large tracts such as orchards and extensive seed and vegetable gardens, the common practice is to run water in large ditches with a system of smaller ditches throughout the field.

If such a system is properly constructed and cared for, little is wasted because it is placed very close to the point where it is needed.

For small areas, sprinklers are generally used. The fault with most of the common sprinklers used to irrigate small areas, such as lawns and small gardens, is that they do not distribute the water evenly. Most of them cover a circular space and there is always some part of the soil which has too much water or too little. One of the most important points in irrigation is to have the water distributed evenly.

Some flat or fish-tail sprinklers distribute water quite evenly, but the newer system of overhead irrigation known as the Skinner system is by far the best for all areas of any size.

This consists of a number of one-inch galvanized pipes with nipples placed along the sides about twelve to twenty inches apart. These pipes with the nipples inserted are mounted upon supports about six feet above the ground. The pipes are connected with the water supply and the water turned on when needed.

Depending upon the pressure, this system will distribute water evenly for a space of from twenty-five to fifty feet on either side of the pipe. The pipe may be located between two beds so that it may be turned on its support and distrib-

DIERAMA PULCHERRIMA

One of the most beautiful and, without doubt, the most graceful of all the African bulbous plants. It is closely related to the humble Ixia, but towers six feet above it. The flowers are much larger than in the picture, and much more brilliant in color. (About one-fourth life size.)

ute the water on either side. When advantage can be taken of the wind, the water will be thrown almost twice as far as when there is no wind.

This system has been somewhat modified to adapt it to small areas where irrigation is not needed often. Instead of mounting the pipes upon permanent stakes, they are carried from one place to another as irrigation is needed and placed upon temporary supports or movable stands.

For greater convenience in handling the pipes, the temporary supports are only about four feet high. On the top of these is nailed a curved piece of sheet iron in which the pipe rests. The movable stands are made of galvanized pipe in tripod form and can be made by any plumber.

The sprinkler pipe is attached to the water supply by a rubber hose and the system operates in the same way as when in a permanent location.

The Skinner system is patented, but it is not expensive to install. The pipes can be purchased at any hardware store but the nipples and the tool for drilling the holes in the pipe for the nipples are patented and must be purchased separately. Many of the seed houses, that handle tools in addition to seeds, sell this irrigating system.

When this system is to be used on a lawn the supports can be made more or less ornamental.

The cost of irrigating lawns by this method is far less than by the use of circular sprinklers, for both time and water are saved and the lawn is supplied with a more even distribution of moisture.

There is another plan of irrigation which is known as the underground pipe or tile system. This is not often used because the first cost is too great. In some cases, however, it has proven to be satisfactory.

The part of any sprinkler system that deteriorates most rapidly is the rubber hose. When it can be replaced by iron pipe it should always be done to save expense.

Where hose is used it is usually necessary to purchase a new supply each season. Its first cost is two or three times less than that of a galvanized iron pipe, but the pipe usually lasts from ten to twenty years. There are several other systems of irrigation of lesser importance, but it is not necessary to describe them here.

The Menace of Weeds

However well the soil may be prepared for garden or lawn, and whatever the attention given, cultivated plants of every description are perpetually menaced by the rivalry of weeds.

A weed may be said to be a plant out of its proper place so far as the economy of man is concerned.

This does not mean, however, that it is out of its proper place in the economy of nature. Nature has a use for weeds, and in fact they have done much good for man.

When crops were first cultivated, farmers stirred the soil in order to destroy the weeds. They did not then fully realize that stirring the soil aided the growth of the crops. They did discover, however, that when the weeds were destroyed much better crops were produced, and thus the weeds forced farmers to stir the soil and allow the air, so necessary to the plants, to circulate among the roots.

Now that farmers have learned the real reason for cultivation at the proper times, whether there are weeds present or not, the destruction of weeds assumes a different aspect.

Weeds are a detriment in many cases from the fact that when proper precautions are not used they take possession of areas of land so that it is impossible to grow useful crops.

There are two general classes of weeds, annuals and perennials.

Annual weeds reproduce themselves by seeds which mature each season, usually in great abundance. Perennials, in cold climates, although most of them produce seeds, also perpetuate themselves by storing food and living matter under the ground where the life of the plant is protected until spring. Many perennials have underground stems which are sent out in all directions. From each node a new plant may grow under the proper conditions.

It is obvious that such weeds are most difficult to destroy because, although they may be prevented from bearing seeds, they distribute themselves over large areas.

The handling of annual weeds is summed up briefly in one sentence: Prevent the production and the introduction of seeds. But with the perennials not only must the introduction and production of seeds be prevented, but the entire plant must be uprooted and destroyed.

When perennial weeds have taken possession of an area of land, they may generally be brought wholly under the control by thorough weekly cultivation during one or two seasons. This often means that one or more crops must be sacrificed. Every weed on the entire area must be destroyed as soon as—and with some kinds before—it appears above the surface.

The vitality and food provided by perennials in most cases does not keep the plant alive more than one season. The plant depends upon its store of food being replenished by another growth each season. If the leaves cannot develop above the ground, so that raw mineral food collected by the roots can be digested and stored again underground, the plant cannot grow the following season.

Thus it is that by cutting off the plants continually for an entire season as soon as they appear above ground they will die out and not appear again on that area unless, of course, the seeds are again introduced.

Most weeds are provided with greater facilities for reproduction and distribution than cultivated plants. Most weeds also have some special means for distributing their seeds over large areas.

Many of them, such as cockleburs (*Xanthium*), sand burs (*Cenchrus*), burdock (*Arctium*) and sticktights (*Bidens*), have burs surrounding each seed which are made up usually of many hooks or spines. These seeds attach themselves to the clothing of persons and to the various domestic animals, and are thus transferred from one locality to another.

Many of the weed seeds such as thistles, wild lettuce, dandelions, etc., are provided with a

LARKSPURS WITH WONDERFUL COLORING

The colors are far more beautiful than can possibly be reproduced on paper.

feathery portion which assists their carriage by the wind.

Other seeds are borne in pods which, when dry, open with a suddenness which throws the seeds great distances.

Some seeds are borne in fruits which are relished by birds and animals. The seeds in this case are usually small and are provided with a hard coating so that they are not destroyed by digestion in the bird's or animal's stomach, but are carried great distances and on reaching the ground are usually in best condition to germinate.

Most weed seeds have the ability to retain their vitality for a long time. Farmers who have plowed fields deeply have sometimes noticed that a certain weed which was present the year before plowing disappeared entirely for two or three years only to reappear again later. This was due to the fact that the seeds were placed by the deep plowing several inches below the surface, and when the soil was plowed deep again they were brought nearer the surface. In some cases, seeds have been known to retain their vitality for twenty years or more.

Although weed seeds are provided with many more contrivances to secure a wide distribution than those here mentioned, this is not the only provision for their perpetuation. Living as they do among many discouragements and difficulties it has been necessary for them to provide protection for the plants themselves against unfavorable weather conditions and against animals. Some weeds have the ability to withstand long and severe droughts while others are able to grow where there is a superabundance of moisture. Some are able to withstand extremely low temperatures.

Protection against destruction by animals is afforded by spines, thorns, bitter juices, and poisons.

Understanding these provisions of nature for the production and perpetuation of weeds it is quite apparent that prompt and efficient methods must be used by farmers and gardeners in destroying them on first appearance.

A few mustard, thistle, or dandelion plants which seem harmless because there are so few, may spread to such an extent that in a few years it will cost thousands of dollars to rid an infested area from the pest which, if destroyed while still few in numbers, would have cost only a few dollars or dimes.

Weeds are much like a leak in a boiler or a fire let loose. They are easily attended to at first, but lead to destruction if proper attention is not given in the beginning. Never is the old saying "A stitch in time saves nine" better exemplified than in the case of weeds.

As has already been intimated, many fields are infested with weeds through the introduction of the seeds in the seeding of the crops to be grown. Weeds that thrive particularly well with certain crops sometimes produce seeds so like the seeds of the crop in size and appearance that it is often practically impossible to separate them.

In many sections a weed known as corn cockle (*Agrostemma*) is a pest in wheat fields. So nearly do the seeds of the corn cockle resemble the kernels of wheat in weight and size that for a long time it was almost impossible to separate the cockle seeds from the wheat. This, of course, caused millers a great deal of trouble, for the corn cockle seeds have a black shell about them which discolors the flour. Finally a special machine was constructed for the removal of cockle seeds.

The perennial morning-glory, commonly called the devil's-shoestring, has often palmed seeds off for wheat among screenings fed to poultry, being about the same size and has established itself on much of the best soils in California.

The darnel (*Lolium*) commonly called cheat, infests grain fields in some sections and so well have the seeds masqueraded that many farmers, thinking their seed was thoroughly clean, later found this weed and have believed that the seeds changed into wheat, barley, oats, or whatever the grain happened to be.

This mimicry, of course, is developed by evolution. That is, those seeds which are most nearly like the seeds with which they are mixed are overlooked in cleaning and remain to perpetuate the race. After many generations of this sort of natural selection, the seeds constantly tend to approach the grain seed in form, size, weight, and color.

Seeds do not change their botanical characters as farmers sometimes suppose, but, having a hard coat, may lie in the ground until a wet season when the grain is destroyed and the weed takes its place.

Many States have long maintained official seed inspection for purity. Now there is a United States law of similar nature. These laws have been so well enforced that there is not so much danger now of infesting land with weed seeds as was the case a few years ago.

Farmers who make a practice of buying grain for seed from their neighbors or other persons who have not had their seeds examined by inspectors are likely to have their fields infested with noxious weeds. From a small sample, the quantity and kinds of weed seeds may be determined. This is especially true of alfalfa, clover, and lawn grass seeds.

If the sample contains weed seeds, it had better be rejected, for there are always weeds enough to contend with without sowing more.

Grains, clovers, and grass seeds are far more apt to have foreign seeds mixed with them than any other class of seeds as they are usually harvested by the wholesale, weeds and all, and it is only by careful screening that the other seeds can be removed. With seeds of hoed crops, such a condition does not exist.

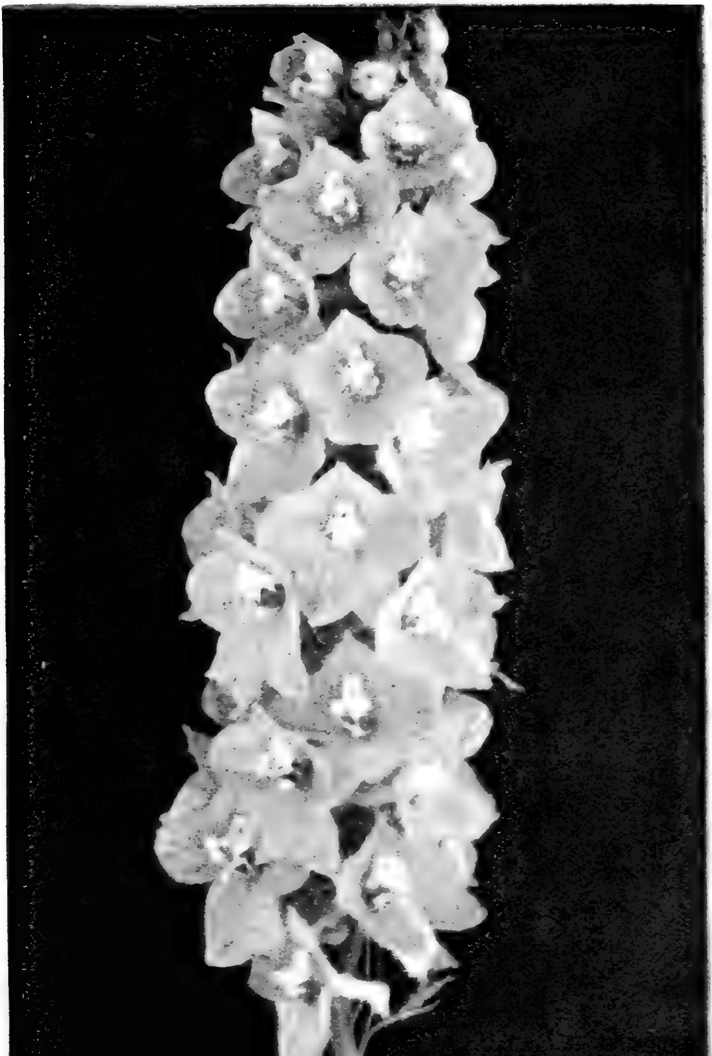
It is impossible, of course, to give here a complete description of all the different kinds of weed seeds, but pictures are given in the natural color of some of the most common ones. By comparing the seeds with these pictures it will usually be possible to determine the kind of weeds that are found in your locality.

Of course, one must always expect to find a few foreign seeds in a sample of grain, but remember that the weed seeds cost the same price per bushel as the oats.

In orchards, especially in California, the two worst weeds are wild morning-glory and a new species of perennial amaranthus.

A BEAUTIFUL HYBRID LARKSPUR

It is difficult to see how this hybrid larkspur could be improved upon as to the symmetrical development of its flower cluster, and the uniformity and excellence of its individual blossoms, nearly all of which, it will be seen, are in full bloom at the same time. But there are almost numberless varieties of equal merit among our hybrid larkspurs. (Nearly one-half life size.)



Both of these produce many long and persistently sprouting roots. The morning-glory sends its roots to great depths and has taken possession of many acres of the best land. This, of course, greatly reduces the production of crops and the value of the land.

The overrunning of a field is due to the fact that the owner of the land was careless in not destroying the morning-glories when they first appeared. This weed spreads in all directions like a fire and its spreading is increased by ordinary cultivation, as small portions of the roots are carried by the cultivator to other locations where they soon grow into new plants.

It is extremely difficult to exterminate the perennial morning-glory in orchards and vineyards because the ordinary cultivating machinery does not run close enough to the rows. The only way to exterminate this weed is to spend all the time and labor necessary for one whole season in cutting off the plants before they appear above the surface. This may be done with a cultivator made with sharp knives that run under the surface. It will be necessary to go over the ground regularly at least once a week. If this pest is allowed to produce any foliage it gives the plant a new start.

The common amaranthus produces an enormous amount of small black seeds. It is an annual and is often called careless weed, because it is seldom found in abundance except on land that has been carelessly cultivated. Thousands of seeds are produced by a single plant and they come up during summer and thrive especially well on rich fertilized soils.

The common amaranthus, however, is almost harmless when compared to the new perennial species which has lately been seen in many public grounds, and is rapidly spreading to farms and gardens. This new weed, unlike the annual, sends down long slender roots deeply into the soil and if cut off, no matter how deeply, will immediately sprout with redoubled vigor.

But this is not the worst.

Like the annual, its sole object seems to be to produce enormous quantities of seeds. This new pest trails instead of growing upright and begins to produce seed almost as soon as the plants appear above the ground. This seed production is continued perennially as long as the plant lives.

The only method of destroying this is to cut off the first plants which appear, and apply a small quantity of salt or sulphate of iron on the cut portion of the root, at the same time burning every portion of the plant removed.

Mustard, wild radish, and wild lettuce, though annuals, are often difficult to exterminate as they are abundant seed producers. The best method of exterminating these is to destroy each plant before it has time to ripen seed.

Usually it is possible partially to rid the land of them by plowing it thoroughly early in the spring and growing some cultivated crop.

Sheep sorrel or redweed, sometimes called "shamrock," is another most persistent weed, very hard to exterminate if once established, especially in lawns and moist shady places. It is a persistent producer of runners, as well as seeds that are projected a great distance when ripe.

It seeds abundantly when the plants are quite young. As the seeds ripen they are projected with great force in all directions. This is best exterminated by unremitting destruction with the hoe before the plants produce seeds.

There are numerous other smaller and more insignificant weeds such as shepherd's purse, several senecios, chickweed, and others which are not as persistent as those already discussed, but which should be kept well under control by thorough cultivation if good crops are to be produced.

It should be borne in mind that weeds are enormously prolific, and that their seeds go everywhere. It does not suffice to keep your garden weeded and your lawn well mown. It is necessary also to pay heed to the weeds along neighboring roads, for their seeds will be no respecters of your boundary lines.

You will be taking steps toward enhancing the beauty of your lawn next season, and will be lessening your work in the flower bed and vegetable garden if you use scythe and hoe freely on the weeds growing along the roadside everywhere in the neighborhood of your grounds.

No effort that you could bestow would have a larger influence toward the beautification of your next season's lawn, and the lightening of your labors in next season's garden than that devoted to the destruction of this season's crop of weeds, wherever found.

Flowers; and the Disposition of Trees

Probably color is the most attractive thing about flowers. Usually solid colors are more attractive, but harmonious combinations are almost as valuable.

A graceful form probably comes next in attractiveness.

Size and abundance of bloom next. Size does not always happen to be an advantage. Some flowers, as the heaths, are attractive because of the smallness of the blossoms. In this case the small size really adds gracefulness to the plant. Where the blossoms are small more are needed to make a good effect, so improvements on flowers with small blossoms should be made along this line where needed.

Everyone must be his own judge of harmony in the colors of plants. Most persons have a natural sense of harmony to direct them to the combination of colors desired.

White is harmonious with all colors. A deep red is not harmonious with blue, except sometimes with a pale blue. The sense of distinguishing harmonious combinations of colors has been more developed since aniline dyes were introduced. This is principally because with the aniline dyes almost any shade of color can be made. Before their introduction the unusual shades were not often seen, some of them never before.

All the prismatic colors are beautiful and attractive in their proper place. The delicate shades of each of these colors are even more pleasing to the average educated mind. Red is the most insistent color. Yellow and orange are next. White is insistent. Black is insistent.

In selecting flowers the aim should be to select those that are striking, harmonious, pleasing, and new in respect to color. In order to be able

THE BOTTLE-BRUSH BUSH

This is a shrub from New South Wales; a rather tender plant, but thriving outdoors at Santa Rosa. It belongs to the myrtle family.

to select flowers for color one must be thoroughly familiar with all of the colors in each variety now in existence. Now that there are thousands of people seeking for new varieties where there was one before it often happens that two or more persons will develop new varieties almost exactly alike at the same time. For this reason, it is perhaps better to work with plants that are not so common.

Each new flower should be developed for some definite purpose. Red is an appetizer even to the birds. They will always eat the red fruit before that of any other color. Red flowers are good for the dining-room and orange or yellow will serve the same purpose almost as well. Delicate shades are needed for the parlor, drawing-room, sleeping rooms, and libraries. A pale blue is very good, and pinks and combinations of pink, rose and white are especially pleasing. It is also desirable to have a bright color occasionally in these rooms where more quiet flowers are kept. This gives a dash and spirit that is needed.

Practically all colors blend well with gray or brown as a background.

Flowers banked around the foundation of a house represent an unconscious exhibition of advanced civilization.

Vines give a peculiar grace to architecture, softening too angular lines, and subduing unattractive colors. Green vines blend with any color.

Flowers harmonize with all surroundings and subdue undesirable forms and colors. Borders of flowers break the hard angles between a building and the ground. Perpetual bloomers and perennials are especially good near buildings. The tall ones should be placed close to the buildings and the small ones in front. The smaller flowers are better on the lawn, in borders, or near the street. It is not well to put too many plants in bunches in front of the home. A single tall plant here and there sometimes lends an artistic effect. Usually when tall plants are placed near the sidewalks or the roads, it is best to have those with thin foliage.

Colors should, of course, be those that attract and please the inhabitants. It is never, however, well to have a predominance of red. Flowers about the house serve to keep those living there in good spirits, adding a cheeriness that tends to keep people happy. White is always a good color. Blue is appropriate but must be accompanied by red or yellow, otherwise it gives a cold effect. Purples and deep crimsons do not always blend as well as other colors.

Hedges and Trees and Shrubs

The larger trees should generally be in the rear of the house. Fruit trees should be back of the house or to one side. The trees that shed their leaves should be on the south and east sides of the buildings to shade in summer and to allow the sun free access during the winter. This leaves the evergreens for protection and ornament during the winter.

Trees with plenty of summer foliage should be planted on the southwest to protect the house from the hot sun in the summer. On large estates oaks and elms and the larger trees may well be planted even in front of the home. Evergreens, especially tall ones, should usually be set out rather sparingly. Do not put them too close to the house, as they keep out the sunlight and make the house cold and dark. A number of evergreen shrubs are, however, always desirable for winter decoration of the place.

Palms are pleasing in a warm climate, but must not be crowded, for they will not be able to exhibit their grace and beauty and will suffer from lack of light and air. Usually the best way is to plant an abundance of trees and shrubs, later removing those that are not needed. Sometimes it takes great courage to cut out part of the trees, especially if some of them have become favorites, but it will be to the detriment of the place as well as other trees if the thinning is not done at the proper time. Evergreen trees and evergreen shrubs should be allowed to grow close to the ground.

It may be of interest to add the names of a few of some desirable ornamental trees and shrubs, though wholly incomplete, and many of those here mentioned are only suitable for mild climates.

Trees for ornament: Arbor Vitæs, Big Tree, Lawson Cypress, California White Fir, Silver Cork Fir, Maidenhair Tree, Silver Pine, Douglas Spruce, Tideland Spruce, White Ash, Basswood, Birches, Kentucky Coffee Tree, White Elm, American Holly, Magnolias, Oaks, Maples, Walnuts, Palms, Dracænas, Laurels, Cypresses, Lindens, Junipers, etc.

Shrubs for ornamental planting and lawn decoration: Black Alder, Andromeda, Japanese Barberry, Button Ball, Spanish Bayonet, Chokeberry, Flowering Dogwood, Inkberry, Jersey Tea, French Mulberry, Wild Roses, Strawberry Bush, Sumach, Sweet Shrub, Wax Myrtle, White Fringe, Wistaria. These are all hardy in most or all of the Eastern States.

To mention those suitable for mild climates would take many pages.

Shrubs for windbreaks, hedges, barriers: Black Alder, Arrowwood, Mountain Ash, Barberry, Chokeberry, Coral Berry, Flowering Dogwood, Wild Grapevines, American Hazelnut, Huckleberry, French Mulberry, Russian Olive, Osage Orange, Sassafras, Waxberry, White Fringe, and Witch Hazel.

For street planting it is necessary to select carefully such trees as will not grow too large, and generally those which will not bear fruit or nuts or shed too many leaves, and evergreens are not often the best, especially where shade is desired. There are many trees well adapted to this purpose. For wide streets and roads the American Elms, Maples, Linden, Tulip tree, Weeping Birch, etc. For subtropical climates, Palms, Dracænas, Magnolias, Grevilleas, Pepper Trees, Laurels, Umbrella Trees, Camphor Trees, Eucalyptus, Acacia, and innumerable others.

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THE FIELD AND FLOWER GARDEN

Some Practical Hints for Their Betterment

MANY have thought that decreased yields are always due to the exhaustion of certain chemicals from the soil. This is not always the case. In fact, it is seldom that decreased yields are due to the lack of plant food.

Plant origination, the highest type of work with plants, has shown the underlying principles of soils and their use. The results of fifty years' work in getting best results from the soil are here summed up in such a way as to show the underlying principles of crop production.

These principles are applicable on every farm, and may be applied in increasing the yield of any crop.

Years ago farming and gardening were "hit or miss" performances. Farmers tried methods because some one else had used them, and but few of them knew the reasons for any of the operations.

In order to understand how to select soils and how to secure the best results from them, one must know the underlying principles of productive ability of soils and the methods used by plants to secure food from them.

Farming is now considered a manufacturing process. As a matter of fact, a farmer uses more kinds of raw materials and produces more kinds of finished products than any other manufacturer. It is just as necessary that he select his raw materials with extreme care as it is that the manufacturer of machinery select the most durable kinds of wood and the strongest kinds of metal.

Farmers have sometimes been criticized for not using more fertilizers, but this is not always a just criticism. Fertilizers are valuable in some cases, but often a better physical condition of the soil would make it possible for the plants to secure enough food materials to increase the yield materially without adding fertilizers, and too often the crop produced would not repay for the purchase of fertilizers.

Profit in crops depends upon the location of the crops grown, the use to which the crops are put, and the cost of fertilizing when fertilizing is necessary. There are other things which affect the profits, but these are the underlying factors.

No definite rules can be given about handling the soil, for each one must work out his own practice according to his own conditions.

The value of soil depends upon its texture, the elements it contains, the exposure, location, natural drainage, the availability of the elements required to keep up its productiveness, etc.

A well-drained alluvial soil of fine texture is the most productive for average crops. Furthermore, it is usually most durable in its productiveness. That is, its valuable qualities continue to manifest themselves year after year.

Other things being equal, a field located in a comparatively level valley or plain is more valuable than one on the side of the hill. Often the soil on the side of a hill is rather thin and there is always the danger of washing. Rains come and carry the most valuable part of the field into the valleys below.

Of course, hillside fields are valuable for some crops. In some cases, where the soil is rich, even better results are obtained on the hills than in the valleys. This is especially true in California and the semiarid sections.

North and east slopes are usually best for late crops, but the south and west slopes are always better for early crops. A slope toward the sun even of only one or two inches to the rod makes a difference in earliness of a week or more. This has been proven by many experiments.

The northern and eastern slopes hold the moisture longer, but do not warm up so quickly. For this reason they are able to withstand drought better, but never yield as early crops as the southern or western slopes.

A clay subsoil a foot or more below the surface with a sandy surface layer is the ideal soil for fruit trees. In fact, such a soil is good for most any crop. If the subsoil slopes sufficiently to drain off surplus water, such a soil will always produce good crops.

Chemistry and Physics of the Soil

Plants secure their food from the soil through minute hairline appendages on the roots, known as root hairs. The roots thus serve only as canals. The root hairs collect the food.

Because of the extremely small size of these root hairs it is plainly seen that any food used by the plant must be thoroughly dissolved before being taken up. These root hairs are deciduous like the leaves, and are only active to any extent where the leaves are in existence and active. All food taken up by the roots is secured in solution and this makes it necessary to keep the soil properly supplied with moisture.

The presence of the proper chemical elements and moisture, however, is not the only thing that is needed for the root hairs to do their work well. Air must be present in the soil or it will be impossible for the root hairs to secure the necessary food for the plant.

The air in the soil must mostly come from the surface so it is obvious that it is always necessary to keep the surface of the ground in such a condition that it will admit air. Thorough cultivation and deep plowing keep the soil in a loose condition.

Knowing that the plant's roots must have plenty of air, one enjoys stirring the soil deeply for he knows that by this method the crop will be increased.

Cultivation must be frequent because the surface of many soils has a tendency to become rather hard and compact, especially after heavy rains.

We may consider that there are minute tubes leading from the surface down into the soil. When the tops of these tubes are closed by having the soil bake it is easy to see that the supply of air is cut off. Stirring the surface, then, makes a connection with the outside air.

Cultivation also goes far in keeping insects and diseases under control. Many insects' eggs and larvæ and many disease germs are found in the soil. When the field is stirred frequently, these are brought to the surface and exposed to the hot sun and many of them are thus destroyed.

Soil is of a very complex composition, and furthermore it is continually changing. A worm burrows into the soil and on his way replaces and rearranges thousands of soil particles.

As the root hair penetrates among the particles of soil it affects a change.

The passing of moisture from one particle to another makes changes which are of extreme importance from the standpoint of fertility.

Because of this ever changing condition, it is necessary to pay close attention to cultivation in order to keep the conditions as near uniform as is possible.

A soil that is not given the proper care as to cultivation often holds its valuable food elements like a deposit in a bank that bears no interest.

Every business man knows that it is an extremely bad policy to allow resources to lie idle, but farmers too often do not consider the elements in the soil as resources.

There are three important ways to make available the supply of plant food in the soil: One is by stirring the soil so that the air makes it possible for the root hairs to secure the elements. Another is by supplying sufficient air and moisture so that the elements in the soil will be dissolved. And the third is by applying fertilizers, which supply the plant foods needed, in an available form.

It does not always follow that when the yield of a certain piece of land is small, that land needs fertilizers. It is very often the case that the poor yield is due to poor seed or shallow culture, or other cause. If great care is taken in selecting seed from the highest yielding fields year after year, one will then know that when the small yield comes it is due to something else.

Expensive fertilizers are sometimes added when a thorough stirring of the soil, drainage, or irrigation would accomplish the same result.

Soil that is producing fruit crops needs less fertilizing than that producing grain crops. The fruits contain such a large percentage of water that the essential elements of fertility are exhausted from the soil very slowly.

On the other hand, grain contains a large percentage of the essential elements of soil fertility and it is necessary to add fertilizers to grain fields much more often than to orchards.

A SELECTED NIGHT-BLOOMING CEREUS (*C. strictus*)

This very fine specimen is the result of careful selection from large numbers of seedlings. The flowers of this variety are nearly nine inches in diameter. They open early in the morning and are completely withered by ten or eleven o'clock. It will be noted that two of the blossoms on the right-hand stalk have withered and that they are marked with strings to indicate that their seed is to be saved for future experiments.

Now that the fertilizer manufacturers are under government supervision it is safe to use any good standard fertilizer on the market. Many experiments have been conducted to determine the right element in which the soil is lacking and supply that alone.

The analysis of soils has often proven of value, especially in scientific researches, but it is not practical for the average farmer to have a chemical analysis made of his soil to determine what kind of fertilizer should be used.

In practically every case good barnyard manure gives excellent results. In the same way a fertilizer purchased in the market usually gives the results desired. Because of the complexity of the soil and the complexity of the requirements of the plants so far as different elements are concerned, it is plain to see that it seldom or never happens that any one element is wholly eliminated from the soil at a time.

Sometimes an element which appears to be exhausted from the soil is merely in an unavailable form. The addition of other elements in such a case, although they do not seem to be needed, may produce the required results because they assist in changing the unavailable elements to an available form.

Nitrogen usually has the most immediate and pronounced effect upon crops when it is applied in fertilizers. Nitrogenous fertilizers always produce quicker results, and when it is desired to get early crops, these are the ones to use, especially in the early part of the season.

Nitrogen is quite often in the form of ammonia in the fertilizer. Ammonia is very volatile and escapes into the air rapidly if not properly incorporated. A commercial product that has a strong odor indicates that the ammonia is escaping into the air.

Use a fertilizer when it is absolutely necessary, but make sure first that some cheaper process, such as cultivation, irrigation, drainage, or rotation of crops, will not accomplish the same result.

The physical condition of the soil in practically every case is more important than the chemical condition, that is, it has a more direct effect upon the crops.

Increasing Crops by Rotation

Many flower lovers have been dismayed at having a favorite collection of lilies almost entirely destroyed by insects. Such a disappointment can generally be prevented by moving the lily bulbs.

Great fields of grain have produced smaller yields year after year until it was finally impossible to grow a profitable crop at all.

The remedy is rotation.

Each grower must be his own doctor, however. There is no short cut to profitable crop yields. They are obtained by the man who understands the bad effects of growing the same crop on one field year after year, and who knows that these effects can be avoided by making a change in crops.

Every horticulturist and every agriculturist should study what follows carefully. It tells *why* failures come, and *why* rotation forestalls such failures.

There are at least four important reasons why rotation of crops is necessary.

In the first place, insects which often gather in great numbers about certain plants are destroyed, or at least their number is reduced when other crops are grown on the land. This is because certain insects are adapted to depend upon certain plants for their nourishment. Lilies and amaryllis are often almost completely destroyed by such insects as mites, small centipedes, wire worms, eelworms, etc.

Absolutely new, uncultivated soils seldom are troubled. It is mostly in gardens where plants from various quarters are grown that difficulty occurs.

These pests gather around the lower part of the bulb and if the bulbs are left in the same place several years the insects often destroy them completely.

Although this is not generally known, it is the common cause for the destruction of lilies. Many have had beautiful lily beds exterminated and have been unable to determine the reason. Often by transferring the bulbs to another location, if thoroughly disinfected before replanting, they can be saved.

If gladiolus bulbs, for instance, are planted in the same place year after year, they do not thrive.

Usually there are fewer and fewer bulbs as the seasons progress, rather than more, and those that are produced are much smaller than the bulbs originally planted. The plants are also sooner or later destroyed.

The third year the crop is almost a complete failure. It is especially necessary to practice rotation of crops with gladiolus and lilies.

The same thing is more or less true with most other bulbs, as most of them have a bitter poison or protective principle that repels these insects. Some of them, of course, are not quite so susceptible to the ill effects as others.

Various bacterial and fungous diseases also attack plants that are grown in one place year after year. These organisms, although they may not be entirely destructive the first year or two, gradually multiply and become a greater pest from year to year.

When trouble arises from this source the remedy is to rotate the crops or, in other words, move the crop infested to another location.

Fungous diseases are especially destructive in potato fields. The potato scale, blight, and wart are well-known diseases which can often be wholly or partially controlled by the proper rotation and the planting of uninfected seed.

The third cause for failures is the unfavorable condition of the soil produced by the toxic substances thrown off from the growing plants. Plants, like animals, give off waste matter which is not only useless but poisonous to the plant itself, and often to other plants of similar nature.

These toxic substances are often less poisonous, and in some cases are beneficial, to other crops. It is obvious that when waste products from a certain crop have accumulated in the soil for a number of years, that soil is not as well suited to the crop as formerly. A change of crops practically always results in a more profitable yield because the waste products of the first crop are often not injurious to the second one.

The fourth cause, which is far less common than the others, is exhaustion from the soil of certain elements necessary to plant growth.

It is very seldom indeed that any one of the elements necessary to plant growth is wholly absent from any kind of soil. It does happen sometimes, however, that an element is not present in available form. The plant's roots, of course, cannot take up certain elements that are in such a form that they cannot be absorbed. When the supply of material in the form that can be used is exhausted, the plant does not thrive.

Quite often the failure of crops when it can be definitely attributed to the condition of the soil is due to an unfavorable physical condition rather than an unfavorable chemical condition.

Rotation of crops often has an important and essential effect upon the physical condition. When alfalfa, cowpeas, clover, or some other legume is grown, the roots grow deeply into the soil and when another crop follows, the fissures or canals opened up by these deep growing roots are used by the roots of the new crop, besides storing considerable nitrogen. In this way it is much easier for the following crop to permeate the soil where there is plenty of moisture. The roots can develop much more quickly and with less effort than if the deep-rooting crop had not been grown on the soil before it.

It is quite evident that the addition of barnyard manure has almost as much beneficial effect upon the physical and bacterial condition of the soil as upon its chemical condition.

The effects of rotation are most astonishing as shown by the results attained especially in California when grain follows a corn crop. There is usually fully twice the yield secured from the small grain crop following a crop of corn than when small grain follows a crop of small grain.

No doubt, the cultivation given the corn during the summer has much to do with putting the soil in the proper physical condition for plant growth. This cultivation destroys more of the microscopic organisms which are injurious to plant life, and releases elements which otherwise would be unavailable.

With the present varieties of plants, it will probably always be necessary to practice rotation of crops. But when plants are developed which are resistant to the various conditions which have been mentioned, rotation will perhaps not be so necessary.

Already certain plants have been developed which are resistant to numerous diseases and insects. Varieties of grapes are grown which resist the attacks of phyloxera, and apples which are resistant to the attacks of aphis are well known.

Peaches and almonds which are not subject to curl leaf have been developed.

Plums which are not affected by the brown rot and plum pocket are now on the market, also cherries, pears, walnuts, and perhaps chestnuts, which are resistant to blight.

Because of the value to be secured from crops which need not be rotated, too much emphasis cannot be placed upon the importance of developing new plants for this purpose which are resistant to the various pests.

It will almost always be found that in fields badly affected with some disease or insect there are one or more plants which are not affected as seriously as the rest of the crop. By selecting such plants and perpetuating them by seeds or division, a new variety may eventually be produced that is resistant to the particular disease or insect which caused the damage.

If resistant plants were developed many old field and garden soils which have become worthless for certain plants could be made to produce profitable crops. Such soils are quite often thoroughly infested with numerous insects and diseases and the failure of crops is due more to this than to the lack of proper chemical elements.

It is possible to get resistant varieties of vegetables, grains, flowers, and trees and the process is the same in all cases.

Nature practices rotation of crops in the forest. A forest of hardwood trees is almost always replaced by softwood trees. After these have grown on the land for some years, they are replaced by hardwood trees. And so the rotation continues.

This is not intended to be a complete discussion on the rotation of crops. It is the principles which underlie the practice that are of the most fundamental importance.

It is impossible to suggest any definite kinds of rotations which will be applicable under all conditions. Each person must familiarize himself as much as possible with the underlying principles and determine the rotation that is needed under his own special conditions.

The physical condition of the soil in practically every case is more important than the chemical condition; that is, it has a more direct effect upon the crops.

THE ALMOND AND ITS IMPROVEMENT

Can It Be Grown Inside of the Peach?

IN THE early years of my experimenting, soon after commencing the importing of plants, I had crossed the Japanese plum with the almond.

The cross was made without very great difficulty, and the results were exceedingly interesting. Each species was fertilized with the pollen of the other, and here as elsewhere it appeared to make no particular difference in which way the cross was made.

The hybrid seedlings partook somewhat of the character of the earliest of the hybrids produced by crossing the plum and the apricot. Most of the seedlings outgrew either parent, their enhanced vigor suggesting that of the hybrid walnuts. But, on the other hand, some of them almost refused to grow at all, being permanently dwarfed, and in this regard suggesting a certain number of the second generation of the walnut hybrids.

This wide diversity of form and vigor in the first-generation hybrids is a rather unusual phenomenon. As a rule, we have observed that first generation hybrids are somewhat uniform in character, and that the tendency to wide diversity appears in the second generation. Attention has more than once been called to the fact that the discovery that such is the tendency among hybrids was the one that put me on the track of most of my successful plant developments.

At the time when these experiments in hybridizing the Japanese plum and the almond were commenced, there were few, if any, other plant experimenters anywhere in the world who had fully grasped the principle that variation occurs in the second generation, and that it is by raising large numbers of second-generation hybrids from which to make selection that the development of new and useful varieties of plants may best and most rapidly be carried out.

This principle is so familiar to-day that horticulturists and botanists who refer to it very commonly overlook the fact that the recognition of the principle is very recent.

Thirty-five years ago I found it impossible to convince most well-known horticulturists, botanists, and biologists—with many of whom I had some spirited discussions on the subject—that the great individual variations occur in the second and a few succeeding generations.

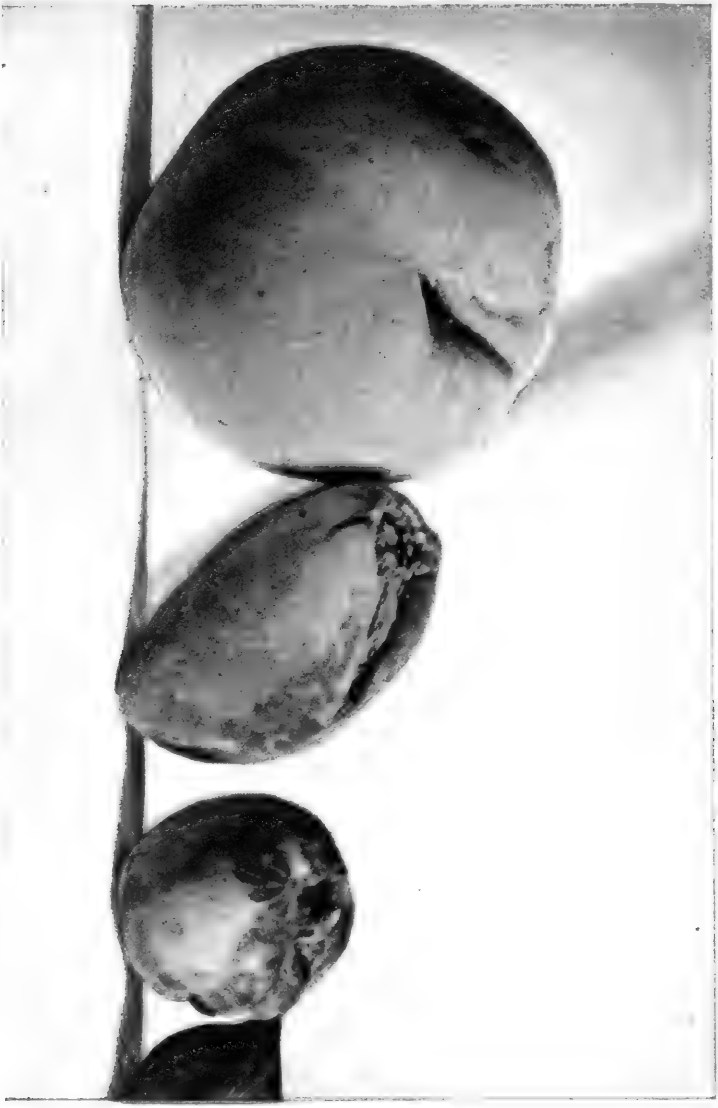
To-day all these men, in common with horticulturists and biologists in general, acknowledge that these variations and recombinations do occur.

Indeed, nothing more is necessary than the most casual inspection of the new varieties that have been developed at Santa Rosa in the intervening period to establish the validity of what was generally regarded as a heretical view only thirty-five years ago.

And yet the case of the first-generation hybrids between the Japanese plum and the European almond, showing the wide diversity just recorded, suggests that it is not always easy to lay down rules of thumb. Observation of the phenomenon of plant development in the field may present complexities that make the sifting out of principles difficult. No one whose first hybridizing experiments happened to be performed with chance hybrids of the plum and almond, and who saw among his first-generation seedlings all the range of forms from dwarfs to giants, would have been likely to conclude that the first-generation hybrids are generally uniform in char-

THE ALMOND AND ITS RELATIVES

Here, reading from left to right, are shown the peach, the almond, and the nectarine. The peach and nectarine are regarded as variant examples of the same species. The almond crosses readily with either, producing interesting hybrids.



acter and that variation takes place in the second generation.

Looking back now, and being able to check the observation with knowledge gained through noting the effect of hybridizing many hundreds of other species, it is interesting to make inquiry as to why the first-generation hybrids of the plum and almond showed such anomalous diversity.

The answer may probably be found in the assumption that either one parent or the other was itself a hybrid. Perhaps both parents were hybrids. The fact that almonds are known to cross with the peach and the nectarine—to which reference will be made more at length presently—lends color to this assumption. And of course there is no question that the Japanese plums are largely hybridized. In a word, then, the hybrids produced by cross-pollenizing the Japanese plum and the almond were probably in reality second-generation hybrids having the strains of other species than the almond and the Japanese plum in their heredity.

Be this as it may, the facts as to the curious diversity among the plum-almond hybrids have more than passing interest.

It should further be recorded that the diversity in size was matched by the wide range of diversity in minor characteristics. The bark and leaves varied extensively among the different hybrids; on some trees the buds were round and plump, and on others long and sharp. Many of the trees produced somewhat abundant blossoms, and the individual blossoms varied widely in color and in size.

But there were other trees that produced no blossoms whatever under any circumstances.

These would form great clusters of buds, but instead of bursting into flowers the buds would drop off and later ordinary branches would come out in their stead.

In the case of buds already opened to form flowers, the blossoms not only varied as to size and color, but they showed the most astonishing diversity as to their essential fructifying organs. Some of the blossoms had numerous pistils and no stamens. Others had numerous stamens and no pistils. In yet other cases there were blossoms having stamens and pistils, but absolutely without petals.

In no case was fruit formed. The blossoms one and all were sterile.

An attempt was made to fructify the blossoms by pollenizing them with pollen from each of the parents. But this effort was futile. The ovaries were seemingly incapable of maturing.

It would appear, then, that the Japanese plum and the almond, as represented by the particular specimens that were used in these hybridizing experiments, were just at the limits of affinity that permitted cross-fertilization, but imposed sterility on the offspring. The parents were a shade more widely removed from each other genetically than were, for example, the plum and the apricot or the Persian and California walnuts. This fact, and not the mixed ancestry of either parent, may have accounted for the diversity of form of the progeny.

As the plum-almond hybrids were sterile, it is obvious that the experiments through which I had hoped to develop new varieties and perhaps new species of fruits could go no further in this direction. It is of course possible that individual plums and almonds or different varieties of the two races might be found that would combine to produce fertile offspring. This supposition finds support in the fact that my earliest crosses between the plum and the apricot were also sterile; whereas later ones produced the fertile plumcot, as the reader is aware.

So it is obviously worth while to continue the experiments of hybridizing the plum and the almond, and there is reason to hope that interesting and valuable results may be attained.

SELECTED ALMONDS

It has been suggested, not without plausibility, that the almond represents somewhat closely the primitive type of stone fruit, from which all our other stone fruits have been developed. Be that as it may, the leathery covering of the present-day almond is something strikingly different from the pulp of the peach or plum or apricot.

My own experiments, however, although they have been repeated occasionally and have never been quite lost sight of during the thirty-five years that have intervened since the first tests were made, have produced only the anomalous results just related. Yet even these, in addition to their scientific interest, may be thought to point the way to more practical developments.

At least they prove that there is no barrier between plums and almonds that may not be partially broken down.

The Almond Crossed with Peach and Nectarine

Since the almond can be crossed with the plum it may reasonably be expected that mating would be effected with its closer relatives, the nectarine and peach, with even greater facility.

In fact, it has been observed that the almond crosses with the nectarine so readily that it is practically impossible to prevent cross-fertilization when the two trees grow in the same neighborhood. The bees appear to visit them indiscriminately, and to effect hybridization so commonly that it is impossible to raise fruit from the seed with any degree of certainty when there has been an opportunity for cross-fertilization; this, however, does not very commonly occur

SOME MAMMOTH SPECIMENS

At the left, a selected specimen of the common almond; in the center, the Palestine almond; at the right a specimen of the Big Fat almond — the latter obviously well named. Note the characteristic texture of the shell, which does not vary greatly in these specimens, but which differs markedly from that of all other stone fruits.

hybrids to rapid growth is something that we have seen manifested in many other cases. It is a rather common result when species that vary by just the right amount are hybridized. The hybrid walnuts furnished the typical illustration of this on the most spectacular scale.

The fruit of these almond-peach hybrids varied widely on different trees. Sometimes the fruit was leathery like that of the almond, but in other cases it was edible and quite peachlike. In a few cases the pulp was so fully developed that it might be considered a fairly good peach. The seed covering was usually in the shape of an almond and smoother, thinner, and generally more elongated than the peach stone. It was hard-shelled and corrugated, but had not the texture of the peach stone. The meat within was generally sweet or slightly bitter.

Thus the fruit of this hybrid might be said to be fairly intermediate between the fruits of the parents, yet on the whole the flesh of the peach and the stone of the almond, respectively, tended to be prepotent. This is what would be expected, when we recall that the flesh is the specialized modern development in the case of the peach, and that the seed is similarly specialized and developed in the case of the almond.

MEATS OF SELECTED ALMONDS

These are the meats of the almonds shown in the preceding picture, arranged in the same order, with the common almond at the left and the Palestine almond in the center. Although these almond meats differ so radically in form, it will be seen that they retain the characteristic almond quality throughout, just as we saw in the case of the shells in the preceding picture. (Nearly twice life size.)

were successively introduced, would result in producing a peach-almond that would have flesh equal to the best varieties of peaches and a nut equal to the best almonds.

Even now there are certain apricots that bear delicious nuts. Inasmuch as the apricot is already in this condition, there is no reason why the peach should not do the same. The apricot seeds of California are now nearly all shipped to France to make almond oil.

At the time when the experiments above referred to were carried out, however, it was not clear that a fruit combining the qualities of the peach and the almond would have great commercial value. The peach industry and the almond industry are so entirely different that the inauguration of altogether new methods would be necessary to make them operable in combination.

Hence the hybridizing experiments were not carried beyond the third generation, and the hybrid trees were thereafter used as stocks for grafting of cions that gave greater commercial promise, even though less interesting from a scientific standpoint.

A New Peach-Almond Cross

A subsequent series of experiments was undertaken, however, to which reference has been made in another connection, in which the almond was combined with the purple-leafed peach.

It has already been recorded that the first-generation hybrids of this cross bore green leaves exclusively, but that purple leaves appeared in a certain proportion of the hybrids of the second and subsequent generations.

In this cross, the purple-leafed peach was used invariably as the pistillate parent. There is every reason to suppose, however, that the results would have been the same had the cross been made the other way.

Among the second-generation seedlings were not only some with red leaves, but others that showed a combination of colors varying from the pure green almond leaves through different shades to the crimson leaf of the peach.

There was thus exhibited a pronounced tendency to segregation of colors in certain cases, and a combination of the colors in others.

Selection being made among the trees with the purple leaves, this characteristic, as might have been expected, reproduced itself, and a race of purple-leafed peach-almonds, was developed. The fruit of this hybrid is purple-fleshed, and as to its general characteristics it is a fair compromise between the peach and the almond, not unlike the hybrid form already described.

This form of peach-almond has considerable merit as an ornamental tree, and it will probably prove of value as an acquisition for the garden and dooryard. Even though a peach that bears an edible seed has no greatly added commercial value, owing to the small size of the seed, such a fruit with large seed of thinner shell, and with peach flavor, should certainly be appreciated.

Improving the Almond

All this has to do with the production of a compound fruit in which the almond seed is only an accessory. It remains to say a few words about the almond itself as a commercial nut.

The importance of the subject will be obvious when we record that last year five thousand five hundred tons of almonds were produced in California alone. When it is further recalled that numberless unsuccessful attempts have been made to establish almond orchards in various warmer regions of the United States, and that the failure of these orchards has been due almost exclusively to a single remedial defect, the importance of the almond from the standpoint of the plant developer will be more clearly understood.

The one great defect of most varieties of almond is that they bloom so early that their

ALMONDS GROWN IN PEACHES

These are the stones of various types of peach-almond hybrids. It will be seen that some of them show the characteristic appearance of the peach stone, where others show the marked influence of almond parents. All bear meats that have the characteristic almond quality, more or less modified.

blossoms are likely to be destroyed by heavy rainstorms or frost. A second minor defect is that many of the varieties of almond do not bear well unless they are cross-fertilized with pollen from other varieties.

The latter defect is obviously one that requires only reasonable intelligence in the planting of different varieties in contiguous rows, so that cross-fertilization may readily take place, or the production of varieties with perfect blossoms. To overcome the defects due to too early blooming is a somewhat more difficult matter.

Fortunately, however, there is a rather wide range of variation among different kinds of almonds as to time of blooming. It follows that there should be no great difficulty in producing, by selective breeding, a variety that combines desirable qualities of nut production with the habit of late blooming. The difficulty has been that until recently orchardists have not recognized the possibility of thus segregating and recombining characters, and they have "trusted to luck" in setting out their almond orchards, so in a large number of cases the profitless trees were removed or regrafted to prunes.

Latterly, the California orchardists have learned that there are two or three varieties that may be depended on, notably the Nonpareil and the Ne Plus Ultra, both of which originated in California from seedlings grown by A. T. Hatch of Salinas County. These may best be pollenized, in the opinion of experienced orchardists, by the variety known as Texas Prolific.

Unfortunately neither of the varieties mentioned produces nuts of the largest size, but their certainty of bearing gives them advantage over varieties that would otherwise be superior but which cannot be depended upon.

It should not be difficult, except that such an experiment necessarily takes time, to crossbreed the different varieties that have individual traits of exceptional value, and thus to produce in the second generation, or through successive selections, varieties that will combine the best qualities. Something has already been accomplished in this direction, notably in the case of such a variety as that known as Drake's Seedling, a late-blooming variety that is prolific and a regular and abundant bearer, notwithstanding its parent form was the Languedoc, which has been pretty generally condemned for irregular bearing. There is no good reason why the almond should not bear as regularly and as abundantly as the apple, peach, or cherry.

As to the shell of the almond, this has been so specialized through selective breeding that in the best varieties it is perhaps as soft and thin as desirable. If it becomes too soft, it is liable to injury in shipping, and thus the appearance of the nuts is marred and their market value impaired; also being subject to destruction by birds before it is harvested. Perhaps, however, selective breeding may advantageously be carried out with an eye to the whitening of the shell of the nut. At present it is necessary to bleach the shells after the nuts are thoroughly dried, first with low pressure steam and then with the fumes of sulphur. Such bleaching is necessary to meet the demands of the consumers.

It would obviously cheapen production and save a good deal of trouble if a variety could be produced that would have the desired color of shell in the natural state. Another defect is that the almond tends to cling to the tree too tenaciously, requiring unnecessary labor. All almond growers would appreciate improvements in these two respects.

My own experiments of late have been in all the directions mentioned, and I have good reason to suppose that I now have better almonds than any heretofore grown.

It is clear, then, that there are various directions in which the almond may profit by the attentions of the plant developer. The steady and increasing demand for this nut warrants the expectation that systematic efforts for its improvement may meet with an adequate financial reward. Already the cultivation of the almond is an industry that exceeds in importance that of any other nut except the walnut and pecan. And it is an industry that will increase in proportion as the efforts of the plant developer make the almond a more certain bearer of better nuts. What has just been said will sufficiently indicate the lines along which the plant developer must work in order to produce these results.

WALNUTS AND OTHER EXPERIMENTS

Mendel's Theories in Practice

THE hybrid walnuts, already known to the reader as the Paradox and the Royal were first publicly announced in my catalogue called "New Creations in Fruits and Flowers," in June, 1893.

The hybrid walnuts themselves were then five or six years old and the Royal had borne fruit, so that a photograph of its large-sized nut could be given. The Paradox, on the other hand, although it had flowered for several seasons, had produced no fruit. It was supposed, therefore, that it would be impossible to reproduce this hybrid from seed.

In subsequent years, however, the Paradox proved its capacity to produce fertile fruit, although it has never been a free bearer. In my supplementary catalogue of the year 1898 I was able to offer seeds of the Paradox for sale, and to make a statement as to the manner of seedlings that might be expected to grow from these seeds. The statement, in view of the date when it was printed, has somewhat exceptional interest in the light of later developments, so I quote it here. It was as follows:

"The six beautiful specimens of this hybrid growing on my home place have been objects of admiration to all who have seen them.

"Young trees could have been sold at almost any price, but, having no time to raise them, we offer this season's crop of nuts which will be a great surprise in producing about one-third of a new type of the broad-leaved Persian walnuts, one-third of a new type of the California black walnut, and about one-third combined, as in the original tree."

The "original tree" in question was, of course, the hybrid called the Paradox, produced by crossing the California walnut and the Persian walnut. So the seedlings, the character of which is predicted in the paragraph just quoted, would of course represent second-generation hybrids from this cross.

I make the quotation here, carefully specifying the date at which the original was printed, because there is a certain interest in knowing that tests made prior to this time with the seeds of the hybrid walnut had clearly revealed to me the fact that "about one-third" of the second-generation hybrids would revert toward one parent, while another third would revert toward the other parent, the remainder being intermediate in character, and in this corresponding to the first-generation hybrid that was their parent.

This implies a fair understanding of the combination of characters of the two parent species in the first-generation hybrid, and the segregation and recombination of these characters in the second-generation hybrid. It will be noted also that the distribution of these characters in the second generation (as predicted on the basis of my observation of earlier seasons) was essentially that which has come to be familiar everywhere within recent years as the typical distribution of characters among second-generation hybrids in what is now known as Mendelian heredity.

To be sure, the figures given are only approximate, nor have I in any of my experiments endeavored to keep accurate account of the precise numbers, the large scale on which I operate making this scarcely practicable—but the close approximation of the rough estimate that I made to the precise figures that have been determined by more recent investigations, sufficiently attests the accuracy of the observations on which the estimate was based.

And, figures aside, the essential principle of the segregation of characters, and their redistribution into three essential groups, one representing each parent, and one combined as in the first-generation hybrid, is as clearly stated as can be desired.

The interest of all this hinges solely on the fact that the statement was published in 1898, based obviously on observations made prior to that date; at a time, therefore, when no one living had the remotest knowledge of the discovery made by Mendel more than thirty years before. Mendel himself died in 1884, and the rediscovery of his work was not made until a year or two after the date of my catalogue, just quoted.

And I may fairly assume that there were few, if any, botanists or plant developers in the world, at the date of this publication, who had any such clear conception of the meaning and interpretation of the prediction contained in the quoted paragraph as my own original observations had given me.

In fact, the observation on the seeds of the Paradox walnut, as here quoted, was made quite casually.

I did not put it forward as constituting a new pronouncement in heredity, because it simply represented a specific application of a general truth regarding the tendency of heritable characters to be segregated and recombined in the second-generation hybrids that had come so often under my observation that it had become a commonplace to me many years before the publication of this catalogue in 1898.

Elsewhere I have stated that the matter had been the subject of controversy with a good many of the leading botanists and horticulturists of the world, and that during the period of perhaps fifteen years prior to the rediscovery of Mendel's experiments, I apparently stood in a minority of one in the belief that such segregation and redistribution of characters in the second-generation hybrids is the usual and all but habitual method of inheritance.

After DeVries and his fellow workers had come upon Mendel's earlier publication and made it known to the world, the matter was no longer in dispute.

But then the neophytes who had so long refused to listen to my claim were disposed, after the manner of neophytes, to become overenthusiasts, and some of them at least thought that the principle of the segregation of heritable characters in the second generation was one that must supplant all other principles of heredity, reducing questions of inheritance to such simple formulas that the veriest tyro could master them, and, having them in hand, could go into the field and create new forms of plant life at will.

And because I ventured to point out that the essential principles that now came to be spoken of as Mendelian had been the guiding principles of my experiments for at least twenty years before Mendelism was heard of, I was denounced in some quarters as reactionary, the fact being quite overlooked that the essential principles involved had been discovered by me quite independently; exploited by me in connection with many hundreds of species; given publication by me prior to the rediscovery of Mendel's forgotten paper; championed by me against the opposition of all the leading authorities of the world; and that therefore the aspect of heredity in question might with full propriety have been named "Burbankian" instead of "Mendelian," were it not that Mendel's discovery had priority because it was published so long ago as 1863, whereas my independent discovery of the principle was not made until almost twenty years later.

Even at that, however, I had had full twenty years priority over anyone else except Mendel in the recognition of the principle.

Therefore, as I just intimated, I have found it a trifle disconcerting to be heralded as reactionary and as scouting the essential principles that I ardently espoused during a period of at least sixteen years subsequent to the death of Mendel, during which they had no other champion.

What I have deprecated, however, in recent years, is the overenthusiasm of certain alleged followers of Mendel, who have entertained what I conceived to be a misapprehension as to the real significance of "unit characters," and who, misguided by a narrow range of experiments, and lacking the breadth of view that comes with wider experience, have supposed that all heritable characters might be classified as fixed and unvarying entities that are transmitted in accordance with the Mendelian formula.

Fortunately, many former holders of this biased and inadequate view have seen its insufficiency, and already there is a tendency to react from it, evidenced in the writings of some of the leading Mendelians; and, coupled with this, the tendency to take a broader view of heredity and to understand that there are countless heritable characters that do not Mendelize in any tangible or demonstrable way; that "unit characters" are themselves made up of subordinated characters; that new "unit characters" from time to time appear, whereas old ones that at one time Mendelized are finally so fixed that they blend with the older structure of heredity and no longer present the phenomena of "dominance" and "recessiveness"—in a word, that heredity is a somewhat larger term than Mendelism, and that the biologist or botanist or plant developer who would gain a really clear conception of the situation must clearly distinguish between the lesser term and the greater, although at the same time recognizing that one is an essential substructure of the other.

So Darwinian heredity, which recognizes the heritability of whole coteries of characters that are too profoundly fixed to Mendelize, is again receiving recognition; and the multitude of special studies of the past decade that were inspired by the rediscovery of Mendel's work and by the exploitation of his formula will take their place as interesting additions to the minutiæ of the scheme of heredity, without being supposed by anyone, except here and there a victim of mental strabismus, to represent the full measure of the great mysteries of inheritance.

We have had occasion in successive chapters to present again and again illustrations of the type of hereditary transmission that lends itself to classification under the Mendelian notation. We shall catch further glimpses of it before we are through. Here it seems worth while, in connection with the story of the hybrid walnuts, to attempt a more comprehensive view of the entire field of heredity, endeavoring to gain a clear notion as to just what are the underlying principles that determine whether or not a certain heritable character or pair of characters shall Mendelize; and in so doing we may correlate our earlier studies and secure a clearer notion of the underlying principles of evolution, and of the origin and development of species, than could perhaps have been gained without the aid of the illustrative cases that have been presented.

Natural Selection

The principle of natural selection applies to the preservation and to the weeding out of species.

In the case under consideration, it was the changed climatic conditions, through which the Northern Hemisphere was transformed from a region of tropical heat to one of arctic cold, that resulted in the destruction of countless species, leaving only a tithe of the original number to constitute the flora of the temperate zone in our own day.

It is easy to see how the altered conditions of temperature made the struggle for existence unduly hard for many species, because there is a tangibility about the coming of a glacial period that finds an analogy in the coming of winter in the regular sequence of seasons. The fact that a plant which thrives in the summer in northern regions cannot survive through the winter unless protected is so familiar as to give us a concrete example of the destruction of species through changed climatic conditions in the geological eras.

But the struggle for existence that goes on all about us among plants of every species is so much less tangible that it is not so easily visualized.

Not unlikely the climate of the Northern Hemisphere is changing now year by year as rapidly as it ever changed in any era of the past. The alteration is so slight within the span of any single life as to be unappreciable. But when we look back, aided by the studies of the geologist, and think of the change of climate that transformed the flora of the Mesozoic time, we see things clustered in perspective, and in our mental vision the picture of the transformation from tropical to arctic conditions corresponds rather to the onset of winter in our annual experience, than to the true picture of a change of climate that required not merely centuries but millenniums.

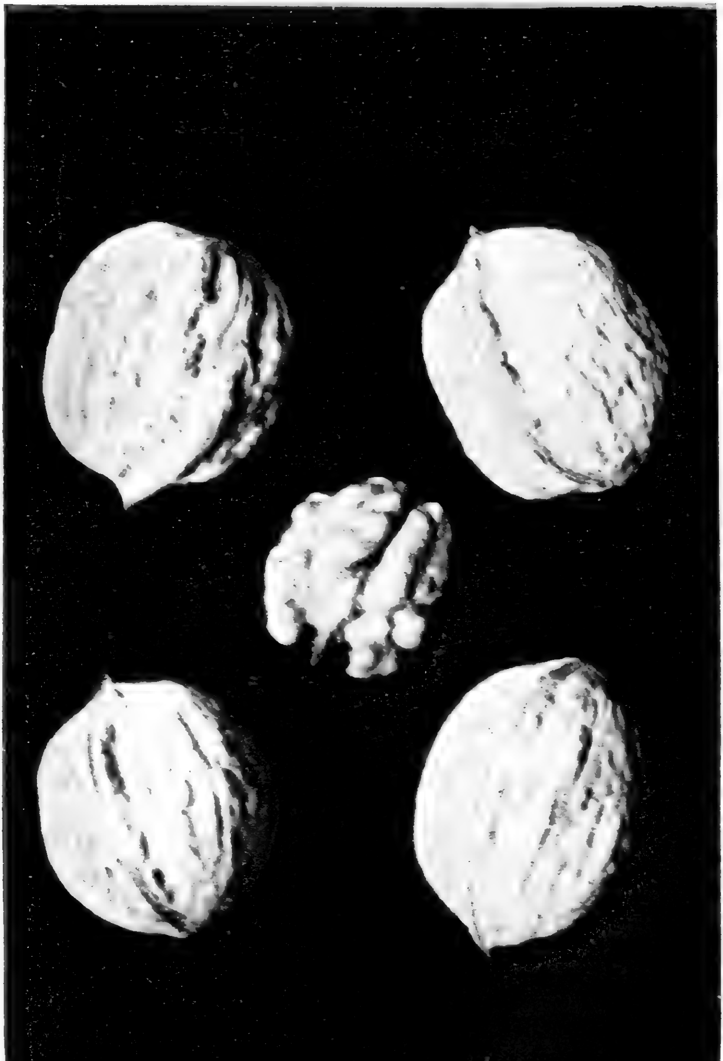
In the same way we conceive of the evolutionary changes through which new species were evolved in the past as having been relatively sudden. I have already referred to the difficulty with which the average mind can grasp the idea that precisely the same sort of change in animal and vegetable forms is taking place to-day that has taken place in all other stages of evolution.

It was one of the great merits of Darwin's exposition of the "Origin of Species" that he gave detailed illustrations of the struggle for existence, and brought tangibly before the minds of thoughtful people the conception that each race of beings is more or less in competition with every other race, and that the race that is adaptable enough to adjust itself to new conditions is the only one that stands any prospect of survival.

The idea of the progression of the normal increase of living creatures in geometrical ratio and of the resulting overpopulation of any territory by the progeny even of a single pair, if there were no counteracting factors, was of course received by Darwin from Malthus. But the application of that idea to all races of animals and plants, and the logical deduction from its application which first made possible anything like a clear understanding of the reason why

HYBRID WALNUTS

The nut of the Paradox walnut has the outward appearance of the Persian walnut, one of its parents. The shell retains, however, a good deal of the thickness of the black walnut, but this can be modified by selective breeding in later generations.



vegetable and animal races have evolved, was due to Darwin.

Alfred Russell Wallace conceived the same idea independently, and must always be credited with a share in the discovery.

But of course it was Darwin's exposition that gave the subject general vogue, and the scheme of heredity that it connotes is with full propriety spoken of as Darwinian evolution.

The essentials of this scheme of heredity may be stated in a few words, as follows: Animals and plants tend to increase in geometrical ratio. If unopposed, the progeny of a single pair of animals or an individual plant would soon populate and overpopulate the entire earth. Opposition to such overpopulation comes from the rivalry of other animals and plants. The struggle for existence thus induced puts a premium on the individual animal or plant that is better able than its fellows to seek means of sustenance. Such an individual will, on the average, live longer and produce more offspring than an individual less well adapted to its surroundings.

The preservation of these favored individuals and their progeny may be described in a phrase as "the survival of the fittest."

The natural processes that determine such survival on one hand, and the destruction of the less fit on the other, may be spoken of as constituting "natural selection."

This term, natural selection, has obvious propriety because it connotes a process closely akin in its results to the artificial selection through which man determines that certain races of animals and plants under domestication shall be preserved, and that others shall be destroyed. But artificial selection is after all only a phase of natural selection, in which a man becomes an active influence or a deciding element in environment.

Because of man's power to transform the conditions of soil, to supply artificial heat, and to bring together and hybridize plants and animals that would not come in contact in the state of nature, the results of artificial selection, epitomizing within certain bounds the results of natural selection, may be produced with unexampled celerity.

Man, for example, eliminates a species in a few decades, where nature would have found no way of correspondingly rapid elimination. The black walnut, for example, has been almost exterminated throughout eastern America because man prized its wood for the making of furniture. But for the presence of civilized man the black walnut would doubtless have maintained its position for ages to come, just as it had maintained it throughout the ages of the past.

Yet we must not forget that on occasion there may be natural methods of elimination that will single out a species and destroy it as expeditiously and as certainly as man could accomplish that end.

A case in point is furnished by the chestnut, which, as we have seen in a recent chapter, has been singled out in certain regions of the eastern United States by a fungoid blight that leaves no chestnut alive in the regions over which it spreads. Yet this blight seems powerless to affect any other species.

Here, then, we have an example of a destructive agency of an unpredicted kind that gives an example of the rapid destruction of a species, through natural selection, because that species could not rapidly enough adapt itself to a new condition.

Given time, the chestnut would doubtless develop immunity to the fungoid pest. But time was not given it, and hence it was destroyed.

This present-day illustration perhaps gives as vivid an impression of one of the more tangible ways of the operation of natural selection as could be desired. But we must suppose that such drastic measures as this are rather exceptional and that in general the processes through which species are eliminated are more subtle in their operation, although their ultimate results are no less striking.

All this has to do, however, with the destruction rather than with the evolution of species.

I have already said that the principles of natural selection apply with equal force, and seemingly with entire impartiality, to the destruction and to the preservation of species.

But it is obvious that mere preservation of species does not necessarily imply also the evolution of species. Natural selection might give a dominant position to a particular species, and preserve it for indefinite periods without essential change.

But this could only occur in case the conditions of environment themselves remained essentially unchanged.

It is fundamental to a clear understanding of evolution to realize that in a changing environment, under natural conditions, no species could be preserved unless it proved adaptable.

Indeed, the more perfectly adjusted the species might be to its environment at a given period, the more certainly must that species be destroyed should the essential conditions of the environment change.

The great penalty of specialization is the danger that attends it from this source. It is held that the species that were eliminated when the great climatic change occurred to which we have more than once referred were those that were the most highly specialized.

But, on the other hand, a species that is able to change in such a way as to adapt itself to new conditions stands at least a chance of being preserved, however, widely the environment may be altered. And, in fact, most species in a state of nature have a considerable measure of adaptability. Individual variation is the universal rule, and such variations are accentuated by natural selection very much as the plant developer accentuates them by artificial selection. So the plants and animals in a state of nature are plastic material, and under changing conditions of environment which represent probably the usual and normal condition of things, they are constantly, even if slowly, being modified. And of course such modifications, when they have been sufficiently added to, alter the character of the species altogether.

Which is only a detailed and roundabout way of saying that species are evolved and transformed into new species under the influence of natural selection.

But whoever considers this matter attentively will come presently to realize that in any such analysis of the operation of natural selection in the evolution of species as that just suggested there is an underlying assumption to the effect that the various modifications of the individual are transmitted to the offspring of the individual.

Unless such is the case, it is clear that there could be no such thing as the evolution of new species. It would avail nothing for the progeny of an individual that this individual was well adapted to its surroundings, unless the said progeny inherit the characteristics that made such adaptation possible.

There is no logical escape from that conclusion. Whatever our conception of the mechanism of heredity, or of the exact manner in which the transmission of variation occurs, no one can be an evolutionist who does not believe that acquired characters are transmitted through heredity.

There was a school of biologists who gained great prominence a few years ago, who denied the possibility of the transmission of acquired traits. Throwing logic to the winds, they based their denials on a metaphysical interpretation of certain observed microscopic structures within the germ cell. These same biologists, while denying that acquired traits could be transmitted, were at the same time ardent upholders of what they called Darwinian evolution.

But such a paradoxical contention must of necessity fail to maintain itself for any considerable period. In the last analysis people are able to put two and two together and discover that the result is four. And in the course of time even the most illogical biologists were forced to see the elemental truth of the proposition that new characters acquired by an individual organism must be transmissible, else there could be no such cumulative change as that which results in the transformation of a species in new adaptations to its surroundings.

In other words, if acquired characters are not transmitted, there can be no organic evolution.

But a good many of the former adherents of this paradoxical view have abandoned their illogical position unwillingly, and even now are only willing to admit that such acquired characters are transmissible as are imprinted first on the germ plasm, and not on the body of the parent organism.

The contention really reduces the entire matter to a question of definition. It is virtually a distinction without a difference when we reflect that, at all events in the case of plants, germ plasm and body plasm are everywhere associated, so that we must suppose that if there is really a distinction between the two, it is a distinction within the substance of the individual cell, as the plant body contains both body plasm and germ plasm. Our earlier studies have shown that we are forced to this conclusion; and obviously, if this interpretation of germ plasm be accepted, it is a mere quibble as to whether the change or modification of an individual plant involves primarily the germ plasm or whether it involves the body plasm of the same cell as well.

Of course such mere incidental modifications of an individual as have to do with injury of its parts, the laceration of tissues, or the like, cannot be supposed to have any influence in heredity.

If such accidental modifications are heritable, the entire scheme of inheritance would become chaotic.

The modification that *is* heritable must be one that involves the constitution, so to speak, of the plant; such modification as would be brought about by changed conditions of nutrition, or by an altered temperature. A certain amount of experimental proof is already in hand that such modifications as these may be inherited. And if the opponents of the theory of the transmission of acquired traits can get any comfort out of the claim that such modifications directly affect the germ plasm, we need not wish to rob them of that cold comfort.

Details as to the special manner of inheritance aside, we may accept it, I think, as the only logical conclusion from a wide survey of the facts of heredity and evolution, that all modified characters that affect the constitution of the individual are heritable. Even the slightest modification of structure due to altered nutrition, to changed temperature, or the like, probably makes its influence felt on the next generation in exact proportion to its value in the great complex scheme of characters with which it is associated.

But this statement must not be misinterpreted. It must not be supposed that any minor modification of an individual can influence, except in an infinitesimal way, the inheritance of the offspring of that individual.

For the new modification will be, in the nature of the case, only as an alien drop or two in an ocean of hereditary tendencies.

Or, stated in somewhat more modern terms, the hereditary factor that represents the new modification will be as one minor factor among thousands or perhaps millions of preexisting factors.

If we revert to an earlier illustration, in which we thought of the germinal nucleus as a piece of architecture made up of multitudes of factors of heredity, we may think of the new factor as one added brick in a structure of palatial proportions, made up of thousands of bricks.

Yet it is by the cumulative effect of such minor modifications, we may well believe, that evolution has been brought about, and that in the long lapse of ages the highest forms of existing plants have been built up by successive stages of inheritance from the lowliest single-celled organisms.

The Status of Mendelism

In the large view, then, whereas it will be recognized that all acquired traits have their influence in heredity, yet it will also be recognized that the vast sum of qualities that are of less recent origin has preponderant influence, and that the racial characteristics as a whole are overwhelming in their power as against any individual modifications.

Yet, to complete our picture, we must recognize also that nature is not conservative, as she is commonly said to be, but is highly progressive. It could not be otherwise in a world in which the natural environing conditions are constantly changing.

The basal law of evolution, as we have seen, is that the unchanging, the conservative organism, is doomed. It is only the progressive, the changeable, the plastic organism that can hope to maintain itself and perpetuate its kind indefinitely.

The price of specific life is that the species shall not maintain its identity.

And this interpretation of the situation gives a clew, so it would seem, to that important and interesting aspect of heredity to which we referred at the beginning of this chapter—the phase commonly spoken of as Mendelism. The essential characteristics of this aspect of heredity, as we have pointed out over and over, is that heritable characteristics are transmitted in a sense independently one of another, in such a way that they may be segregated and put together again in new combinations in successive generations.

The detail within this scheme of transmission with which Mendel himself was chiefly concerned, and which absorbed the attention of his followers until it was found that there was need of taking a wider view, was involved in the phenomena of dominance and recessiveness. Mendel found, for instance, as we are aware, that when a tall pea vine was crossed with a short one the hybrids of the first generation were all tall, because, as he said, tallness was dominant and shortness recessive. And in the second generation one-fourth of the vines were short because the factors for shortness were segregated, according to the theory of chances, and one-fourth of the vines were pure recessives.

The fact of such dominance and recessiveness between pairs of heritable characters is too obvious to escape attention of any careful practical experimenter, now that attention has been called to it. But it is equally obvious that there are vast numbers of other heritable characters regarding which no such clear matching as to dominance and recessiveness is observed to take place.

And so the early enthusiasts were led finally to see that Mendelian dominance and recessiveness apply only to a certain small number of hereditary factors in the case of any individual plant or animal.

They came presently, after much heated argument, to admit that dominance and recessiveness constitute after all only a minor aspect of Mendelian heredity.

Yet this aspect of the subject, even if not all-important, has obvious interest. And the question naturally arises as to which ones among the numberless hereditary factors in the case of any given organism will "Mendelize" in the main, and why these factors will thus Mendelize while others fail to do so.

The answer is found, apparently, in the simple assumption that the factors that show the phenomena of dominance and recessiveness are those that are relatively new acquisitions in the germ plasms of the species under observation. Traits that have been the common heritage of the ancestry for untold generations, constituting the fundamental structures of the organism, do not Mendelize. They have proved their merit, and are accepted as part of the necessary equipment of the plant, not subject to the testing process that Mendelism essentially constitutes.

Such fundamental structures are, for example the root and stem and leaves and stamens and pistils of a flowering plant. As to their broad essentials of form and structure, these fundamental organs are inherited *en bloc,* and never jeopardized by being weighed in the Mendelian scale.

But the newly acquired characteristics, such as details of leaf form, or color of petals, or size

THE ROYAL WALNUT

This magnificent tree, one of the first seedlings of the Royal walnut, stands in a dooryard beside the Sebastopol road, near Santa Rosa. It bears mute but eloquent testimony to the success of one of our early experiments in hybridizing forest trees.

and quality of fruit—these are matters that are subject to modification because they have not as yet established themselves as fundamentally necessary in any detail of form or color to the species. These fall within the scope of Mendelian testing.

For hundreds of thousands of years, doubtless, the progenitors of plants that now have flowers were provided with roots and stems and leaves, and with essential reproductive organs, but had no blossoms. In comparatively recent times the blossoms were developed. And the modifications of color of the blossoms in the case of any given species are, as we have found reason to suppose, of still more recent origin.

These modern details, then, and their like, are the ones that are subject to variation and that are still matter for change and adaptation; still in the experimental stage, as it were. And precisely because such is their status, these are the things that are subjected to the Mendelian test when they are brought in juxtaposition, through hybridizing, with forms that differ as to these details.

And as only the relatively new structures Mendelize, so it is the newer member of any pair that assumes prepotency or dominance. Contrariwise, the older member is recessive.

Students of different examples of Mendelian heredity, as applied to animals and plants, have puzzled long to discover the underlying principle that determines which character shall be dominant and which recessive. But this simple principle appears to furnish the explanation.

The new trait or characteristic is dominant over the older one precisely *because* it is new.

By making it dominant, nature gives it the best possible chance. It will reproduce itself in all the immediate progeny of the individual that possesses it. Thus nature shows anew that she is progressing. She accepts the new characteristic and gives it more than an even chance.

But at the same time she is not so foolish as to renounce the old character without full testing. She allows it to be subordinated for a generation, but in the next generation it reappears, isolated, to compete with the dominant character. And whether in the end the new dominant character will prove itself and prevail, or whether the recessive character will reestablish itself, depends entirely on the value for the species of one character as against the other.

Mendelian heredity, then, is a testing out process for new characters. It is, as it were, the skirmish line of the advance guard of evolution. So long as a character is subject to Mendelian transmission, showing the phenomena of dominance and recessiveness, it is a relatively new and unfixed character still on trial.

And in proportion as any character has proved itself and has passed the trial stage, it becomes blended with the hereditary factors that have more stable position, just as conscious acts of the individual become instinctive or reflex when often enough repeated.

In this view, then, the so-called unit characters that Mendelize are, as was said before, merely the fringe to the great fabric of heredity. They serve the plant developer an admirable purpose, and it is with their manipulation that he is chiefly concerned. Their relative insignificance is evidenced in the fact that the plant developer cannot possibly produce major modifications in the organisms with which he deals.

He does not attempt to make squash vines into oak trees, or blackberry vines into tomatoes.

He recombines those newer, and hence less important, structures and qualities of which the fact of their Mendelizing is adequate proof of their newness and relative unimportance. If he would get beyond this and create really new forms, adding something to the plant that no ancestor of the plant ever had, he could hope to do this only if a term of life were granted him that would be measured not in mere years but in millenniums. For evolution is a slow process, and the history of the development of natural species is measured in geological eras.

Selection and Mendelism

Perhaps it may be worth while to illustrate this matter a little more in detail, that we may make clear precisely what manner of thing the plant developer is doing when he produces a new race by selection.

We have stated over and over that the process of hybridizing and the process of selection are complementary. One supplements the other. In hybridizing we make possible new combinations of the hereditary factors, and in selecting through successive generations we isolate certain definite combinations, and thus produce what we call new varieties. Now it is frequently stated by the experimenters who have paid attention only to a few conspicuous characters that Mendelize, that all possible combinations of characters will occur among the second generation hybrids, provided only enough of these are produced.

Possibly this statement is correct. But it is not susceptible of demonstration because it would not be feasible to produce enough individuals in a single generation to put it to the test. For the number of possible combinations increases in geometrical ratio, as we have seen, with the increased number of characters under consideration. And a really penetrating view of the situation reveals to us hereditary factors in the germ plasm of each individual plant that would be numbered, could we isolate them, not merely by tens or scores; not merely by hundreds or thousands; but rather by hundreds of thousands or millions.

To those experimenters who have been prone to think of "unit characters" as few in number, such a statement will perhaps seem anomalous. Yet there can be no question that it is fully justified.

In point of fact, what the present day student of heredity usually speaks of as a unit character might better be referred to as a "unit complex," or by some allied term that would suggest its complicated character. The word "gene-complex" has been suggested in a similar connection.

It would appear that the real purpose of selective breeding through many generations is to remove one after another of the factors that dominate or mask other factors, so that subordinate or recessive factors may make themselves manifest.

No one who has experimented widely will doubt that it is possible by a series of selections extending over several generations to accentuate a given character, say to bring out the crinkled formation of the poppy petal, or the corrugations in the leaf of a wild geranium, or an added row of petals in a balloon-flower. And it goes without saying that, according to the modern terminology, the character thus isolated must be represented by a hereditary factor which was present in each successive generation utilized in our experiment, but which for some reason was not enabled to make its influence so potentially felt in earlier generations as it was in later ones.

And the only logical explanation appears to be that in each successive generation of the plants carefully selected and inbred, there was a new redistribution of factors, always along Mendelian lines, which isolated, in the case of the individual we selected, the particular character which we had under observation more and more completely.

Whereas, in a simple case of Mendelian heredity, where one pair of factors is in mind, there is complete isolation of the recessive factor in one case in four; in this complex case there is isolation of groups of factors, and in one case among thousands there may occur such relatively complete isolation of the factors for quality we are seeking as will serve our purpose. Such isolation might occur in the second generation, but it cannot be counted on to occur until we have tried again and again, in each successive generation, using material that is little less complex because a certain number of disturbing factors have been segregated and removed.

We may perhaps illustrate the meaning of all this a little more clearly if we suggest that each so-called unit character with which Mendelian heredity deals is in reality made up of a thousand factors. I do not mean to imply that the number is just that; it is merely that a thousand is a convenient round number for purposes of our computation.

There would be, then, a thousand factors for color combined to make up what we commonly speak of as the unit factor for color; there would be a thousand subordinate factors for form of flower; a thousand others for texture of petal; a thousand others for odor; yet another thousand for hardiness; and so on for each and every patent characteristic of flower and twig and stem and root of the plant. In the aggregate, let us say, there are a thousand different "unit characters," each made up of a thousand minor factors, so that the total number of hereditary factors stored in the germ plasm and seeking for recognition, in the case of a single plant, is a round million.

Each of these million factors has been developed in the long slow process of evolution, one after another added, generation by generation, or era by era, beginning with the time when the remote primordial progenitor of the plant was a single-cell organism.

In the course of the ages, development has taken place along diverse lines, and it has come to pass that certain combinations of hereditary factors have been grouped into systems that have so long been working in harmony together that they cannot be separated. The members of one such group determine the architecture of the root; the members of another group determine the architecture of the stem; and so on for each of the patent characters.

But there are other groups of factors that are less ancient in their origin. There were some that made their way into the germ plasm of the ancestors of the plant so recently as half a million years ago. There are others that are mere parvenus of perhaps ten thousand years. And there are yet others that are upstarts of literal yesterday.

Each one of these hereditary factors is striving for recognition and endeavoring to make tangibly manifest the condition or quality or form or constitution of tissue that it specifically represents.

And, according to the view just presented, the thousand factors that make up any given complex stand in such sequential relation to each other that each successive one controls in a measure its predecessor in point of time, and is controlled by its successor. The very newest factor that has been admitted to the coalition has a more powerful influence than any other *single* member of the coalition.

But meantime this most powerful individual is after all only one among a thousand.

In a company of a thousand men, some one man is stronger than any other. But this strongest individual would be infinitesimally weak in comparison with the combined strength of the other 999.

This is the important thing to bear in mind. The newest member in each of the thousand or so hereditary "complexes" that we speak of as unit characters is the most powerful individual factor. But, inasmuch as the great body of antecedent factors are using their influence in unison in another direction, it is inconceivable that the influence of the single new factor should greatly change the aggregate result.

In this view, what we term a species is a company of organisms in the germ plasm of which the groups of factors for each main characteristic have become purely and unqualifiedly recessive, so that they act as a unit in producing a given character. They thus determine the chief characteristics of heredity in the Darwinian sense, which finds its popular expression in the phrase "like produces like."

Meantime, there are always minor groups of newer characters that are striving for recognition, and while these are relatively insignificant because of their newness and small number as compared with the whole, yet they are conspicuous and important in the eyes of the plant developer because they represent precisely those modifications of form and constitution and color that mark what we speak of as variations from type; and because they are so matched against one another in heredity—in the manner that we call Mendelian— as to make it possible for the plant developer to segregate and recombine them variously by hybridizing, and thus to develop new races from the old stock.

When, however, the plant developer, through his hybridizing experiments, brings together groups of characters in which the old guards, so to speak, that have control over the fundamental characters are in conflict, no union is possible.

Either fertilization will not take place, or the offspring will be sterile. Only within narrow limits, and as regards the new and relatively unessential characters, can there be diversity or, at most, the accentuation of old characters.

Such an accentuation, for example, occurs, we may suppose, in the case of the hybrid walnuts, which take on gigantic growth. Both Persian walnut and California walnut have in their germ plasm the hereditary factors of large groups of remote ancestors of the Mesozoic era, when gigantism was the fashion, but these factors have for long generations been subordinated by newer one born in a less favorable era. Now, however, hybridization brings the two strains together, and the two dominant groups of factors for slow and relatively dwarfed growth in some way mask or neutralize each other, enabling the earlier groups to make their influence felt.

And here, as we have seen, the factors for growth that have thus been rudely disturbed as to their hitherto harmonious coalitions, are reassorted in the second generation, as united groups acting along Mendelian lines, so that part of the progeny of the second generation are giants, and part of them are dwarfs, and that all manner of intermediate forms find recognition in the case of different individuals.

In no other way known to us could such a disturbance of the coalitions of hereditary factors have been brought about. So the plant developer who thus brings together racial strains that have been long separated, introduces a disturbing element that in its practical effects may produce such modifications as could only be produced otherwise through the aggregate influences of environment for almost numberless generations.

But let it be repeated that even when the hybridizer effects such a disturbance as this, he can do no more than to enable subordinated hereditary factors to make themselves manifest.

He is dealing with material that has been brought together through age-long experiments, and even though the new combinations that he effects may be striking ones, he may rest assured that even his most spectacular achievement is but a feeble replica of plant developments with which nature has experimented thousands of times over in the course of the long evolutionary ages.

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