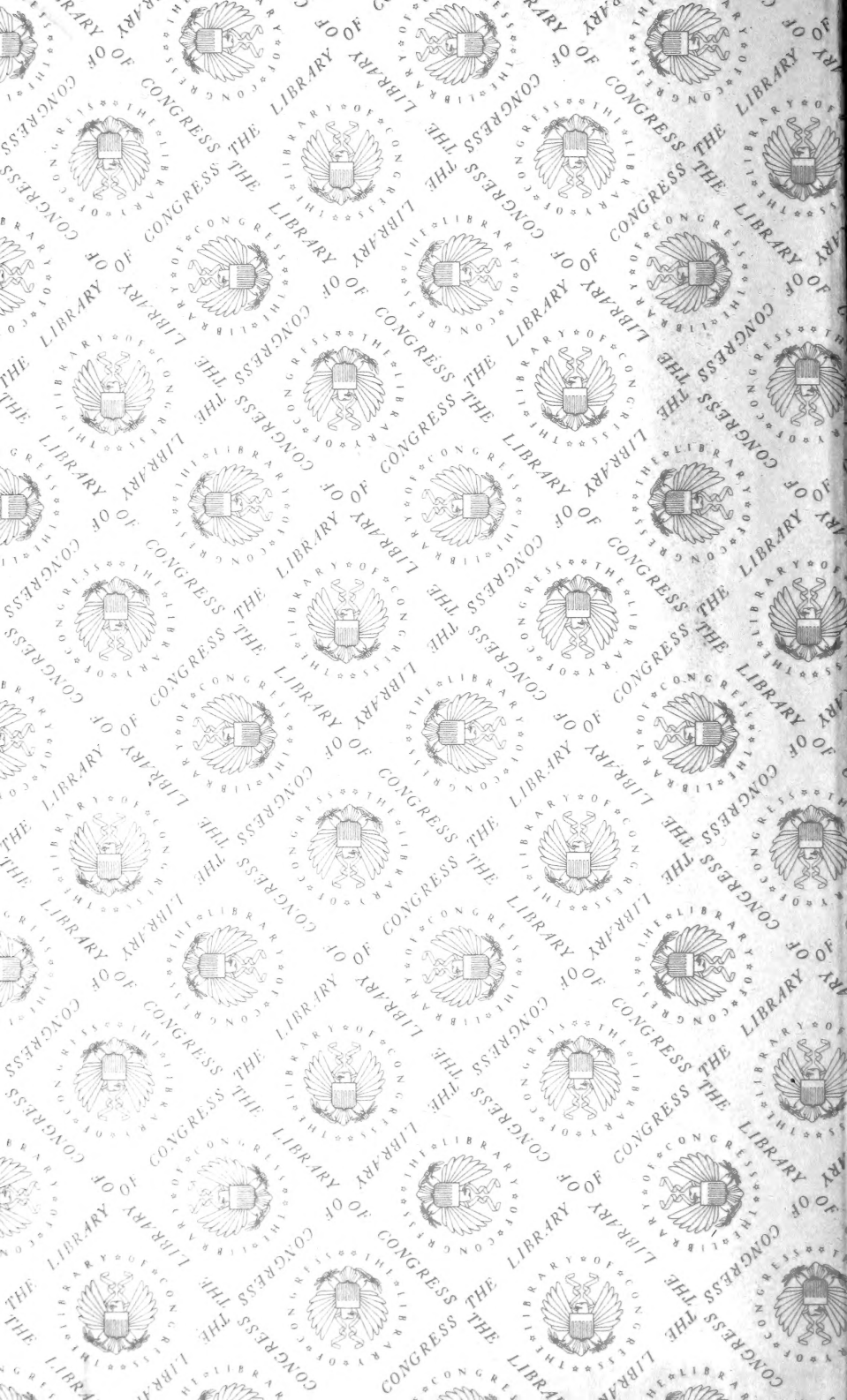
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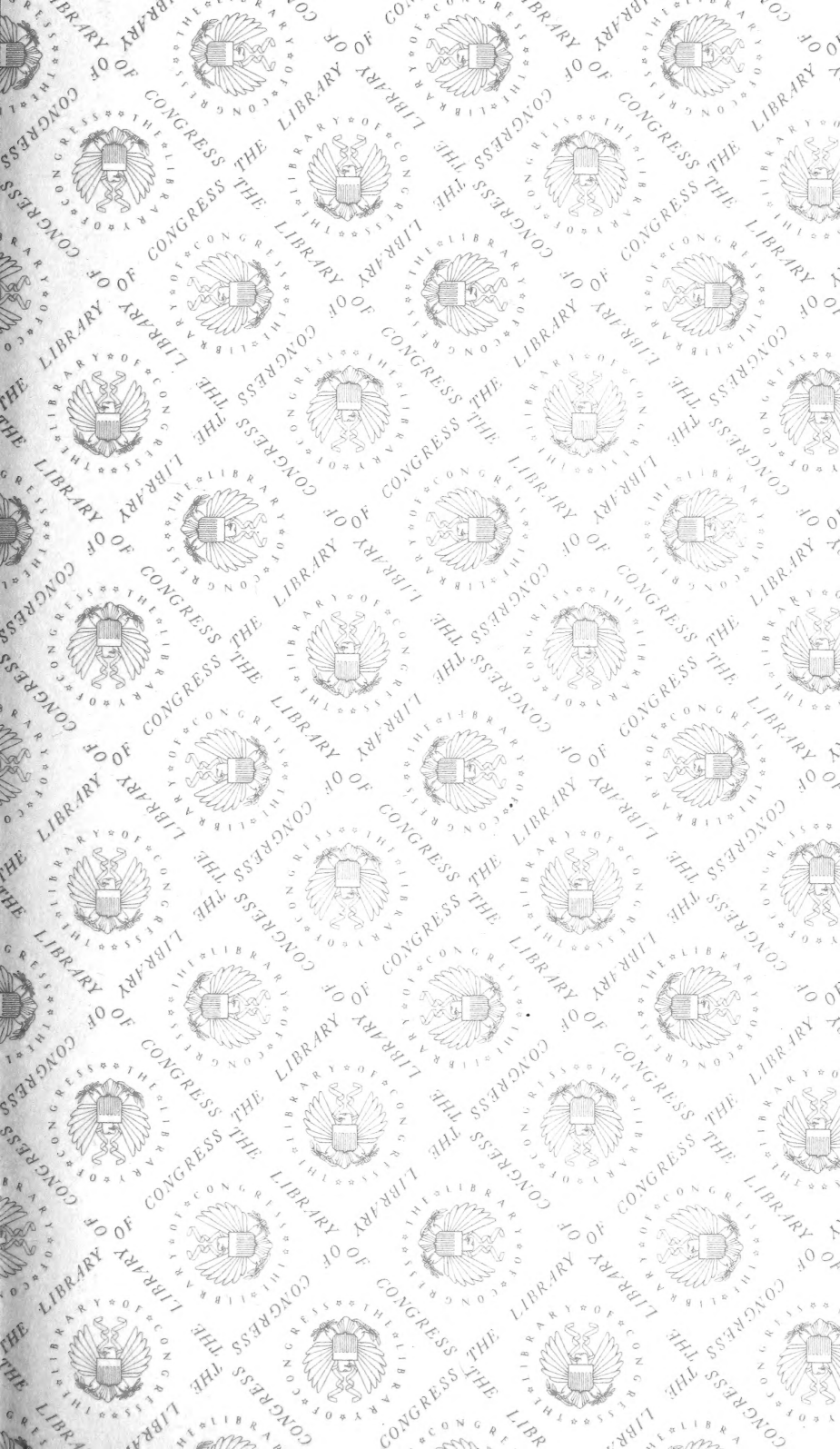
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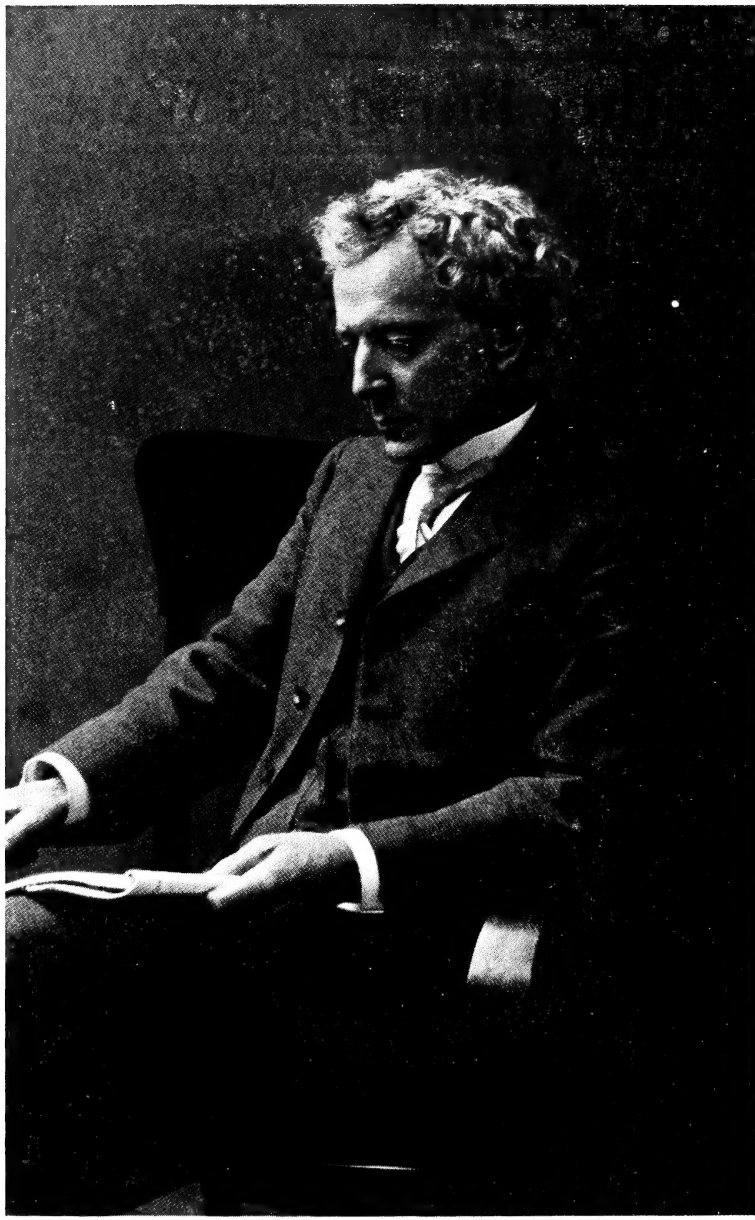

Luther Burbank

The Scientific Aspects *of* Luther Burbank's Work

By

DAVID STARR JORDAN
AND
VERNON L. KELLOGG

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Luther Burbank

LUTHER BURBANK is a modest, quiet, devoted worker in science, with a keen eye, a deft hand, a broad intelligence and a sensitive soul. He has taken up as his life-work the modification of plant life by the processes of crossing and selection. He has devoted himself whole-souled to this work, and with an industry amazing and almost without parallel. For years he has kept thousands of different experiments going, acting on the mechanical certainty that in plant-crossing there will be as many gains as losses, as many tremendous improvements as utter failures. For the sake of the one great gain, he ean burn a ton of vegetable debris made up of plants which failed or only partly succeeded.

Mr. Burbank has no patent on his methods. They are as open as the day. Thousands have used them before, as thousands will use them later. But not one in a hundred thousand has or will use them with like intelligence, deftness and skill.

It is Darwin who first gave us the knowledge on which all this work rests. The origin of species demands variation, selection, segregation, and behind all this the law of heredity,

the fact that "like produces like" or nearly alike. Burbank is a creator of species. So is any man who applies these elements to animal or plant life. To call him a "wizard," as some men and some magazines do, is to injure him in reputation and to befog his great services with a trivial epithet.

Burbank's ways are Nature's ways, for Burbank differs from other men in this, that his whole life is given to the study of how Nature does things. His greatest service to science is to show what can be achieved through deeper knowledge of things as they are. He has shown the infinite variety of Nature as exhibited in the varying life and ways of the millions of kinds of living things. He has shown the unity of Nature in again demonstrating the final essential simplicity of creative processes. He has put into practical utility the teachings of his greatest master, Darwin, and he has enriched the world with thousands of fruits and flowers, useful and delightful, which but for him would have existed only among the conceivable possibilities of creation. He works in his own way with the tools he needs and the methods he can use. He has helped mankind by increasing enormously the economic values plant life. He has helped even more our science and our philosophy by his practical and successful test of biologic theories. Among the men of science of century that is, Burbank is assured of a high and honored place, not as a "wizard" or as a clever operator, but as a man of broad views, exact knowledge, and noble and ennobling character.

D. S. J.

Some Experiments of Luther Burbank

By David Starr Jordan

David Starr Jordan

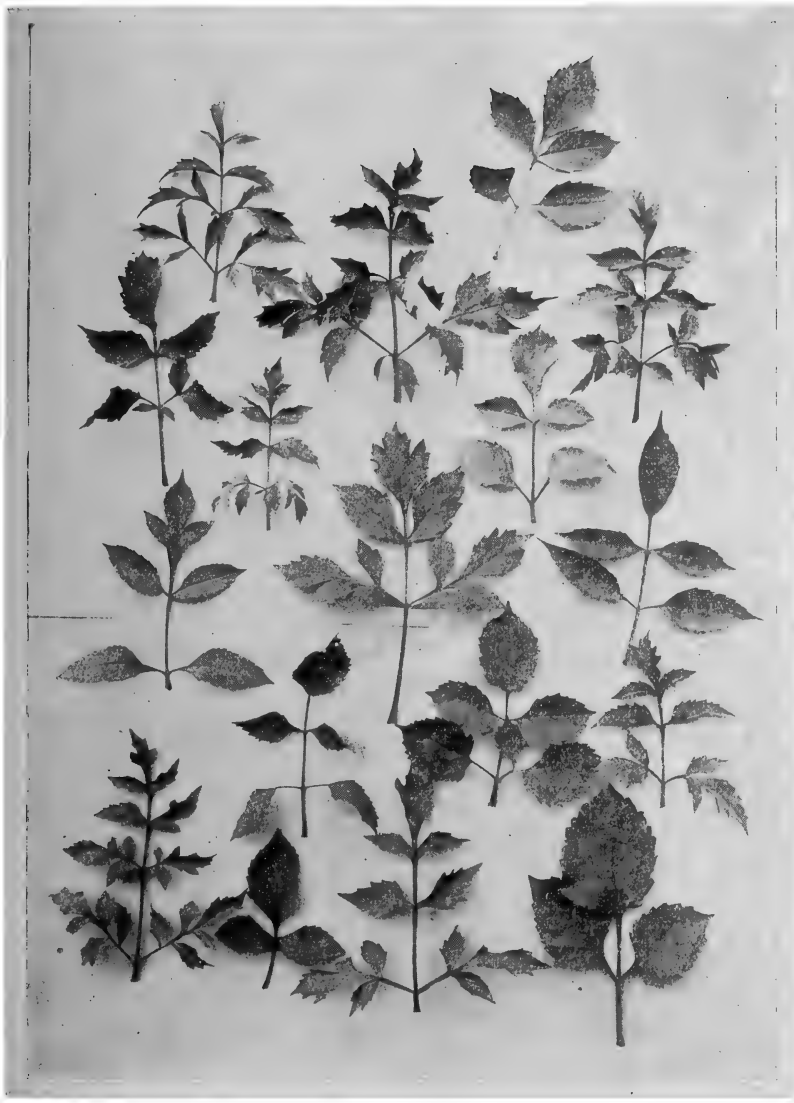
Some Experiments of Luther Burbank

DR. LUTHER BURBANK, of Santa Rosa, California, is beyond question, the most skilful experimenter in the field of the formation of new forms of plant life by the process of crossing and selection. He is the creator of many of our most useful plant forms: roots, nuts, fruits, grains and grasses, as well as of many of our most beautiful flowers. His methods are the practical application of the theories of Darwin and his followers, and to a degree wholly exceptional among plant breeders, Mr. Burbank has kept in touch with most modern work in the field of bionomics, and very much of his time and energy is devoted to experiments of scientific interest not likely of themselves to yield immediate practical results. In the

nature of things, the demands of his work, and the necessity for the sale of new forms produced by him, have prevented the keeping of detailed records of his work, although steps have been taken toward the provision of explicit records in the future. For the rest, Mr. Burbank's success in practical achievement gives weight to his views on theoretical questions.

The process of formation of new types may be grouped under four heads: selection, crossing, hybridization and mutation (or saltation). The process of artificial selection is used in all cases, those varying strains likely to prove useful being preserved, the others destroyed. The word 'crossing' may be advantageously used for the mingling of strains within a species, and 'hybridization' for the breeding together of members of different species. The name 'mutation' (or preferably 'saltation') is applied to sudden changes of characters for which no immediate cause is apparent.

Not many of Mr. Burbank's results are due to unassisted selection, as the processes of crossing



SAMPLE LEAVES OF COMMON GARDEN DAHLIA *(Dahlia variabilis)*, SHOWING ORDINARY VARIATION *within* A SPECIES WHEN UNDER CULTIVATION.

and hybridization save time by the increase of the rate or degree of variation. There is, however, no evident limit to the results to be obtained by simple selection. New and permanent species of wheat have, without a shadow of doubt, been produced by selection alone.

In the California poppy *(Eschscholtzia californica)*, stripes of crimson are never seen on the inside. Mr. Burbank once found a seedling in which the outside crimson had struck through like a crimson thread which had been misplaced. In other generations, by selection, this red was more and more increased, until finally out of it is developed a crimson poppy, of which Mr. Burbank has now many specimens, seeding more or less true to the type. The 'Shirley' poppy *(Papaver rhæas)* is well on the way to blue by selection.

It is questioned whether competition in minor details, or 'intra-specific selection,' can form species permanent as wild species are. As to this, Mr. Burbank notes that the cultivated species produced after the fashion of his crimson eschscholtzia

'have a very brief history compared with the wild species, and, moreover, they are constantly being placed in a new environment by man, being influenced by new soils, new climates, new fertilizers and the like.' "Breeding to a *fixed line* will bring fixed results. Man's desultory breeding is brief, the struggle for existence is mostly absent, and new ideals and new uses are required instead of ability to endure under natural conditions. Man's efforts at selective breeding are fluctuating, with frequent saltations."

Dr. De Vries notes that in the common sugar beet, which is a biennial species, there are from one to ten per cent of plants which bear seed the first year. None of these is ever chosen for seed, and yet the long-continued process of natural selection has never succeeded in rooting them out. As to this Mr. Burbank observes: "This long-fixed tendency to insure continued existence in the past is not yet bred out. Analogous to this is the tendency in flocks to produce black sheep, and the

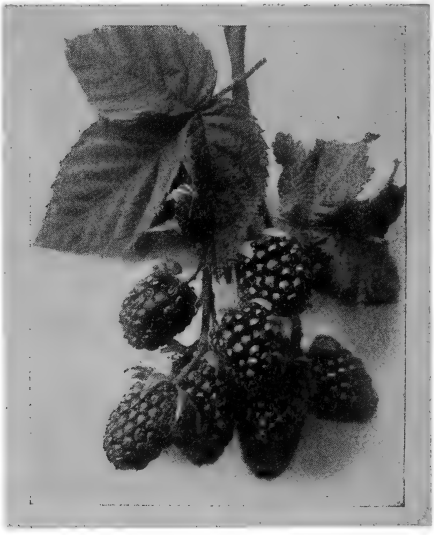
appearance of zebra stripes on horses — ancestral traits not yet bred out."

From the pale yellow Iceland poppy (*Papaver nudicaule*) are developed white, yellow and orange forms, and some with striped petals and a strong tendency to become double. Selecting the Iceland poppy for size alone, flowers three and one-half inches across have been developed. A large scarlet poppy, *Papaver glaucum*, closes its two inner petals when a bee or two have entered, shutting in the bees, which buzz angrily and cover themselves with pollen until they are set free. If not visited by bees, the flowers *do not close*.

A wild form of one of the Liliacæ, *Brodiæa terrestris*, was made white by selection of the palest among the pale wild ones. *Brodiæa lactea* taken from the high Sierras where it is a dwarf, becomes, after two years of cultivation, more than twice as high as the original stock, but not nearly as high as the same species grown in the valley.

"Crossing is done to secure a wealth of variation. By this means we get the species into a state

of perturbation or 'wabble,' and take advantage of the 'wabbling' to guide the life forces into the desired habits or channels. The first crossing is



Primus, THE FIRST FIXED RUBUS SPECIES ARTIFICIALLY PRODUCED.

generally a step in the direction in which we are going, but repeated crossing is often necessary and judicious selection always necessary to secure valuable practical results. Crossing may give the

best or the worst qualities of the parent, or any other qualities; and previous crossings often affect the results."

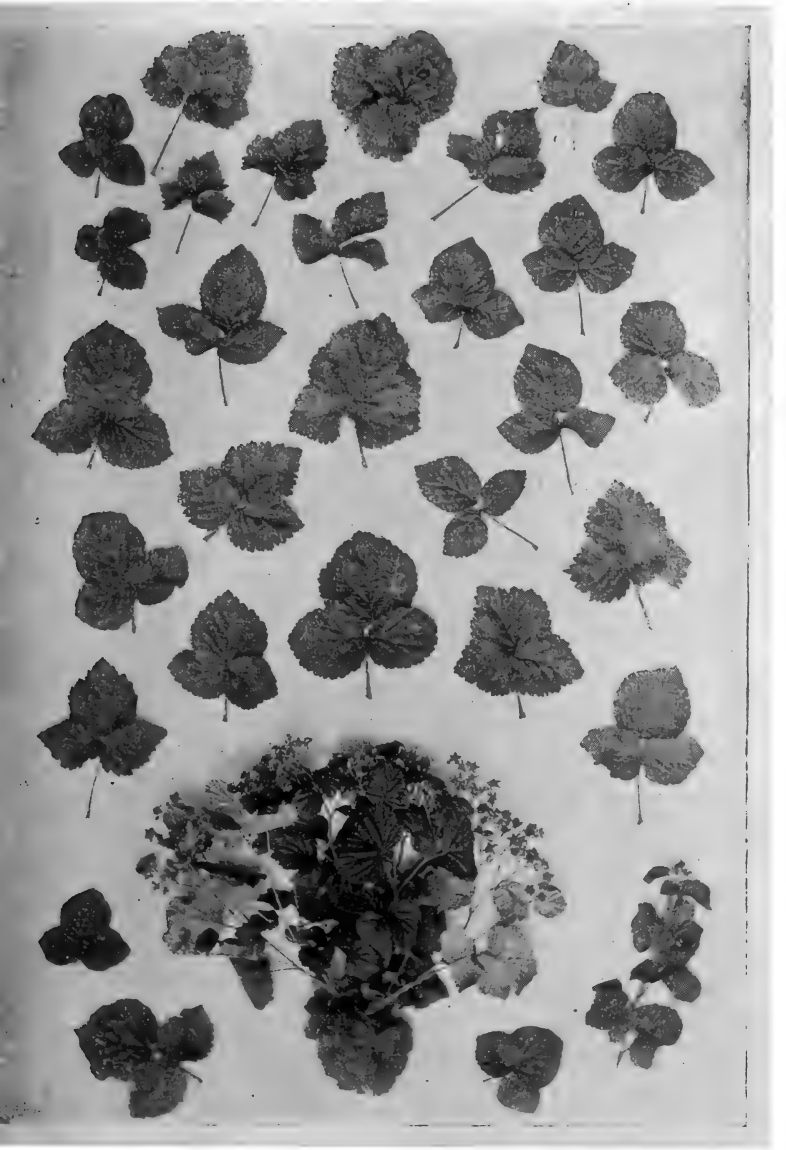
"Hybridization differs from ordinary crossing only in degree. A species is only a race which has assumed greater fixity. The purposes and results of crossing within the species and of hybridization of different species are essentially alike. The formation of the new individual by the sexual relation of two parents is in itself a species of crossing, giving each new individual in its degree new traits or new combinations."

"Bees and other insects, as well as the wind, cross plants, but they do not work intelligently, therefore rarely to any advantage economically to man. No mechanic could invent such devices as those which tend to prevent self-crossing in plants. *All evolution and improvement are dependent on crossing*, therefore nature has produced more wonderful devices for this purpose than for any other."

"Mutations, or saltations, are often found; that

is, fixed forms springing up, generally from unknown causes, forms which are not hybrids, and which remain constant; as, for instance, colored flowers which yield white forms, these yielding white constantly in their progeny. *These mutations can be produced at will* by any of the various means which disturb the habits of the plant. It comes out when the conditions are ripe. New conditions bring out latent traits. I should expect mutations to arise in the American primrose and most other plants under wholly new conditions. Extra food or growth force as well as crossing favors variation, as does abrupt change of conditions of any kind. Five or six generations will usually fix a mutation. Sometimes it is fixed at once."

"On the average, perhaps about six generations fairly fix a variation, but this varies greatly, depending upon previously acquired hereditary tendencies. Bringing a species into a new environment disturbs its fixity. Rich soil especially gives rise to variations in growth which seem to be new, and by repetition become inherently fixed. Sometimes



LEAVES SHOWING A NUMBER OF STRAWBERRY-RASPBERRY HYBRIDS AND A CLUSTER OF THE BLOSSOMS.

ancestral states are brought about by good soil; sometimes (perhaps oftener), also, by starvation; *new* variations oftenest by rich soil and general prosperity. *There is no evidence of any limit in the production of variation through artificial selection, especially if preceded by crossing.* Mutations are probably due to the sudden appearance of latent tendencies in new combinations, producing novel effects analogous to new chemical combinations."

"*Mutation is not a period, but a state* induced by various hereditary and external conditions. It is not by any means certain that there is any period in the life-history of the species when it is more subject to mutation than at other times, other conditions being similar. By crossing different species we can form more variations and mutations in half-a-dozen generations than will be developed by ordinary variation in a hundred or even a thousand generations."

"The La France and some other roses, as well as dahlias, callas and many other plants, every once in a while throw out, on some particular

year, a number of unusual sports in various localities. This is probably a matter of season, the forces outside bringing about parallel mutations. The evolution of species is largely dependent on crossing the variations contained within it. Forms too closely bred soon run out, because generally only by crossing does variation appear. It is of great advantage to have the parents a certain distance apart in their hereditary tendencies. If too close together there is not range enough of variety. If too far apart, the developed forms are unfitted for existence because too unstable. *Correlatea changes work together to produce the effect of mutations.* Environment effects a permanent change in species by selection of those which fit it or by producing changes in individuals which are better equipped to survive. *Heredity is the sum of all past environment*, conditions both latent and apparent. Latent traits often arise when circumstances make them possible. Environment of a lifetime does not necessarily or usually appear in another lifetime, but *continues in the same direction* and will strike

into the nature of the plant in time. We may refer to Emerson's remark on the 'baking into the picture of the pigment laid down by environment.' Selection is 'cumulative environment.' Fortuitous variations occur everywhere. They come up all the time, from past environments, past heredity and present opportunity. No two individuals are alike. Where there is a marked tendency in one direction, we have the case of a persistent effect of environment. Monstrosities are engorgements of force. They are generally a thousand times more likely to develop another sort of monstrosity than normal individuals are. You are likely to get from sports and monstrosities either extremes of variance. *They do not, however, maintain themselves, because heredity pulls back their descendants.* A wide variance is more easily pulled back than a slight variance. There are cases where the monstrosity might pull back its species. This is more likely to happen if the forces of natural or artificial selection were in its favor. There are many cases where the variant in minor points is

prepotent and outweighs the original stock. Monstrosities produced by crossing often perpetuate themselves as well as the species does."

"One difficulty with the mutation theory of Dr. De Vries, in my opinion, is lack of sufficiently wide experimentation. Fuller investigations will certainly show that the 'sports' or 'chance' variations comes under the same law as that of 'fluctuating' variations, mutations being only fluctuating variations carried beyond the critical point where past fluctuating variations can not withstand the accumulated forces without disintegration, thus bending them in a new direction."

"Professor Hubrecht is certainly in error in stating that the mean fluctuations can not be carried into the extreme or 'sport' variations by selection. Professor Hubrecht speaks of two divergent processes, 'fluctuating variations' and 'mutations,' which he says: 'Darwin has not sufficiently kept separate.' They are not separate; one is only a tendency toward the other, and which continued, though latent, may, or will, at last become domi-

nant, so as to swing the fluctuating variations fully out of the old orbit into the 'mutation' or 'sport' condition. Radical changes of environment for a series of generations will produce a tendency to sport, but hybridization will bring it about far more abruptly, and for practical plant or animal breeding or for scientific study of all these variations, far more satisfactorily."

"The misunderstanding evidently comes from not having a clear knowledge of latent and dominant hereditary forces. A knowledge of these explains the whole matter and makes harmony between Darwin and Wallace, leaving Professor De Vries careful experiments good, but coming to different conclusions on the results."

"Professor Hubrecht also states that 'now for the first time — forty years after the appearance of the 'Origin of Species — the actual birth of a species has been observed by him.' As I have produced several good species by hybridization, apparently as good as nature herself has produced, and as others have done the same by selection

alone, the above sentence is hardly true. But as before stated, hybridization followed by selection is the shortest plan by which valid new species can be produced. In other words, the *'period of mutation' can be produced at will!"*

"The mutation theory of the origin of species seems like a step backward toward the special creation theory, and without any facts as yet adequate to support it as a universal theory, however valuable and suggestive the experiments of Dr. De Vries may be."

There is a remarkably close analogy between hybridization and grafting. Bringing over from France a prunus (*P. mirobolana* var. *pissadi*), of which there was no other specimen in America, it was grafted on to the Kelsey plum, a variety of *Prunus triflorus*. The graft itself did not bloom, but the presence of the graft brought about in the tree a cross off the two species. This is the only case known to me in which the graft affected the reproductive system of the plant, forming a cross between forms which had never crossed. Many

hundred descendants of this cross are now living. Darwin acepted with reservations the account of the graft hybrids in potatoes, and there still remains some doubt of reliable testimony of the supposed act. He also speaks of a now well-known grafts hybrid of a yellow and purple cytisus, which is perhaps the most remarkable fact in this line on record."

Opuntia ficus-indica AND ITS HYBRID WITH *O. vulgaris*, THE HYBRID FLOWER FAR LARGER THAN EITHER PARENT.

DIAGRAM

SHOWING THE ZONE OF LIFE AND PARALLELISM OF RESUITS IN CROSSING AND GRAFTING. (L. B.)

Utter refusal to unite under any circumstances, either by crossing or grafting. (Outside of zone of possible union.)

CROSSING BY SEEDS.		CROSSING BY GRAFT.
Pollen acts as a poison.		Grafts blight and die as if poisoned.
Union partial, mosaic or temporary; seed rarely produced; seedlings generally inherit tendencies and qualities of one parent only; second or later generations revert fully.		Grafts often form a temporary union but are not in a normal condition. Avoided by nurserymen and planters with great care, as results are often disastrous to the grower.
Union free; seedlings show unbalanced condition, varying widely; often unusually vigorous; best condition for scientific or natural selection. Good qualities can be made permanent to the race.	*Mendelian State.* *Mutative State.*	Grafts unite readily but separate under unusual stress — drought, overbearing, lack of nourishment, etc. Avoided by nurserymen and planters.
Unite freely; seed of superior germinating quality produced abundantly. Seedlings normal with ordinary amount of variability.	*Large Variation.*	Grafts unite readily, thriving well; sometimes better than when grafted on their own stock.
Ordinary plant life as oftenest met with.	*Usual Fluctuations.*	Grafts unite and thrive as we oftenest see them.
Self-fertile; seed produced, but as there are very limited opportunities for profitable variations, this state ultimately ends in		Grafts grow on their own roots.

EXTINCTION.

All these varying states shade off from one to the other, with few hard and fast lines of separation.

"In some directions the strains of heredity are much more unbalanced than in others. An impulse from outside forces may bring about new combinations. This is illustrated by De Vries by a ball with many facets, which, if lightly touched, will return to its original position, if vigorously touched will turn over. Burbank once crossed a pole bean (*Phaseolus vulgaris*) with a lima bean *Phaseolus lunatus* var. *macrocarpus*). There was no visible effect in the appearance of the pod or the bean, but, when planted, each bean developed a cotyledon, part of one species and part of the other. The lima bean represented the end of the cotyledon, and was united to the lower part by serrated edges; below was the smaller and striped cotyledon of the pole bean. The cotyledons finally parted at the joints between the two, the upper portion falling off, as is often the case with grafts which are uncongenial. The forms were tremendously vigorous, but all came back to the common pole or horticultural bean after the second generation, as though it were an uncongenial graft

hybrid, the alien portion being finally entirely rejected. It often happens in grafting, that the branch will be united thoroughly at the point of grafting, but in great stress, as the overbearing of fruit, the grafted portion will separate and entirely fall off."

"In one sense, hybridization is only a mode of grafting, both being a more or less permanent combination. The different results from hybridization are shown in the diagram below."

"Where the plants are very different, having a different line of descent, and consequently different structure, there will be no hydridization at all. From this we have every gradation to the point where the individuals are very closely alike, and here we have scarcely any variation at all in the progeny, a condition which favors extinction. Again, in grafting, we have every intergradation between total inability to unite and absolutely perfect blend."

"Sometimes a graft strengthens a plant by increasing the body of foliage and thus strength-

ening the roots. Grafting a Japanese pear on the Bartlett pear will give the latter new life through the increase in the foliage, which gives material for root action and further extension."

As illustrations of the results of crossing and hybridization, the following notes were taken on plants in Mr. Burbank's gardens:

In the beginning of his work Mr. Burbank crossed all sorts of beans and had a half acre of them. Some climbed to the height of twenty or thirty feet, producing all sorts of pods—some with pods long and slender and stems so short that the pods doubled up on the ground. These forms could have been fixed in time, though the variations were unusually persistent and very amazing in their variety and abundance.

Crossing the red and white pole bean, two or three of the beans grew large and bore striped pods, the beans themselves being jet black. From this cross many varieties were developed having all the colors known in beans.

The results of selection are often so simple as

to form a mathematical rule, as in the case of Mendel's peas, which holds good with the tribe of peas (*Pisum*), but not generally with others so far experimented on. At other times they are so complicated that to follow them requires the highest skill, or may be utterly impossible.

A rubus (*R. cratægifolius*) from Siberia has fruit the size of a large half pea, brownish, seedy and tasteless. Hybridizing with the California blackberry (*R. vitifolius*), some of the hybrids have the best qualities of both berries combined, and a perfect balance of characters. Out of over five thousand second generation hybrid seedlings, every one is true to the seed. This refers to the Primus blackberry, which is now fully as true a species as any classified species of *Rubus*.

The raspberry has been hybridized with a strawberry: the results were thornless plants with trifoliate leaves looking like a strawberry plant and sending out underground stolons like the strawberry. At last, however, the plants send up canes three to five feet high bearing panicles of flowers

more profuse in number than those on either parent. After flowering the plant never produces

Stems of Blackberry-Raspberry Hybrids.

a berry, the fruit forming a small knob, with no effort at maturity.

In the hybrid of the strawberry and raspberry, the resultant plants bore three or four times as

many flowers as the raspberry, seven or eight times as many as the strawberry.

Tendencies strong in the parent, even though for a time latent, usually come out strong in the descendants. Ordinary hybrids of forms closely related generally form a perfect blend from both parents. When the parents are far apart all sorts of variations occur, the so-called Mendelian condition being one phase of the results.

Hybridizing the iceberg white blackberry with the Cuthbert raspberry develops a plant with foliage and growth midway. About half the plants bear fruit which is red like the raspberry, about half bear fruit which is white like the iceberg blackberry; the quality is midway between the blackberry and the raspberry. In the crossed fruit (first generation) the flavor is not superior, but it is quite intermediate between blackberry and raspberry. The form of the receptacle is intermediate. Some of the fruitlets separate at the base, but not above. In crossing it makes no difference which sex is taken as the male parent;

Leaves of Blackberry Raspberry Hybrids.

it all depends upon the hereditary tendencies of the sex.

Crosses of wild species yield results similar to those from cultivated species, but the latter are more available. The white blackberry is a wild variation crossed with the Lawton for size and vigor; the result is a much clearer white than the wild one, larger, and very much more productive, in these respects fully equal to its staminate parent, the Lawton.

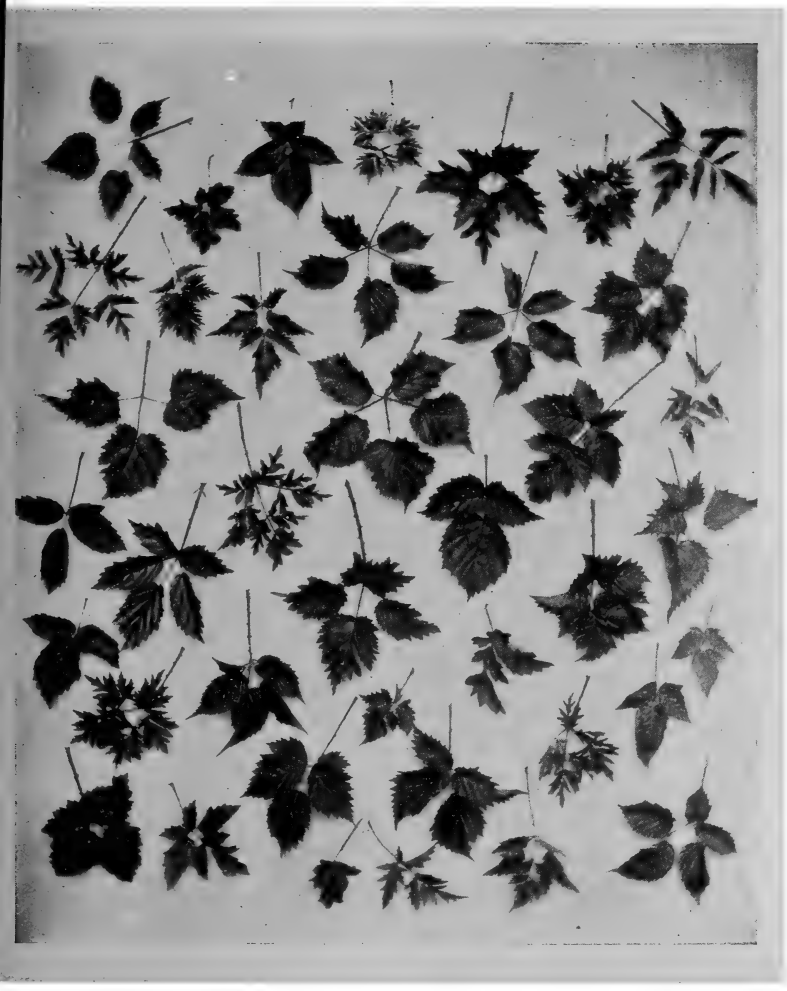
Apples brought up from the south temperate zone are entirely confused here, yielding leaves, buds, flowers and small apples at various seasons. One of these apples in time, however, became adapted to the conditions and developed into one of the best apples in Mendocino County.

"Animals or plants changed by transference from one country to another never quite go back to the old conditions, even if placed in them again, as hereditary tendencies acquired under the new environments, even though latent for many generations may be called forth again under

favoring conditions. Exceptions seem to be as important as the rules in this work. Nature leaves so many loopholes that there is almost no rule without exceptions. She does not tie herself up to any unvarying conditions. Adaptability is more important than perseverance."

A blackberry plant with an immense mass of fruit developed from a seedling from the Himalayas. One plant covers 150 square feet, is 8 feet high, and has a bushel or more of fruit. This is only a young small plant; when full grown this variety is many times larger.

A purple larkspur reared by Mr. Burbank is produced by crossing a native blue with a native scarlet, the color being entirely a blend. The blackberry was crossed with apples and with all the various rosaceous plants. Over five thousand plants were produced. The apple-blackberry cross came out essentially apples in foliage and growth, though raised from blackberry seeds. Only two of them ever bloomed, all were thornless, one of them bearing rose-colored flowers. From the



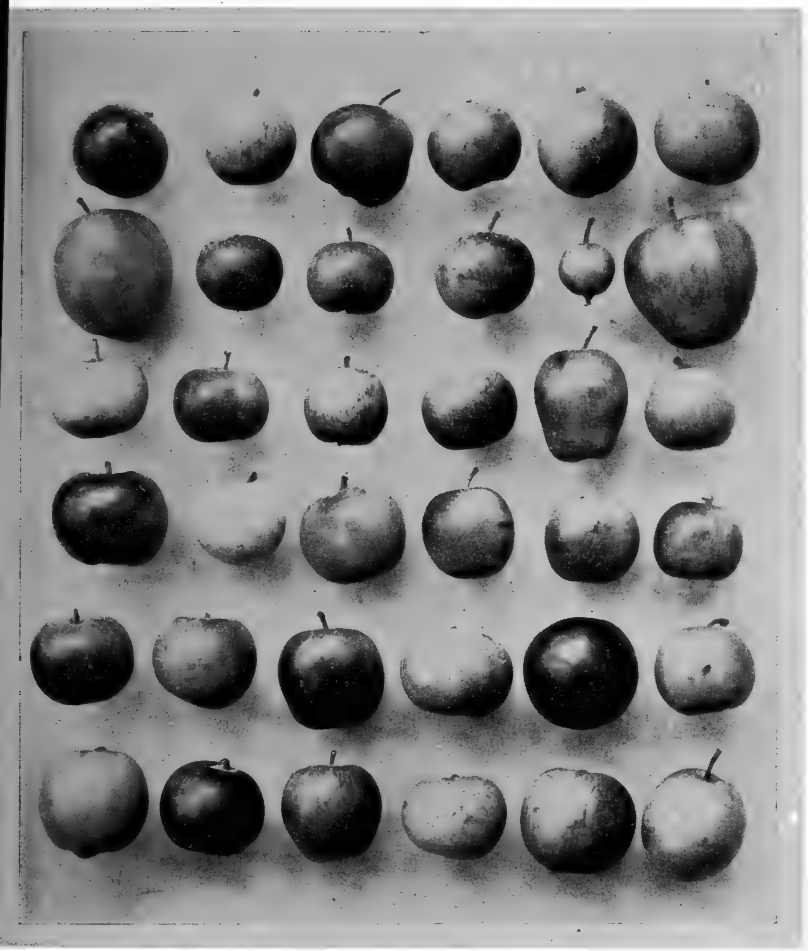
Leaves of a Blackberry Hybrid, all grown from Seed of One Plant.

mountain ash and blackberry a salmon-colored fruit with no thorns and no albumen in the seed was developed. A hybrid between the English and the black walnut grows fully four times as fast as the English walnut; it bears little fruit. The seedlings from the fruit produce some English, some black, and some hybrid walnuts, and not rarely entirely new forms. Crossing often brings about great vegetative life at the expense of reproductive life, or the reverse. The young (second generation) hybrids of the black walnut and the English walnut show very great variation in their leaves, resembling neither parent. The hybrids of the English and California black walnuts are most rapidly growing trees and unusually productive. The first hybrid, of the English with the Japanese walnut, *Juglans sieboldi,* is largely like the Japanese in the nuts, but rather more like the English in foliage, the second generation being very variable as usual.

By crossing types already crossed, we may often bring out the original stock which had been lost

in cultivation. The English walnut has usually five leaflets, the black walnut fifteen to nineteen. The first generation hybrid has eleven, with a fragrance to the leaves that no original walnut has. This tendency or trait is just as real as any other. The American walnut (*Juglans nigra*) and the California black walnut (*J. californica*) are closely related species and when hybridized yield fruit of very large size and in enormous quantities.

Descendants of hybrids usually revert to either one or the other parent or break up in all directions. A cross of the eastern black walnut (*Juglans nigra*) with the California nut (*J. californica*) yields a hybrid which is a very great grower. From the seed of this tree a surprising variety of mutations are developed, not only resembling every possible combination of both parents but numerous strange forms. In fact, among about two thousand seedlings now alive, almost every type or form of walnut foliage may be found. There are startling variations in size, form and number of leaflets, in the size of the plant, in the



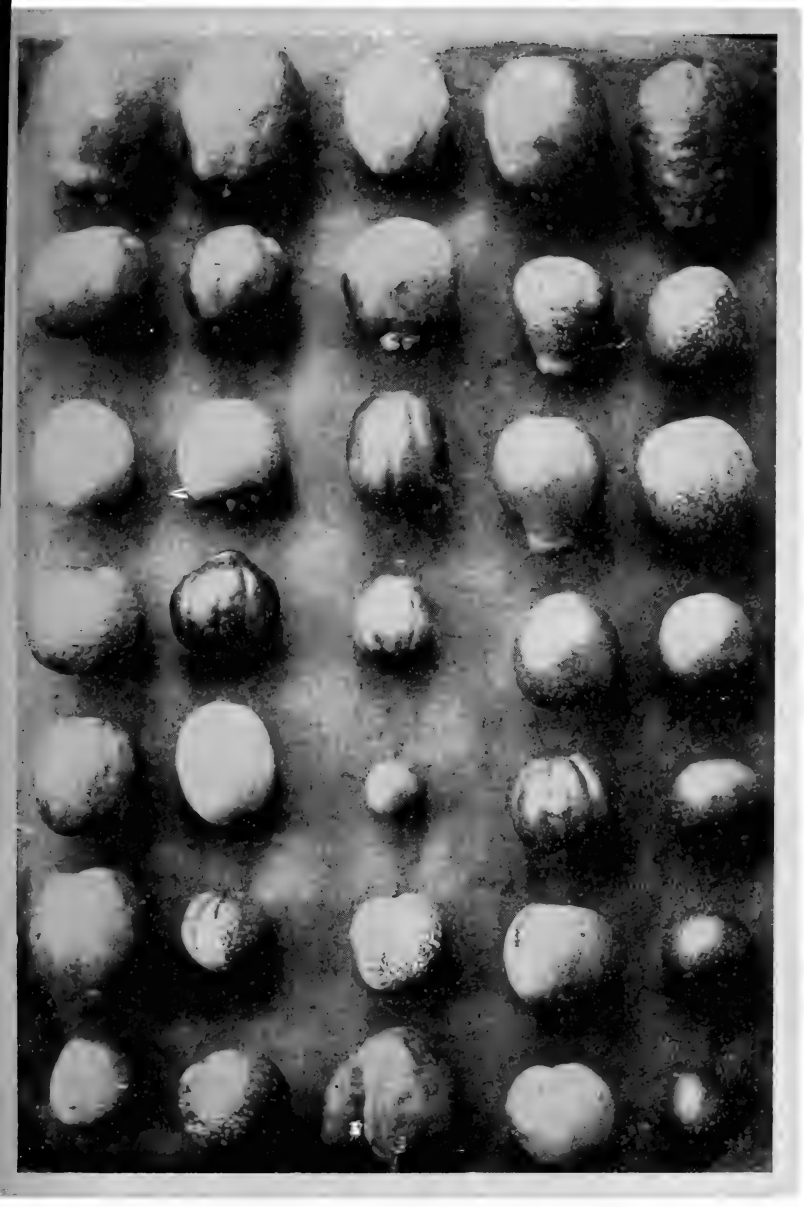
Apples—all Seedlings from One Variety, 'The Early Williams,' showing about the Normal Variation of Apple Seedlings.

serration of the margins, in the degree of roughness of the surface, in every feature in which one walnut may differ from another.

Some time since, a hybrid mesembryanthemum was developed, and lasted for four years, forming an attractive plant with a profusion of white flowers. Then all individuals, wherever located, died at once, doubtless because conditions were adverse: but there was no visible cause of soil, of insect pest, of fungus or of climate. These plants all died from the root up. A hybrid of petunia and nicotiana has abundance of flowers and large vigorous leaves, but the roots are inadequate. A hybrid red poppy is formed by uniting the opium poppy with the oriental poppy. These hybrids bloom every day of the year, while the blooming season of either parent is only a few weeks, but they yield no seed. The seed capsules are developed in great variety, some of them four to six times as large as the capsules of either parent. Others are scarcely thicker than the stem which bears them, while others are absolutely and

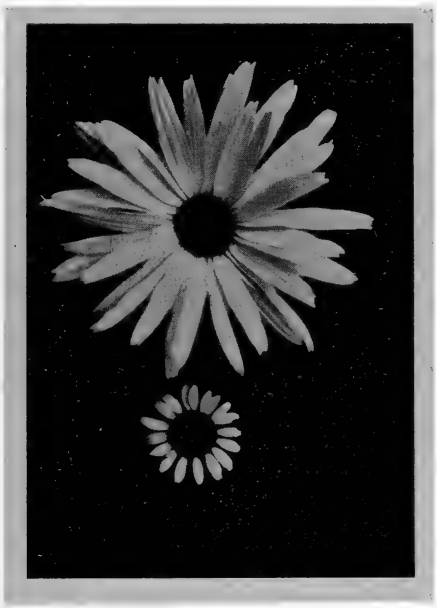
completely absent. This hybrid poppy is tall and generally branches like the opium poppy. It is perennial, although its pistillate or seed ancestor is a short-lived annual. This red poppy can even be divided at the root and multiplied like the perennial oriental poppy. These hybrids have generally a dark mark at the base of the scarlet petals as in the oriental poppy; in some the leaves are smoothish and glaucous, as in the opium poppy; in most, deep green and hairy, more as in the other. Many flowers have their stems coalescent with that of the neighboring flower.

"These second generation hybrid poppy plants unexpectedly all proved to be *perennials*, and are now making a tremendous growth; the clusters of foliage of some of them are fourteen to eighteen inches across already. Among this *second* generation hybrid lot of poppies each single plant seems to be different from every other plant in the lot and strange to say the leaves now resemble not only poppy leaves, but celandine, various thistles, primroses, turnips, mustards and numerous other



SEEDLINGS OF JAPANESE QUINCES, SHOWING NORMAL VARIATIONS.

plants are very closely imitated, showing most astounding variations."



THE ORIGINAL AND IMPROVED (SHASTA) DAISY.

The striped amaryllis, *vittata*, hybridized with a Mexican species, *formosissima*, has narrow twisted petals of a very deep scarlet and nearly plain.

The leaves are much narrower than in the *vittata*, the stalks more slender, and the plants more profuse bloomers.

Hybridizing crinum with amaryllis develops a plant with a fine flower but no seeds. Crossing

JAPAN WALNUT. RESULT OF CROSS OF THE TWO. ENGLISH WALNUT.

the small hardy white calla with a yellow one which is not hardy, develops, with selection, a hardy yellow calla.

A crinum from Florida is hardy but not handsome. Crossing this with a handsome crinum from Mexico, the plants were selected for those which should be both hardy and handsome. The

Leaves from Second Generation Seedlings from Cross of Common Persian Walnut *(Juglans regia)* and California Native Walnut.

desired qualities of the two species have been combined and other valuable new qualities incidentally developed as regeneration and selection proceeded.

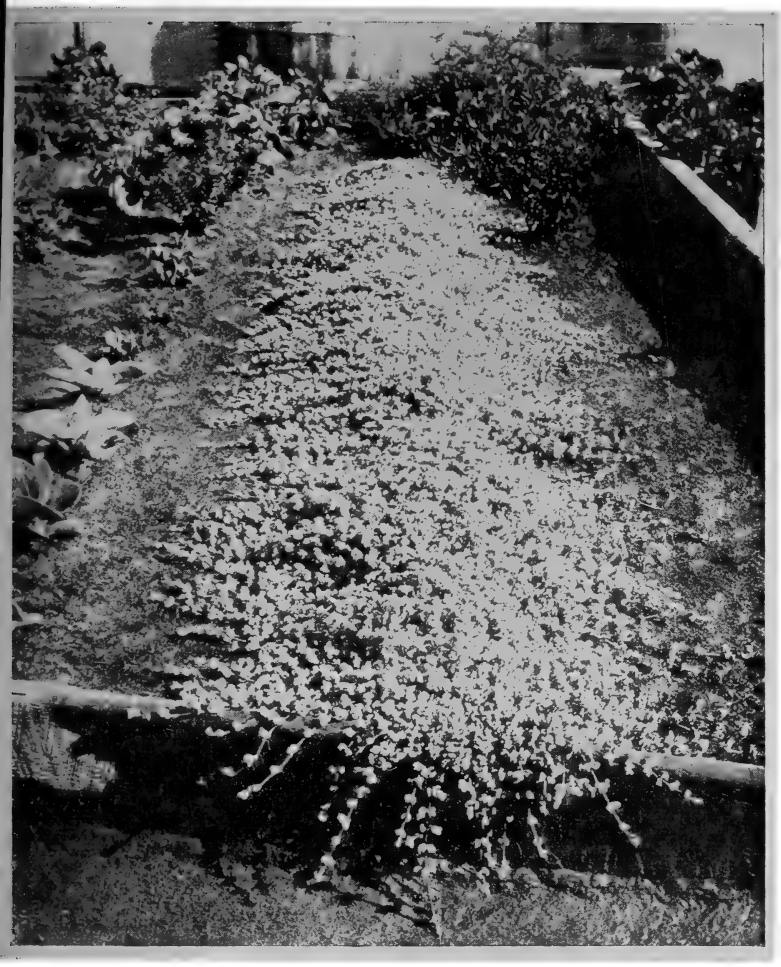
In hybridizing callas, the yellow ones with the white, to form a hardy yellow race, some of the resultant plants have pale flowers, some light yellow, and those chosen are made deep yellow by selection from second and later generations. Both parent plants in this case have leaves blotched with white, and this is found in all the descendants.

Hybridizing the wild flower, *Erysimum arkansanum*, which is yellow, with a native wild white species, resulted in the first generation a perfect blend of yellow and white; with a second generation the species separate completely, about five per cent of those examined being yellow, the other ninety-five per cent white; white dominant. With a hybrid *Thalictrum*, seed pods are developed more abundantly than with either parent, but the seeds are not produced.

We may expect variations in form, size, color, quality, fragrance, vigor or any other characteristic.

To get variation in any one direction is to open the door to anything else. Hybridizing the Japanese quince with the common quince, we have large-leaved seedlings which look quite different from the parent (common quince). The final result is a seedling looking like the Japanese quince, without the power of continued growth (too wide a cross to blend permanently or profitably).

Some of the black raspberries when hybridized with some of the blackberries usually die when the time comes to bear fruit. Many hybrids perish under the stress of reproduction. The *Amaryllis vittata* is now eight to eleven inches across, being nearly four times as broad as before the work of selection for size was begun, and with vigor and freedom of growth and bloom amazingly increased. On a strip of poor land it grows very small, with narrow leaves and slender flowers, but on the same poor land some of the hybrid variants grow very large and pay no attention to the soil. A variant of *Ampelopsis quinquefolia*



HYBRID MESEMBRYANTHEMUM.

has very large leaves, highly colored in the fall, but no fruit. *Mimulus tigrinus* of Europe has very many variations. Its flowers are yellow, with

Sample of Hybrid Poppies.

patches of orange and other colors. When crossed with some of our native species, the seedlings are greatly improved in all respects, even in blooming, yet rarely produce seeds.

It is generally much easier to develop variations in seedlings from variegated flowers than from

SAMPLE LEAVES OF TWO SPECIES OF BOCCONIA, SHOWING ONE OF THOUSANDS OF CASES OF GREAT VARIATION IN FOLIAGE IN CLOSELY RELATED SPECIES.

those of solid color (the variegation shows a lack of complete amalgamation). A double mimulus is formed of the *hose-en-hose* sort. One hybrid

LEAVES FROM HYBRID POPPIES, showing unusual variation in foliage even for second generation hybrids. Blossoms vary about as much as the leaves — the habits of the plants also. These are an average random selection from about two thousand second generation seedlings.

poppy produces an abortive flower inside the capsule. All seedlings always vary more or less. With the same parent, one fruit may be two and

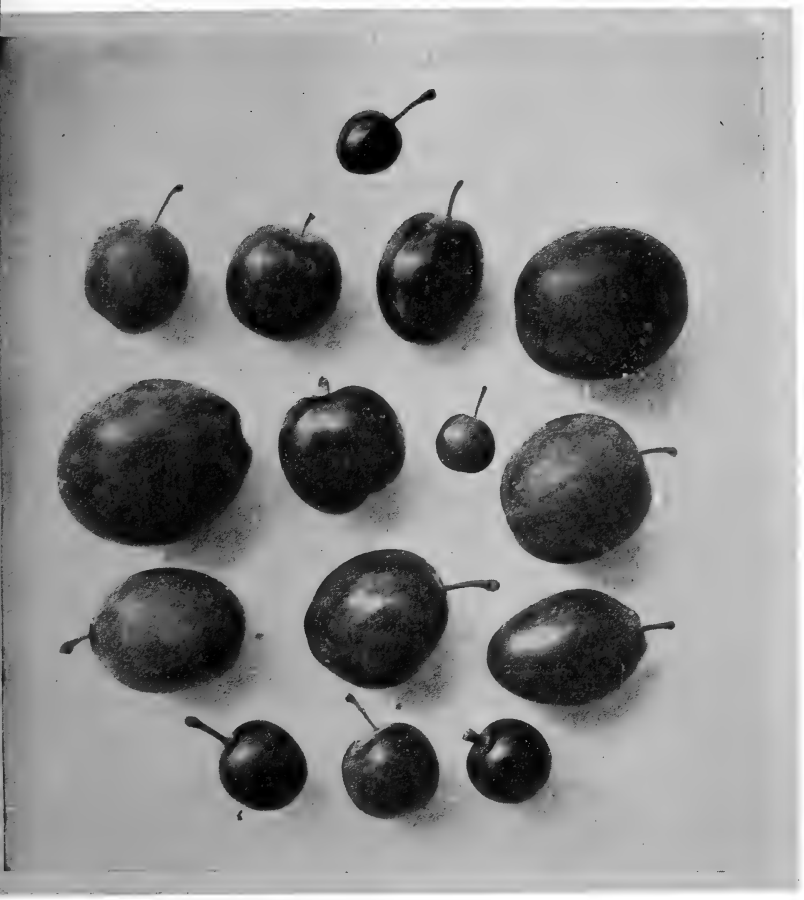
CAPSULES OF SECOND GENERATION HYBRID POPPIES, showing series of variations from complete absence of capsules to capsules of unusual size and to double capsules of unusual size. These selected at random from about two thousand plants. The individual plants which produce these types generally follow them in all the capsules.

one half or more times the diameter of the other, of a different color, flavor or differing in almost all respects. "There is no prepotency of male or female as such. Prepotency depends wholly on

heredity. We can not rely on the stoneless types being prepotent, but a certain number of trees producing stoneless fruit usually come from crossing them with those having stones. The prepotency to produce a stone, or a half stone, having been more thoroughly fixed by ages of stone-producing trees, will perhaps be about ninety-nine times out of one hundred. But other things being equal, there is absolutely no balance in favor of either sex. This may be set down as fixed.''

With plum-almond crosses there is every kind of variation in the flowers. Some have all stamens, some have many petals or none, some never open, and some have pistils only.

The Climax plum is a cross of the bitter, flat, tomato-shaped Chinese plum, *Prunus simoni*, and the Japanese plum, *Prunus triflora*. The Chinese plum produces almost no pollen; hardly a grain of it is known, not more than one could put in his eye without feeling it; but the whole fruit shipping industry of the world has been changed by this hybrid plum (Climax) produced by it.



Original Wild Stoneless Plum at the Top, and Fourteen of its Seedlings when crossed with the French Prune Below, about one-fourth Size.

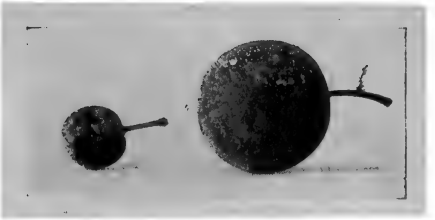
With many crosses of many things it is certain that forms of great importance will come out every year, though never in profusion.

In developing a spineless cactus for stock-feeding, selections were made from the three hard northern species, *Opuntia rafinesquii*, *O. mesacantha* and *O. vulgaris*, the latter the common prickly pear; these were crossed with *O. tuna*, of Southern California, *ficus indica*, from Alba, Spain, and with a small opuntia from Central America, almost thornless.

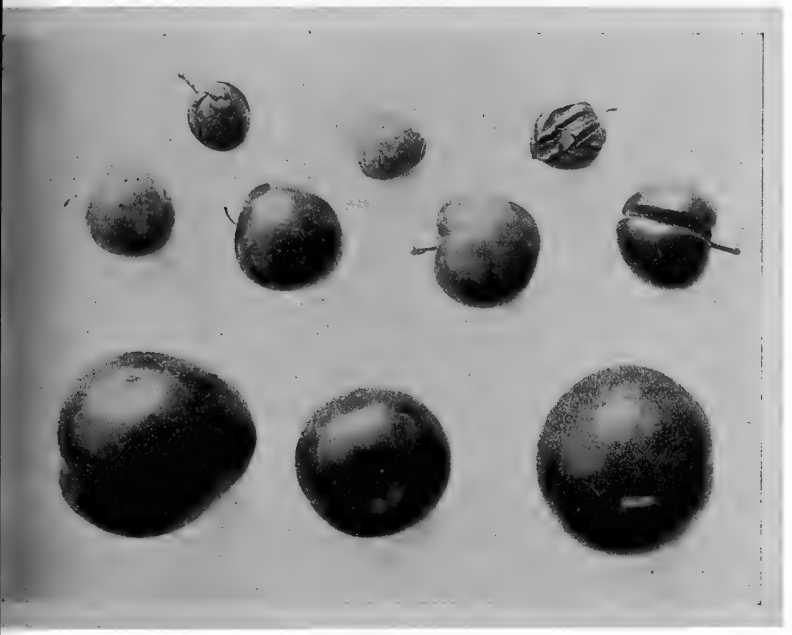
The cactus of all species has smooth cotyledons, but the first bud is covered with thorns. These thorns have also been eliminated by selecting the smoothest individual seedlings without crossing. Crossing in this case generally interrupts the process, as it brings out well-fixed ancestral traits, but later, to combine the best qualities of several species, crossing and selection must be resorted to. Examples seen were shoots of the original stock, prickly; the second generation, slightly prickly; the third, without thorns; and

later the spicules even within the substance of the cactus have been removed so as to make the cactus very excellent food for cattle. This will have very great value in the arid regions. Some cacti lose the thorns on the plant but retain them on the fruit; others *vice versa*. By crossing and extensive and intensive selection a cactus may be improved in various ways besides being deprived of thorns and of the internal spicules in six or less generations; these, by means of cuttings, may be multiplied rapidly to any extent, but the process, to be complete, generally takes longer. This thornless cactus should prove of very great value in the development of desert regions as Arizona or Sonora, as the quantity of food produced per acre is enormous. Its value is being already (1908) fully tested on a large scale near Indio, in California, and in the state of Victoria in Australia. It is evident that the thornless cactus cannot be expected to flourish as a wild plant on the desert, for cattle and other browsing animals would devour it root and branch. Its effectiveness

PLUMCOT—AN ABSOLUTELY NEW FRUIT

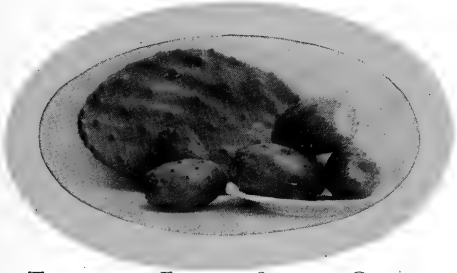


ORIGINAL AND IMPROVED BEACH PLUM.



TEN VARIETIES OF PLUMS GROWN FROM THE SEED OF THE BURBANK PLUM CROSSED WITH THE APRICOT PLUM, SHOWING VARIATIONS.

is as a forage plant to be cut and thrown to cattle as green fodder. For this purpose it is extraordinarily abundant as to quantity, and at the same time most excellent as to quality, having a high



THALLUS AND FRUIT OF SPINELESS CACTUS.

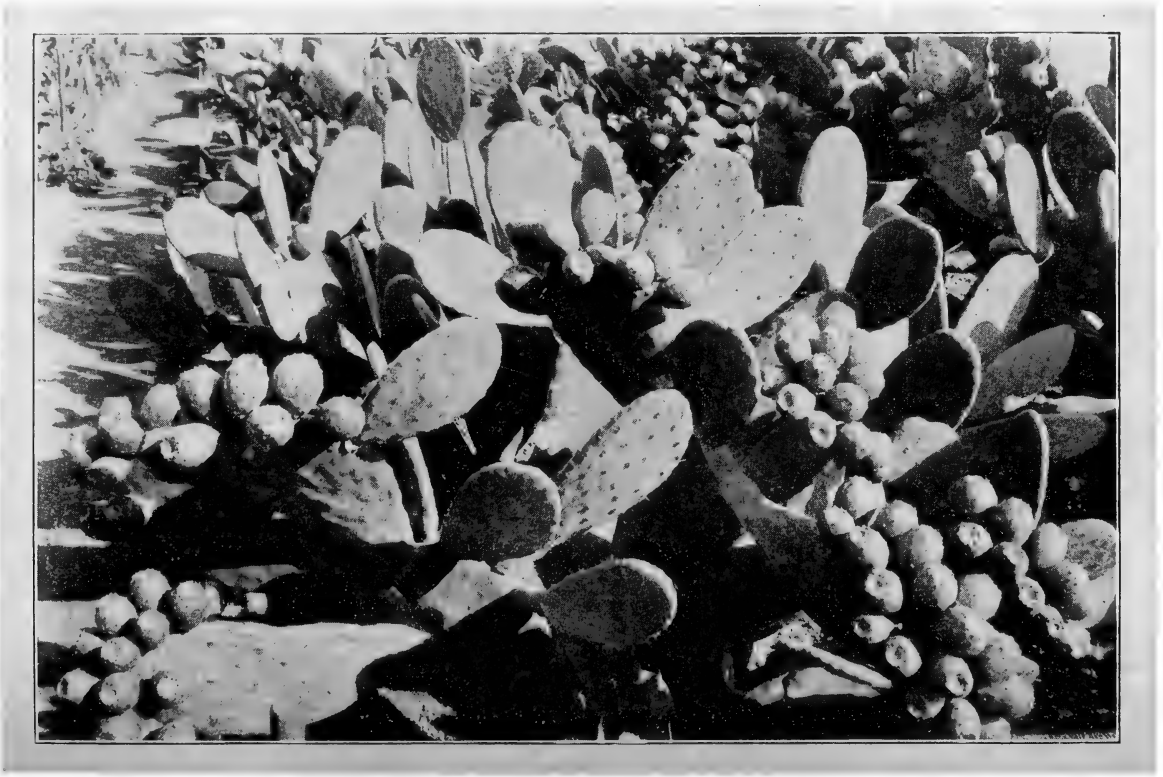
nutritive value, exceeding in this respect most or all of the grasses.

Incidentally, in this connection, the edible fruit of the *Opuntia ficus-indica* or "Barbary Fig," which has been long cultivated in Southern Europe and Northern Africa has been greatly improved under selection. This plant was originally a native of Tropical America, but has been long grown in gardens of Spain, Italy, Morocco and

Algiers, and the yellow and red "figue de barbare" may often be found in the Paris markets.

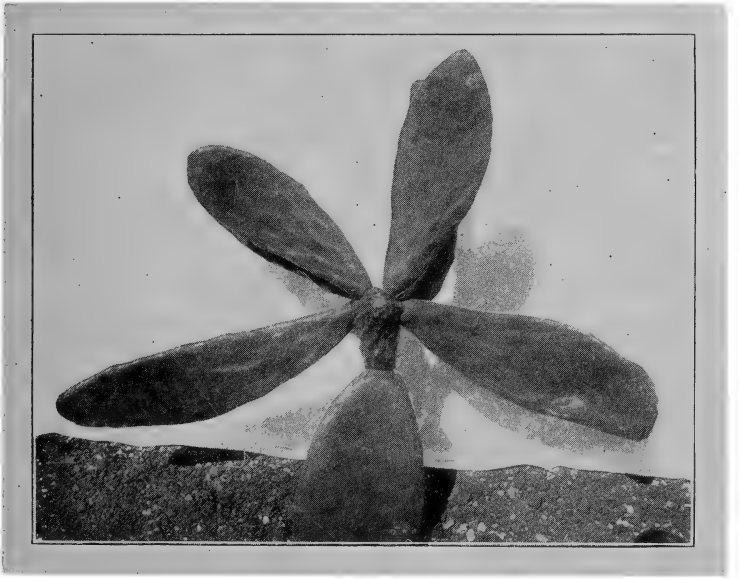
BED OF SEEDLINGS FROM SPINELESS CACTUS, SHOWING HERE AND THERE REVERSION TO THE ORIGINAL SPINOUS FORM..

Burbank has now (1908) when this interpolated page is written, upwards of 500 kinds of edible cactus, with fruit yellow, crimson and



EDIBLE CACTUS OR "BARBARY FIG" *(Opuntia ficus-indica)* FROM MALTA.

green, some with the flavor of Rockford canteloupe, others with the characteristic quality of peach, plum and pomegranate. These fruits are

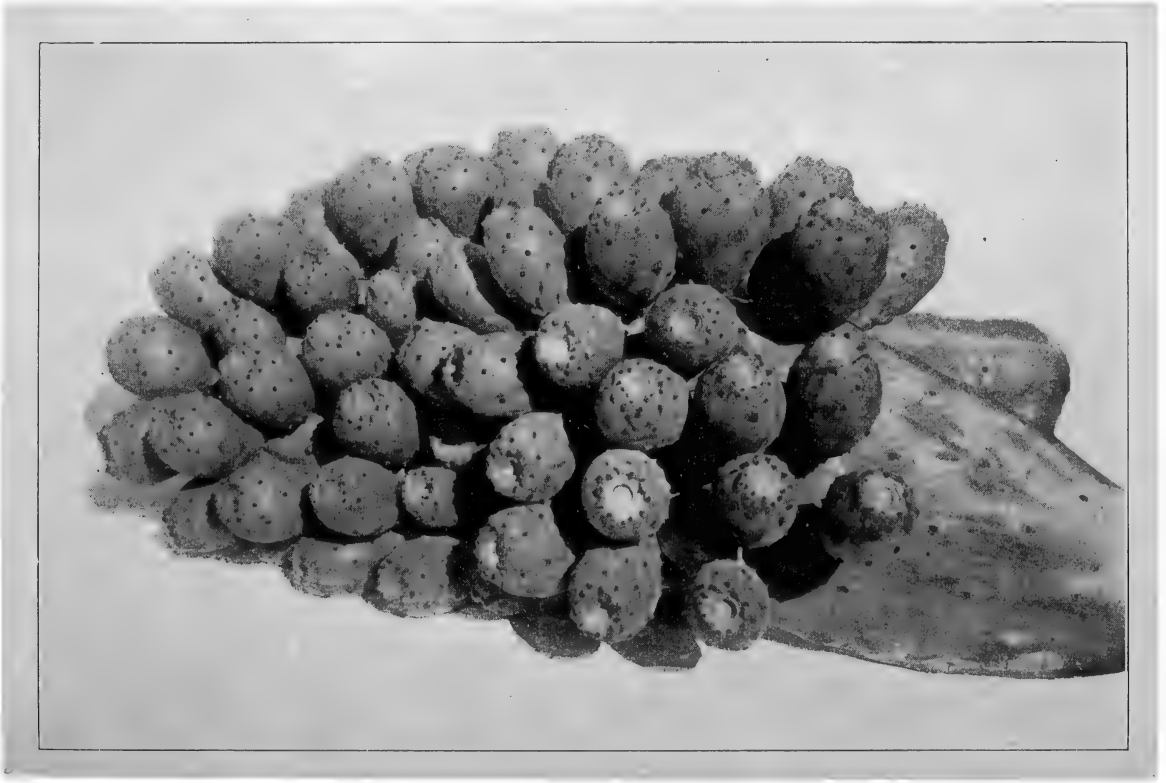


THORNLESS OPUNTIA, WITH JOINTS GROWING OUT FROM THE FRUIT.

extremely grateful to the palate. They are borne in enormous profusion. They are ripe at all times of the year, and they bear transportation

perfectly. All they lack is a reduction in the too large number of the small and stony seeds. When this change is made as can be readily done in a few more selected crossings, no fruit of California shows so much promise as this. As every new seedling is a new variety as is the case with the apple and the potato there is no visible limit to the possible range of improvement in the flavor of fruit or in abundance of desired crop. 'The dehorning' of the cactus is perhaps economically Mr. Burbank's greatest achievement. Next to this in time will rank the enlargement and perfection of the cactus fruit.

The Bartlett plum is a remarkable creation. A plum in all respects, but with the exact flavor of a Bartlett pear, and the same granular texture. The 'rice seed' plum has extremely small seeds. The stoneless plum is a cross of the French prune with a wild plum having the stone almost eliminated by a fortuitous variation. The result thus far is a great number of stoneless plums of good size, but in flavor inferior to the best cultivated ones.



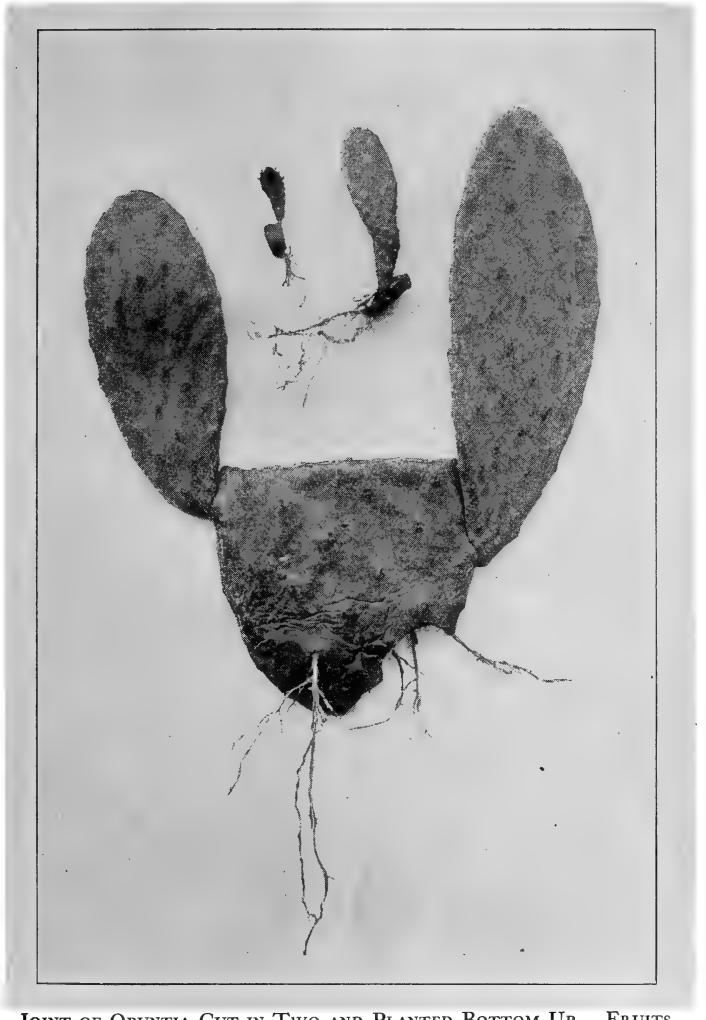
TWO JOINTS OF OPUNTIA, EACH WITH FIFTEEN POUNDS FRUIT, EACH TWO YEARS OLD.

These are being crossed again to improve the flavor, and new selections made.

Crossing the Japan and the New England chestnut (*Castanea japonica* and *C. americana*), the trees, leaves, growth and nuts are midway; second generation and later generations as usual show more varied combinations and variations. To breed the burrs off from chestnuts is dangerous, because it allows the birds to get in at the nuts. The burr is originally intended to keep off the birds. In developing his perfect variety of the Persian (often called English) walnut (*Juglans regia*), the shell was made too thin, so that the birds could break in. It was necessary to make new selections and crossings to thicken the shell and still retain its other superior qualities.

The Pierce grape was a bud sport from the Isabella, producing much larger fruit. This bud sport remains constant. All the seedlings even from it are similar to the Pierce grape, following the bud sport (*Pierce*) and not reverting to the real parent form of the Isabella. Some ripen

early, some late; some are pale, and some are black; but all resemble the Pierce more than the Isabella. Cultivating a choke cherry, the seeds all from one parent tree, many variations are found, although the soil in which they are placed is uniform. Among them was found one variant less bitter than usual; others earlier or later ripening and with larger or smaller fruit or leaves, and an almost bewildering number and variety of other variations. A peach-almond cross often develops a tree as large as ten peach trees or almond trees of the same age. Sometimes a similar cross with different individuals of the same species will produce opposite or totally different results, owing to past heredity, either recent or far back. Crosses are sometimes more vigorous than either parent and more than any descendant, but other cases are just the reverse. The more variant crosses are often less vigorous, and sometimes yield seedlings that can not exist. Sometimes all die in the fruiting season. A peach named 'Quality' is one of the best peaches extant — a cross of the Muir and



JOINT OF OPUNTIA CUT IN TWO AND PLANTED BOTTOM UP. FRUITS OF OPUNTIA, THE LARGER PLANTED BOTTOM UP.

the Crawford. A cross of the nectarine and peach also produces variant types of value. In some hybrids of petunia and tobacco, the roots fail while the tops may be of unusual vigor. These individuals can only be kept alive for any length of time by grafting, another instance — if other were needed — of the parallelism of crossing and grafting.

"A character may be latent through many generations or centuries, appearing when the right cross brings it out, or it may appear under especially favorable or peculiar conditions of growth."

The essential of Burbank's method may be here briefly restated. In the formation of all races or breeds of animals or plants we may have the following stages :—

1. Unconscious selection with more or less complete isolation of the chosen forms.

2. Conscious selection of the most desirable individuals.

3. Conscious selection directed towards definite or special ends.

4. Crossing with other races or other species, to increase the range of variation or to add or combine certain desirable qualities or to eliminate others which are not desirable. This must be accompanied by segregation or isolation, and it must be followed by conscious selection which must be directed towards definite end. On this last series of processes all animal breeding and all plant breeding as a fine art must depend.

In the beginning men were satisfied with strawberries as strawberries. If they transplanted them, they took what they found. Later the best strains were kept together, and at last through purposeful crossing, the fine art of making new kinds of strawberries was developed. The same method applies to any plant or animal. It might apply to man if selection and segregation were part of our scheme of society. Unfortunately for this plan, the best cannot be selected or segregated, fortunately, perhaps, as the control of one's own affairs develops man's best quality, personal initiative. In that regard, freedom may be a

better end in human development than any type of physical perfection.

According to Burbank, "the facts of plant life demand a kinetic theory of evolution, a slight change from Huxley's statement that 'matter is a magazine of force,' to that of matter being force alone. The time will come when the theory of ions will be thrown aside and no line left between force and matter. We can not get the right perspective in science unless we go beyond our senses. A dead material universe moved by outside forces is in itself highly improbable, but a universe of force alone is probable, but requires great effort to make it conceivable, because we must conceive it in the terms of our sense experience."

Whether we accept this or not, whether or not indeed we can conceive what it means, this view of life, which Burbank shares with many other philosophers, opens to us many new vistas of thought, and what means more for the progress of knowledge, it suggests to us many new avenues of experimentation.

Some Experiments by Luther Burbank

Luther Burbank, while primarily an artist, is, in his general attitude, essentially a man of science. Academic he doubtless is not, but the qualities we call scientific are not necessarily bred in the academy. Science is human experience tested and set in order. Within the range of his profession of moulding plant life, Mr. Burbank has read carefully, and thought carefully, maturing his own generalizations and resting them on the basis of his own knowledge. Within the range of his own experience he is an original and logical thinker, and his conclusions are in general most sound. He is not a physiologist, still less a histologist, and the phenomena of heredity as shown in cell-division and cell-multiplication, he has not studied for himself. The researches of Weismann and those suggested by his theories of heredity Burbank has given little attention to, and he has, therefore, a confidence in the inheritance of acquired characters, such as effects of environment, which most biologists of today do not share. On the other hand, many of the best of them would

fully agree with Burbank. In his field of the application of our knowledge of heredity, selection, and crossing to the development of plants, he stands unique in the world. No one else, whatever his appliances, has done as much as Burbank, or disclosed as much of the laws governing these phenomena. Burbank has worked for years alone, not understood and not appreciated, at a constant financial loss, and for this reason—that his instincts and purposes are essentially those of a scientific man, not of a nurseryman or even of a horticulturist. To have tried fewer experiments and all of a kind likely to prove economically valuable, and finally to have exploited these as a nurseryman, would have brought him more money. In his own way, Burbank belongs in the class of Faraday and the long array of self-taught great men who lived while the universities were spending their strength on fine points of grammar and hazy conceptions of philosophy. His work is already an inspiration to botanists as well as horticulturists, opening a new line of search in

heredity, as well as a new field for economic advance. Already his methods are yielding rich results in the hands of others. We shall by such means find much more than we now know of the evolution of organisms, while the improvement of organisms for the use and pleasure of man is yet in its infancy.

Scientific men belong to many classes; some observe, some compare, some think, and some carry knowledge into action. There is need for all kinds and a place for all. With a broader opportunity, Burbank could have done a greater variety of things and touched life at more points; but, at the same time, he would have lost something of his simple intensity and fine delicacy of touch — things which schools do not always give and which too much contact with men sometimes takes away.

Great men are usually men of simple, direct sincerity of character. These marks are found in Burbank. As sweet, straightforward, and as unspoiled as a child, always interested in the

phenomena of Nature, and never seeking fame or money or anything else for himself. If his place is outside the temple of science, there are not many of the rest of us who will be found fit to enter.

Eleagnus longipes, JAPANESE GOUMBERRY, IMPROVED BY SELECTION.

Scientific Aspects of Luther Burbank's Work

By Vernon Lyman Kellogg

Vernon Lyman Kellogg

R. BURBANK has so far not formulated any new or additional laws of species-change, nor do his observations and results justify any such formulation, and we may rest in the belief that he has no new fundamental laws to reveal. He has indeed the right to formulate, if he cares to, some valuable and significant special conclusions touching certain already recognized evolution factors, in particular, the influence on variability of the two long-known variation-producing factors of hybridization and modification of environment. His reliance on the marked increase in variability to be got after a crossing in the second and third generations over that obvious in the first will come as a surprise to most men first getting acquainted with his work. He has got more starts for his new things from these generations than in any other way. He is wholly clear and convinced in his own mind as to the inheritance of acquired characters; 'acquired characters

are inherited or I know nothing of plant life,' he says; and also convinced that the only unit in organic nature is the individual, not the species; that the so-called species are wholly mutable and dependent for their apparent fixity solely on the length of time through which their so-called phyletic characters have been ontogenetically repeated. He does not agree at all with de Vries that mutations in plants occur only at certain periodic times in the history of the species, but rather that, if they occur at all, they do so whenever the special stimulus derived from unusual nutrition or general environment can be brought to bear on them. He finds in his breeding work no prepotency of either sex as such in inheritance, though any character or group of characters may be prepotent in either sex. He believes that no sharp line can be drawn between the fluctuating or so-called Darwinian variations and those less usual, large, discontinuous ones called sports. Ordinary fluctuating variation goes on under ordinary conditions of nutrition, but with extraordinary envir-

onmental conditions come about extraordinary variation results, namely, discontinuous, sport or mutational variation. These variations are the effects of past environment also, having remained latent until opportunity for their development occurs. Starvation causes reversions, but reversions can also be produced by unusually rich nutrition. New variations are developed most often, as far as environmental influences go, by rich soil and generally favorable conditions. So-called new qualities are usually, if not always (the fact may sometimes not be obvious), simply new combinations of old qualities, both latent and obvious. To get a new and pleasing odor it may often be sufficient simply to lose one bad element in an old odor. So one might go on for some pages with specific conclusions or deductions reached by Burbank on a basis of experience. But it is true that he has at his command the knowledge of no new fundamental scientific principles to give him advantage over us. And yet none of us has done what Burbank has been able to do, although many

of us have tried. What then is it that Burbank brings to his work of modifying organisms swiftly and extremely and definitely that others do not?

To answer this it will be advisable to analyze, in general terms, at least, the various processes which either singly, or in combinations of two or three, or all together, are used by Mr. Burbank in his work. We may roughly classify these processes and means. First, there is the importation from foreign countries, through many correspondents, of a host of various kinds of plants, some of economic value in their native land and some not, any of which grown under different conditions here may prove specially vigorous or prolific or hardy, or show other desirable changes or new qualities. Among these importations are often special kinds particularly sought for by Burbank to use in his multiple hybridizations; kinds closely related to our native or to already cultivated races which, despite many worthless characteristics, may possess one or more particular, valuable ones needed to be added to a race already

useful to make it more useful. Such an addition makes a new race.

Second, the product of variations, abundant and extreme, by various methods, as (*a*) the growing under new and, usually, more favorable environment (food supply, water, temperature, light, space, etc.) of various wild or cultivated forms, and (*b*) by hybridizations between forms closely related, less closely related and, finally, as dis-similar as may be (not producing sterility), this hybridizing being often immensely complicated by multiplying crosses, *i. e.*, the offspring from one cross being immediately crossed with a third form, and so on. These hybridizations are made sometimes with very little reference to the actual useful or non-useful characteristics of the crossed parents, with the primary intention of producing an unsettling or instability in the heredity, of causing, as Burbank sometimes says, 'perturbation' in the plants, so as to get just as wide and as large variation as possible. Other crosses are made, of course, in the deliberate attempt to

blend, to mix, to add together, two desirable characteristics, each possessed by only one of the crossed forms. Some crosses are made in the attempt to extinguish an undesirable characteristic.

Third, there is always immediately following the unusual production of variations, the recognition of desirable modifications and the intelligent and effective selection of them, *i. e.*, the saving of those plants to produce seed or cuttings which show the desirable variations and the discarding of all the others. In Burbank's gardens the few tenderly cared for little potted plants or carefully grafted seedlings represent the surviving fittest, and the great bonfires of scores of thousands of uprooted others, the unfit, in this close mimicry of Darwin and Spencer's struggle and survival in nature.

It is precisely in this double process of the recognition and selection of desirable variations that Burbank's genius comes into particular play. Right here he brings something to bear on his work that few other men have been able to do.

It is the extraordinary keenness of perception, the delicacy of recognition of desirable variations in their (usually) small and to most men imperceptible beginnings. Is it a fragrance that is sought? To Burbank in a bed of hundreds of seedling walnuts scores of the odors of the plant kingdom are arising and mingling from the fresh green leaves, but each, mind you, from a certain single seedling or perhaps from a similar pair or trio. But to me or to you, until the master prover points out two or three of the more dominant single odors, the impression on the olfactories is simply (or confusedly) that of one soft elusive fragrance of fresh green leaves. Similarly Burbank is a master at seeing, and a master at feeling. And besides he has his own unique knowledge of correlations. Does this plum seedling with its score of leaves on its thin stem have those leaves infinitesimally plumper, smoother or stronger, or with more even margins and stronger petiole or what not else, than any other among a thousand similar childish trees? Then it is saved, for it will

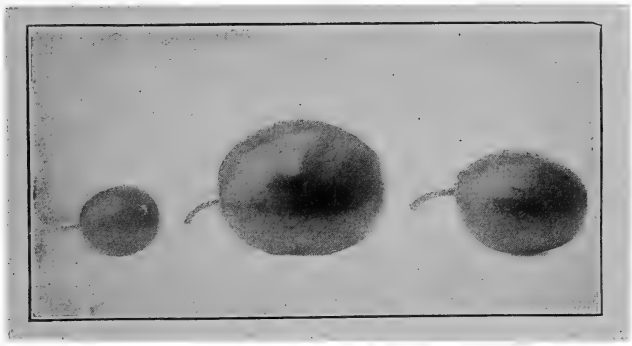
bear a larger, or a sweeter, or a firmer sort of plum, or more plums than the others. So to the bonfires with the others and to the company of the elect with this 'fittest' one. Now this recognition, this knowledge of correlations in plant structure, born of the exercise of a genius for perceiving through thirty years of opportunity for testing and perfecting it, is perhaps the most important single thing which Burbank brings to his work that other men do not (at least in such unusual degree of reliability). Enormous industry, utter concentration and single-mindedness, deftness in manipulation, fertility in practical resource, has Burbank — and so have numerous other breeders and experimenters. But in his perception of variability in its forming, his recognition of its possibilities of outcome, and in his scientific knowledge of correlations, a knowledge that is real, for it is one that is relied on and built on, and is at the very foundation of his success, Burbank has an advantage of true scientific character over his fellow workers, and in it he makes

a genuine contribution to scientific knowledge of plant biology, albeit this knowledge is so far only proved to be attainable and to exist. It is not yet exposed in its details and may never be, however unselfish be the owner of it. For the going to oblivion of scientific data of an extent and value equivalent, I may estimate roughly, to those now issuing from any half dozen experimental laboratories of variation and heredity, is the crying regret of all evolution students acquainted with the situation. The recently assumed relations of Mr. Burbank to the Carnegie Institution are our present chief hope for at least a lessening of this loss.

HYBRID WALNUT "PARADOX," *Juglans regia* AND *J. Californica*. EACH ONE YEAR OLD, SAME PARENTS AND SAME NURTURE. ONE 500 SIZE OF OTHER.

But let us follow our saved plum seedling. Have we now to wait the six or seven years before a plum tree comes into bearing to know by actual seeing and testing what new sort of plum we have? No; and here again is one of Burbank's contributions (not wholly original to be sure, but original in the extent and perfection of its development) to the scientific aspects of plant-breeding. This saved seedling and other similar saved ones (for from the examination of 20,000 seedlings, say, Burbank will find a few tens or even scores in which he has faith of reward) will be taken from their plots and grafted on to the sturdy branches of some full-grown vigorous plum tree, so that in the next season or second next our seedling stem will bear its flowers and fruits. Here are years saved. Twenty, forty, sixty, different seedlings grafted on to one strong tree (in a particular instance Burbank had 600 plum grafts on a single tree!); and each seedling-stem certain to bear its own kind of leaf and flower and fruit. For we have long known that the scion is not materially influenced

by the stock nor the stock by the scion; that is not modified radically, although grafting sometimes increases or otherwise modifies the vigor of growth and the extent of the root system of the stock.



ONE OF THE STONELESS PLUMS (CENTER) AND TWO OF ITS PARENTS. On the right hand is the common French prune.

If now the fruit from our variant seedling is sufficiently desirable; if it produces earlier or later, sweeter or larger, firmer or more abundant, plums, we have a new race of plums, a 'new creation' to go into that thin catalogue of results. For by simply subdividing the wood of the new branch, *i. e.*, making new grafts from it, the new plum can

be perpetuated and increased at will. Simple, is it not? No, it is anything but that in the reality of doing it; but in the scientific aspects of it, easily understandable.

Perhaps it may not be amiss to call attention to what must be the familiar knowledge of most of us, and that is the fact that many (probably most) cultivated plants must be reproduced by division, that is by cuttings, buds or grafts, and not by seeds, in order to grow 'true.' For a piece of a cultivated plant will grow out to be very much like the individual it was cut from, but the seeds will not, in most cases, reproduce faithfully the parents, but will produce a very variable lot of individuals, most of them strongly reversionary in character. Grow peach trees from the stones of your favorite peach and see what manner of peaches you get; but if you want to be sure of more peaches like the ones you enjoy, graft scions from your tree on to other trees. Indeed one of the plant-breeder's favorite methods of making a start for new things, of getting the requisite beginning wealth and

eccentricity of variation, is to grow seedlings, especially from cross-bred varieties. Burbank will

ZEA MAYS, (CUZCO CORN). PARENT OF INDIAN CORN. Female flower at base of each tassel and protected by a leaf. Male flower below; this prevents self fertilization.

give you a thousand dollars for a pinch of horse-radish seed. Sugar-cane seed is needed. The amelioration of many kinds of fruit and flowers and

vegetables is checked, because in our carelessness we have allowed these kinds to get into that condition of seedlessness which almost all cultivated races tend toward when grown from cuttings. In our oranges and grape-fruit and in a score of other fruits, the elimination of seeds is exactly one of the modifications we have bred and selected for, in order to make the fruits less troublesome in their eating. But when we lose the seeds entirely of a whole group of related plant kinds we may find ourselves, as we have found ourselves actually in many cases, at the end of our powers of amelioration of these plant sorts. Burbank believes that the very fact that plants when grown asexually always sooner or later lose their power to produce seeds is almost sufficient proof (if such proof is needed) that acquired characters are transmitted.

Another of Burbank's open secrets of success is the great range of his experimentation — nothing is too bold for him to attempt, the chances of failure are never too great to frighten him. And another secret is the great extent, as regards

material used, of each experiment. His beds of seedlings contain hundreds, often thousands, of individuals where other men are content with hun-

LEAVES OF HYBRID BLACKBERRY PLANTS OF THE SAME PARENTAGE

dreds. Another element in his work is his prodigality of time. Experiments begun twenty years ago are actually still under way.

In all that I have so far written, I have purposely kept to general statements applicable to Burbank's work as a whole. My readers might

be more interested, perhaps, to have some illustrations of the application of various processes of making new sorts of things, some analytical account of the history of various specific 'new creations,' but considerations of space practically forbid this. Just a few briefly described examples must suffice. More than is generally imagined, perhaps, Burbank uses pure selection to get new things. From the famous golden orange colored California poppy (*Escholtzia*) he has produced a fixed new crimson form by selection alone. That is, noticing, somewhere, sometime, an Escholtzia individual varying slightly redder, he promptly took possession of it, raised young poppies from its seeds, selected from among them those varying in a similar direction, raised new generations from them and so on until now he who wishes may have his California poppies of a strange glowing crimson for the price of a little package of seed, where formerly he was perforce content with the golden orange. For me the golden orange suffices, but that does not detract from my eager

in terest in the flower-painting methods, of Mr. Burbank. Even more striking a result is his blue Shirley poppy, produced also solely by repeated

Hybrid Chestnut in Fruit, Six Months Old.

selection from the crimson field poppy of Europe. "We have long had various shades of black and crimson and white poppies, but no shade of blue. Out of 200,000 seedlings I found one showing a faintest trace of sky blue and planted the seed from

it, and got next year one pretty blue one out of many thousand, and now I have one almost pure blue."

But another brilliant new poppy was made in a different way. The pollen of *Papaver pilosum*, a butter-colored poppy, was put on the pistils of the Bride, a common pure white variety of *Papaver somniferum* (double), and in the progeny of this cross was got a *fire-colored single* form. The character of singleness was common to the ancestors of both parents, the character of fire color in the lineage of *somniferum* only, although the red of the new form is brighter than ever before known in the somnifera series. Both characteristics were absent (or rather latent) in both parents. And yet the perturbing influence of the hybridization brought to the fore again these ancestral characters. The foliage of this fire poppy is intermediate in type between that of the two parents.

The history of the stoneless and seedless plum, now being slowly developed by Burbank, shows an interesting combination of selection, hybridization

and reselecting. Mr. Burbank found a plum in a small wild plum species with only a part of a stone.

California Poppy (*Eschscholtzia*) Rendered Bright Crimsonas a Result of Selection only, without Crossing.

He crossed this wild species with the French prune; in the first generation he got most individuals with whole stones, some with parts of a stone, and even some with no stone. Through

three generations he has now carried his line by steadily selecting, and the percentage of no-stone fruits is slowly increasing, while quality, beauty and productiveness are also increasing at the same time.

The plum-cot is the result of crossing the Japanese plum and the apricot. The plum-cot, however, has not yet become a fixed variety and may never be, as it tends to revert to the plum and apricot about equally, although with also a tendency to remain fixed, which tendency may be made permanent.

Most of Burbank's plums and prunes are the result of multiple crossings in which the Japanese plums have played an important part. Hundreds of thousands of seedlings have been grown and carefully worked over in the twenty years of experimenting with plums, and single trees have been made to carry as many as 600 varying seedling grafts. The Bartlett plum, cross of the bitter Chinese Simoni and the Delaware, itself a Simoni hybrid, has the exact fragrance and flavor of the

Bartlett pear. The Climax, a successful shipping plum, is also a cross of the Simoni and the Japan-

Rhodanthe naglesi, A ROSE-COLORED EVERLASTING FLOWER IMPROVED IN SIZE AND COLOR BY SELECTION ONLY.

ese triflora. This Chinese Simoni produces almost no pollen, but few grains of it ever having been obtained. But these few grains have enabled Burbank to revolutionize the whole plum shipping

industry. The sugar prune, which promises to supplant the French prune in California, is a selected product of a second or third generation variety of the Petite d'Agen, a somewhat variable French plum.

Next in extent probably to Burbank's work with plums and prunes is his long and successful experimentation with berries. This has extended through twenty-five years of constant attention, has involved the use, in hybridizations, of forty different species of *Rubus*, and has resulted in the origination of a score of new commercial varieties, mostly obtained through various hybridizations of dewberries, blackberries and raspberries. Among these may specially be mentioned the Primus, a hybrid of the western dewberry (*R. ursinus*) and the Siberian raspberry (*R. cratægifolius*), fixed in the first genereration, which ripens its main crop before most of the standard varieties of raspberries and blackberries commence to bloom. (Mr. Burbank does not recommend this for general cultivation; the 'Phenomenal' and Himalaya are better.)

In this Primus berry, we have the exceptional instance of a strong variation, due to hybridization,

Heuchera Leaves made Crested by Selection of Varying Seedlings.

breeding true from the time of its first appearance. It usually takes about six generations to fix a new variety, but like de Vries's evening primrose mutations, the Primus berry is a fixed new form from

the time of its beginning. An interesting feature of Mr. Burbank's brief account, in his 'New Creations' catalogue of 1894, of the berry experimentation, is a reproduction of a photograph showing "a sample pile of brush 12 ft. wide, 14 ft. high, and 22 ft. long, containing 65,000 two and three-year-old seedling berry bushes (40,000 blackberry × raspberry hybrids and 25,000 Shaffer × Gregg hybrids) all dug up with their crop of ripening berries." The photograph is introduced to give the reader some idea of the work necessary to produce a satisfactory new race of berries, "Of the 40,000 blackberry × raspberry hybrids of this kind 'Phenomenal' is the only one now in existence. From the other 25,000 hybrids, two dozen bushes were reserved for further trial."

An astonishing result of the hybridization between the black walnut, *Juglans nigra*, used as the pistillate parent, and the California walnut, *J. californica*, staminate parent, are walnut trees which grow with such an amazing vigor and rapidity that they increase in size at least twice as fast as the

combined growth of both parents. Many tremendous growers are got in the first generation, but in the second there are included some of the most rapidly growing trees, perhaps, in the world. This hybrid has clean-cut, glossy bright green leaves from two to three feet long with a sweet odor like that of apples, but it produces few nuts. Curiously enough the result of hybridization by using the pollen of *nigra* on pistils of *californica* produces in abundance large nuts of a quality superior to that possessed by either parent.

The famous Shasta daisy is the result of a multiple crossing between an American and a European species of field daisy and then between these hybrids and a Japanese form. The fragrant calla, known as 'Fragrance,' is decended from a single individual found by Burbank while critically examining a block of Little Gem calla seedlings. He was surprised in this examination by a fragrance resembling that of violets or water-lillies; as he had long been seeking a fragrant calla, the individual giving this perfume was carefully handed out.

No farther selecting was done; this plant was the single ancestor of the fragrant new race.

And so one might go on for pages, but with slight variations in detail all these pages would tell only the same story: the stimulating or inducing of variability by environmental influences and by hybridizations; the search after, and keen recognition of, promising special variations; the selection of the plants showing these variations; rearing new generations from them, repeated selection, and new hybridizations to eliminate this characteristic or introduce that, and on until a desirable combination is found. Then the careful fixing of this form or type by repeated selection through several generations.

But an end must be made of this. Let us, in a paragraph, simply sum up the essential things in the scientific aspects of Burbank's work. No new revelations to science of an overturning character; but the revelation of the possibilities of accomplishment, based on general principles already known, by an unusual man. No new

laws of evolution, but new facts, new data, new canons for special cases. No new principle or process to substitute for selection, but a new proof of the possibilities of the effectiveness of the old principle. No new categories of variations, but an illuminating demonstration of the possibilities of stimulating variability and of the reality of this general variability as the fundamental transforming factor. No new evidence either to help the Darwinian factors to their death-bed, or to strengthen their lease on life; for the 'man' factor in all the selecting phenomena in Burbank's gardens excludes all 'natural' factors. Here are some of Burbank's own words, touching these matters that scientific men are particularly interested in, in his work:

"All scientists have found that preconceived notions, dogmas, and all personal prejudice must be set aside, listening patiently, quietly and reverently to the lessons one by one which mother nature has to teach, shedding light on that which before was a mystery, so that all who will may see and know.

"Crossing gives the raiser of new plants the only means of uniting the best qualities of each, but just as often the worst qualities of each are combined and transmitted, so that to be of any value it must be followed by rigid and persistent selection, and in crossing, as in budding and grafting, the affinities can only be demonstrated by actual test.

"All wild plants of any species are under almost identical environments, having their energies taxed to the utmost in the fierce struggle for existence. Any great variation under such circumstances is not likely to occur, and is much more likely to be stamped out at once by its struggling competitors, unless the variation should be of special use in competition, in which case it will survive, and all others may be supplanted by it. Thus we see how new species are often produced by nature, but this is not her only mode. Crosses and hybrids are very often found growing wild where two somewhat similar species grow contiguous, and if the combination happens to be a useful one, as it

often does, the new creation is encouraged by nature; then time and environment fix it, and man comes on the scene, perhaps ages later, and discovers it, and, not knowing all the facts, wonders where the connecting links have gone. It is botanically classified as a new species, which it is most certainly.

"In cultivated plants the life struggle is removed, and here we find variation almost the rule rather than the exception.

"Varieties are the product of fixed laws, never of chance, and with a knowledge of these laws we can improve the products of nature, by employing nature's forces, in ameliorating old or producing new species and varieties better adapted to our necessities and tastes. Better food, more sunshine, less arduous competition, will of themselves induce variation in individual plants which will be more or less transmitted to their seedlings, which, selected consecutively through a certain number of generations, will become permanent. Environment here exerts an influence as in all chemical cosmical

and celestial movements. These small increments from environmental forces may produce a gradual or sudden change according to circumstances. The combustion of food liberates the moving force, environment guides it as it does the planets.

"When once the persistent type is broken up, old latent forces may be liberated and types buried in the dim past reappear. This, called atavism, is a concentration of ancestral forces — reverberating echoes — from varieties long since passed away, exhibiting themselves when from some cause, for instance crossing, present forces are in a state of antagonism, division, perturbation or weakness. These echoes, if collected by crossing and section, produce combinations of superlative importance and value."

Finally, in any summation of the scientific aspects of Burbank's work must be mentioned the hosts of immensely valuable data regarding the inheritance of characteristics, the influence of epigenetic factors in development, the possibilities of plant variability, and what not else important

to evolution students, mostly going unrecorded, except as they are added in mass to the already too heavy burden carried by the master of the laboratory, and as they are summed up in those actual results which the world gratefully knows as Burbank's 'new creations.'