Seedling Red Leaved Plum

One of the most striking of plum seedlings, being the result of Kelsey, Cerasifera, and Triflora crosses. The magnificent reds of leaves and fruit make a strikingly handsome and effective combination that is as pleasing as it is unusual.

New Plums and Prunes in The Process of Making

Some Suggestions on Which Others May Build

On one occasion a nurseryman who had bought a number of fruit trees from me stopped before a tree in my orchard and tasted the fruit with the air of an expert.

"That's the best plum I ever tasted," he said, as he looked at the tree with admiring eyes. "At last you have a perfect plum. It has just the right amount of fruit on it; the taste is perfect! Sell me that tree and I will make a fortune from it."

"It's not for sale," I was compelled to answer.

Thinking I wanted a fancy price, he started to figure what he could pay.

I interrupted to tell him the faults of the fruit. It could not be shipped; it would not bear with any degree of certainty. He had chanced to see the tree on the very day in the year when it was on exhibition at its best. We had had a week of cool weather and all the plums had ripened slowly together on the tree; they had responded to ideal weather—and produced a beautiful fruit of superior flavor. But conditions are not always ideal by any manner of means—and this plum could not stand adversity.

The next year the would-be purchaser saw the same tree—coming, in fact, for the further observation of it—and found the fruit worthless. For three days we had had unusually warm weather, and the fruit lacked quality. My estimate of it had been verified.

I tell the anecdote to illustrate the need of caution in judging a new fruit. The work is not over when the plum is produced; the fruit must be tested under varying conditions and in successive seasons.

But, of course, there is no great difficulty in applying the final tests. That requires only patience and open mindedness. The real difficulties were encountered at an earlier stage of the experiment.

What some of these difficulties are, and how they may be overcome, will be told in the succeeding pages. We have considered the ideal plum somewhat attentively from the standpoint of marketman and consumer. Let us now regard the same subject from the standpoint of the orchardist and plant developer.

The first step in plum improvement obviously involves propagation by seeds. In my own work great effort is made to secure seed of the best varieties at the outset.

As we have seen, seedlings from cultivated fruits always show a wide range of variation. Such variations offer opportunity for selection.

An Outline of Methods

The simplest method of working for improvement is to select the best seedlings thus obtained, without attempting pollenizing experiments.

An extension of the method calls for cross fertilization within the species—followed, of course, by selection.

A yet bolder method, and one calling for much more time in the work of selection, may be used—that of hybridizing individuals of different species.

Finally the method may be so elaborated that several of the best varieties of different species are intercrossed to form new varieties. The plum "Combination," as an instance, combines the characteristics of three widely varying species and of numerous varieties within these species. Most of my recent plums carry the strains of many diverse species.

This perfected method has been little used by other plant originators, but its practicality and value are demonstrated in my orchards.

The wide range of results attainable when these methods are used is shown by the fact that I now have plums the flavor of which is very similar to the following fruits: peach, apricot, apple, pear, lemon, orange, banana, pineapple, and berries of various kinds.

In addition to these, there are flavors that cannot be described because they are unique—due to new combinations or blends.

Although the flavor of a fruit is only one of its important attributes, it sometimes determines the value or lack of value of a new variety, and it is always an important factor. In many cases I have produced new varieties of plums which were good in every respect except the flavor, and because of this one defect they were destroyed.

Plums in my present colony are of every imaginable color and quality and ripen at all seasons from the earliest to the latest. Some trees have green foliage and some have purple. The trees also differ in growth in almost every imaginable way. Some are adapted to cold climates, some only to warm. Some require much moisture. Some will thrive under semi-arid conditions. A few give promise of being adapted to such a variety of climates that—like the Burbank plum—they may be grown practically throughout the plum-growing regions of the world.

The Egg Bartlett Plum

This is one of Mr. Burbank's most interesting plum developments, in that the fruit has the characteristic flavor of the Bartlett pear. It furnishes a curious illustration of anomalies that may result from crossbreeding. A plum with the flavor of the pear is a very curious product.

And the explanation of this diversity is found in the wide range of ancestral strains that have been blended to produce this versatile company.

Europe, Asia and America have furnished the foundation materials upon which have been built the sixty-two varieties of plums, prunes, and plumcots that have already been sent out from my experiment grounds since the first importation of Japan plums in 1885.

The Asiatic plums have been the most used, thirty-eight of the varieties introduced being developed from them.

Fourteen introductions were developed from American, and thirteen from European species.

Native Raw Materials

A good deal has been said in earlier chapters of the influence of foreign blood in our plum family. Let us now give recognition to the contributions of the native stock.

The native plums of America, although usually of a good flavor, are not nearly as large as the Asiatic species, and usually not as large as the American cultivated plums, and no larger than the wild ones from Europe.

But they possess the important characteristic of hardiness. For this reason, it has been necessary to use them in many cases to combine with more tender species in order that the new varieties might become standards in the colder sections of the United States and other countries.

Six important American species have been used in these experiments: They are known as the American plum (*Prunus Americana*), the Wild-Goose plum (*P. hortulans*), the Chickasaw plum (*P. angustifolia*), the Western Sand Cherry (*P. Bessevi*), the Beach plum (*P. maritima*), and the California wild plum (*P. subcordata*).

These were the native wild plums of the middle western states and the Rocky Mountains south to the Gulf of Mexico. Most of them are unusually hardy. Cold does them no harm even in the northermost part of the central division of the United States.

As to quality of fruit, these wild plums differ, but all have attractive flavors, and these flavors have been blended variously in no fewer than eleven new varieties that I have thought worthy of introduction.

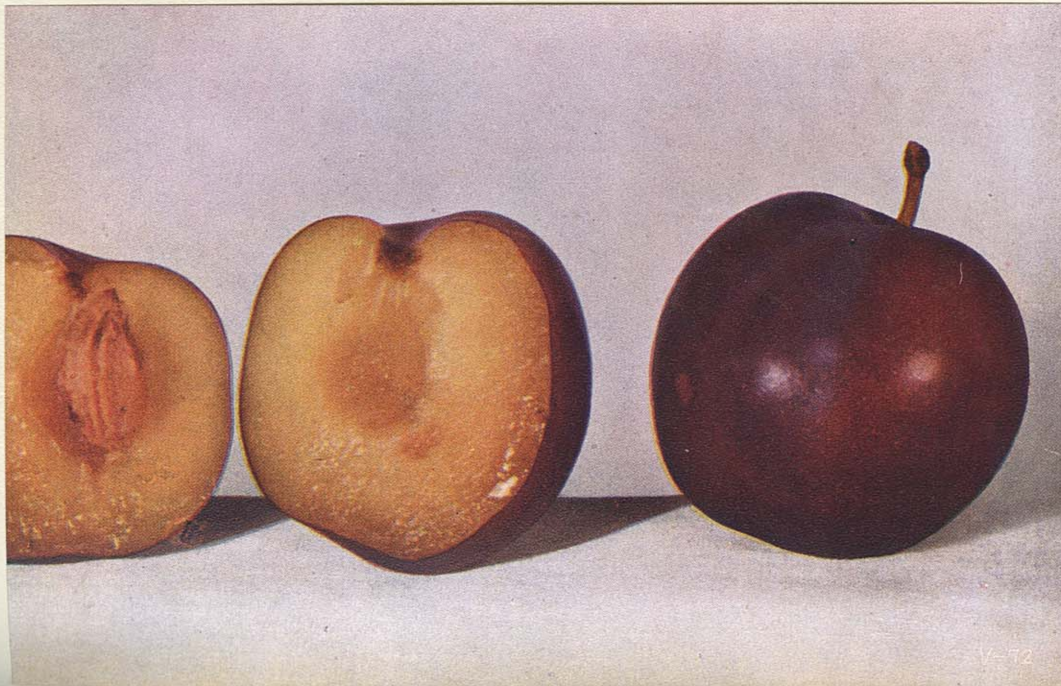
Anyone who has experienced the delightful flavor of my plums, Gold, Shiro, Geewhiz, Duarte, or America, will be interested to know that these new varieties (along with seven others) are American plums, reconstructed through combination with other species, but owe their flavor largely to their wild American ancestors.

To develop the earliest plum in existence from six species of later plums seems an impossibility. Yet this is what happened when the Wild-Goose type was combined with five other late-ripening species. The plum introduced from this complex combination has been aptly named "First." It was the *first* introduced variety in the making of which the Wild-Goose had a part, and the *first* plum to ripen of all those grown in California at the time of its introduction in 1901.

If the Wild-Goose plum is mentioned, the Chickasaw should not be overlooked; for although it has not served in the production of any introduced varieties, its hardiness has contributed valuable attributes to many varieties still in the proving orchard.

But perhaps the greatest interest attaches to the story of the little Beach plum. In its wild state this is not much sought; for its fruit varies from the size of a large pea to that of a small hazel-nut, and it is inedible unless cooked. Yet this little plum has some flavor; it makes preserves of delicious quality.

The results produced on my grounds with this species are so important as to indicate that the Beach plum is highly valuable to use in the development of new plums for cold climates. I have produced four important varieties in which it is one of the parents.



June 25th Plum Fruits

This is a crossbred Japanese plum that fruits a month before ordinary plums. It has the further interest of being one of the few Japanese plums approaching the freestone character. The habit of ripening its fruit in June gives this plum peculiar value.

The story of these ennobled Beach plums is so interesting and suggestive that it is worth telling somewhat in detail.

THE ENNOBLEMENT OF THE BEACH PLUM

Perhaps the most astonishing result produced by hybridizing the little Beach plum is the fruit to which I have given the provisional name Giant Maritima.

This is a second-generation hybrid from an improved hardy Beach plum pollenized with one of the hybrid Japan plums.

In 1895, the first year this seedling bore, the fruit was one hundred times larger than its seed parent, the Maritima. In 1896, the fruit was even larger than in the previous year, and in 1899, as the tree gained in age and strength, the size was still further increased.

In that year some of the fruits were measured and found to be eight and a quarter inches in circumference.

The Beach plum from which this remarkable hybrid was developed is a native of the Atlantic coast of North America, growing on the sands and among rocks near the seashore from Labrador to North Carolina. It is known botanically as *Prunus maritima.*

It is one of the hardiest of all known wild plums, and habitually productive. It is a low, compact bush, rather than a tree, with rough, even thorny, branches, and small dull green oval leaves. The flowers are small, but are produced in great profusion, making it almost worthy as an ornamental plant. The fruits, as I have said, are small, usually less than half an inch in diameter; and they are bitter, being almost or wholly inedible unless cooked — yet making excellent preserves.

The Beach plum for many years has been known to possess some horticultural possibilities, especially hardiness, productiveness, and general "staying" qualities under the most trying conditions. The value of these characteristics was discovered soon after my general plum experiments were started, and every effort was made to cross it with some of the larger and finer species. For several years this cross could not be effected, mostly because the Beach plum blossoms very late, long after all other plums have shed their bloom.

Finally, however, very late blossoms of the latest plums of other species were cross-fertilized with some of the earliest Beach plum blossoms, the crosses being made both ways.

In the meantime I had been growing seedlings of the Beach plum by the hundred thousand. By continuous selection I had produced varieties bearing fruits nearly an inch in diameter, of a pleasing form and color, of delicious flavor. The trees, moreover, had almost incredible productiveness together with increased size and vigor.

Although my most enthusiastic friends often laughed at these extensive experiments with what they called my "huckleberry plum," and some of the best fruitgrowers made sport of the insignificant fruit, I saw in the little Beach plum great hardiness, late blooming, enormous productiveness, and the ability to withstand adverse conditions, and was sure of some measure of success.

Several crosses were finally made between the improved *Maritima* and the best cultivated varieties of other American plums. No really good fruits were obtained in the first generation, but some excellent varieties, both in productiveness and quality, were produced in the second, third, and fourth generations.

Some of the first-generation hybrid Maritimas make a much stronger growth than their wild parents, sometimes attaining four to six feet in two years, while the wild Beach plum on a good soil rarely grows more than three to three and one-half feet high in the same time.

The wild tree has short limbs, black bark, and small leaves. The first generation hybrids of these with the American and Japanese plums have

"Three-String" Plum Fruit

On the Burbank experiment farms the plants to be saved are marked with a white strip of cloth or string. The name of this plum indicates that it has been so marked, not once, but on three occasions, a triple tribute of its value. A fruit thus honored in the Burbank orchard must have altogether exceptional merits.

longer, smoother, and larger leaves, lighter colored wood, and longer and more slender branches.

These hybrid seedlings are easily distinguished the first season, as the Beach plum has red roots, while those of the hybrid vary, most of them being lighter. Beach plum seedlings, no matter how young, from seeds crossed with other varieties, show various shades between the pale yellow or brown root of the European and Asiatic varieties and the red root of the wildling, and if there were no other test this would be amply sufficient to prove that the plants were hybrids.

Such, then, was the parentage of the Giant Maritima, which first bore fruit, as already noted, in 1905—fruit over two inches in length. When I first came across this enormous fruit on a tree with the Beach plum foliage and blooming habits, the branches literally hanging in ropes of gigantic fruits, I could hardly believe my own eyes.

The fruit begins to ripen here early in July, and when ripe it is a deep crimson, covered with a thin pale bloom. The flesh until fully ripe is very firm and solid, but it breaks down quickly when ripe. It is honey-yellow, with a pale greenish tinge. The quality is good. The fruit is fragrant, and as large as the Kelsey, Wickson, Climax, or any other plum known in 1905.

It is found necessary to thin the green fruit carefully, otherwise the tree would be crushed with its weight of fruit. It has been grafted into numerous older trees, and appears to be a strong grower. Having originated from such an unusually hardy wild stock on one side, it will no doubt produce a crop of fruit almost anywhere. In itself, however, this will never prove of much commercial value, as it lacks firmness of texture.

The Beach Plum in Other Combinations

The wild Beach plum was also crossed with my Combination plum, which has in its ancestry plums of almost every type. The resulting seedlings were not as good as had been anticipated, but two were very much liked by a well-known California fruitgrower, and were sold to him in 1908.

One of these was given the name "East." It is a prolific variety. The fruits are globular, pale yellow, half covered with a crimson bloom and numerous indistinct dots. The flesh, pearly yellow in color, is of good quality, though probably inferior to some of the best Japanese hybrid plums. The fruit ripens here from August first to fifteenth.

This was tried at San Jose for several years, but found to be too soft for shipping. It is, however, a desirable variety for home consumption. It has never been offered to the public.

The other plum from this cross is known as "Pride." It also proved to be of little value as a shipping plum. It ripens too quickly, so that it will not stand shipping any great distance.

Pride is apple-shaped, which is usually a desirable form. It is a good grower, an excellent bearer, and ripens about July 20th. The skin of the fruit is a deep red with a whitish bloom. The flesh is a dark red—showing a Satsuma cross—and of excellent quality.

Besides these, nearly two thousand other promising Maritima hybrids are now being grown from these crosses. Many of them are excellent in habit, productiveness, and hardiness. As yet they have not been sufficiently tested to warrant their introduction.

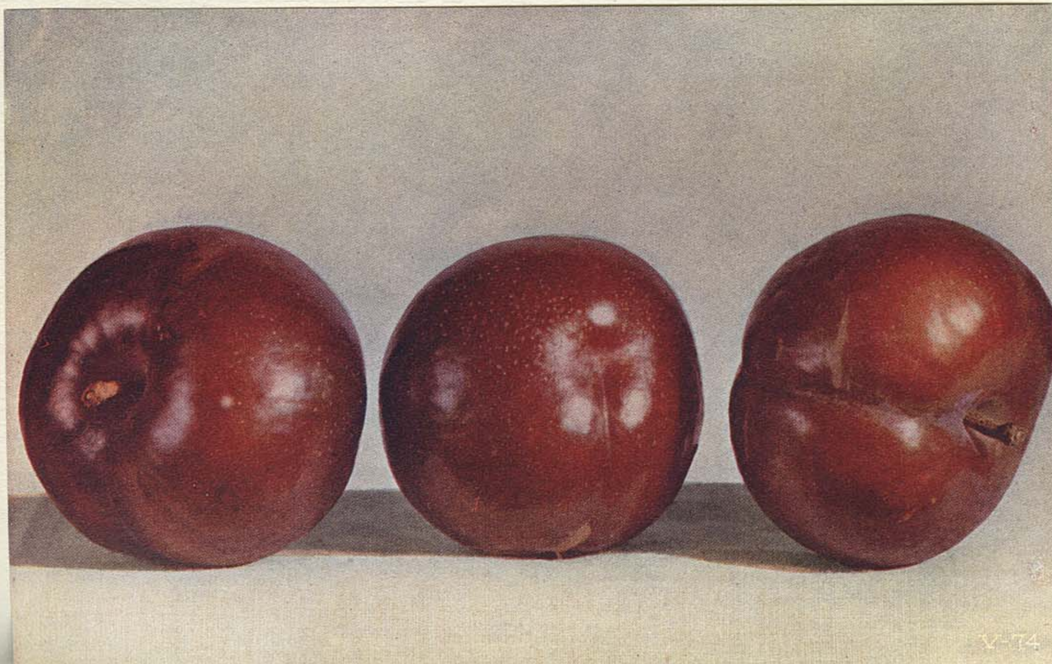
Tribute from the Sand Cherry

Another native American plum which is as hardy as the Beach plum is *Prunus bessevi* commonly known as the Western Sand Cherry. Although it is called a cherry, it is really a plum and has been successfully crossed with the plums, as pointed out in an earlier chapter. It is thoroughly hardy in the central and northern states, and is found most often in Minnesota and the Dakotas.

My work with this variety has not been so extensive as with the Beach plum, but has resulted in the development of one new plum which has

The Apple Plum

It is difficult for the casual observer to believe at first that the plum here represented is not an apple, as it has the form, color, general appearance, and rare keeping qualities of the fruit that suggested its name. It is a remarkably free grower, having led to the comment that buds and grafts of this variety "would probably grow if fired among the trees from a shotgun."



been thought worthy of introduction. It was offered in my catalog of 1911-12 under the name Epoch, and is described there as follows:

"'Epoch' should be one of the hardiest of all known plums, as it is a cross of the western Sand Cherry and the American plum, both being about as near 'Arctic' plums as can be mentioned.

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

As this variety has not been introduced long enough to get reports from growers in various parts of the country, it is not possible to say just how valuable it will prove to be. Its hardiness, however, is well established, for it has been grown in North Dakota, where the young trees have endured a temperature which no other plum had been able to live through.

This work of developing hardy fruits for the colder sections is being pushed by other workers.

Professor N. E. Hansen, for example, of the South Dakota Experiment Station, has been working for many years, especially in crossing the Sand Cherry with some of my best hybrid plums and with other varieties. He has been successful in producing several good varieties.

It is to be hoped that others will enter into this work, as hardy fruits are much needed in many northern regions of our country.

The California Wild Plum

Almost every imaginable flavor is to be found among the California wild plums. Some are quite sweet, some are sour, others are distinctly bitter. A few are delicious. The fruit usually is small and round, about the size of the wild plums of the Mississippi Valley; and of brilliant red color, or sometimes yellow, and rarely purple.

Strange as it may seem, the best fruit is produced abundantly where the trees are growing on rather poor soil.

The trees in different localities (and the same is true in a measure of each tree in the same locality) seem to have an individuality of their own, a somewhat characteristic condition with our California wild trees and shrubs. Some of these plum trees grow large and tall, with a straight, upright habit. Others form spreading bushes of low, compact growth that often bear abundantly when only a foot or two high, bending to the ground with their burden of fruit.

Under cultivation this plum has improved, and some selected seedling varieties are of very superior quality. Some of these plums when cooked have a flavor closely similar to that of the best cranberries, which they resemble also in color.

When crossed with the Japanese, American, and European plums, a large and handsome fruit is developed, the form being usually nearly globular, but sometimes oval. The trees of these crosses are also greatly improved over the wild ones in form, size, and symmetry of growth. They are always hardy and vigorous, and are as a rule exceptionally prolific.

For jellies and canning, these hybrid fruits are probably superior to any other class of plums, and a few of them are most excellent when eaten uncooked. In particular one which I have recently distributed under the name "Nixie" is valuable for use in any form.

The California wild plum has also had an important part in the production of the new varieties known as Combination, East, and Glow, all plums which exhibit the superior quality of the wild parent.

Thus have the native plums of the United States been used in producing new varieties.

Another View of the Apple Plum

In noting the very peculiar apple-like character of this fruit, it is interesting, by way of comparison and contrast, to consult the earlier pictures, showing the wide variation of plum forms, including the inverted pear shape of the Kelsey, the even oval of the Splendor prune, and the almost spherical form of other types. With such material to combine, almost any results may be expected.

The European species, though used to a slightly less extent, have produced results of even wider value.

The early settlers—either because they did not expect to find plums in America, or because they were attached to their own varieties—brought plums from Europe, known botanically as *Prunus domestica.*

The plums, like the settlers who brought them, found the adopted country hospitable. They thrived and multiplied. Seeds sprang into new varieties in the fence corners and some of them bore better fruit than the colonists had seen in Europe.

It was natural that these new varieties should spread while the less valuable ones were neglected. When a farmer journeyed from Plymouth to the home of a friend near Boston and saw there a plum better than the one he had brought from Europe, he secured grafts and gave the better variety the preference on his own farm.

Thus by the exchange of grafting wood, new varieties of plums were distributed among the pioneer farmers of the new land.

The Share of Europe

To-day there are at least a hundred improved varieties of the European type of plum, all of which, up to the last few years, originated from chance seedlings in the gardens of the first settlers.

It appears that some at least of the European plums originated in southwestern Asia. At all events, a plum that is thought to represent the original wild form has been found growing in the region about the Caucasus Mountains and the Caspian Sea.

It is known that the plum was one of the fruits and the dried prune a staple food of the Huns, Turks, Mongols, and Tartars, who maintained in this region a crude horticulture from a very early period. Here, even at the present time, plums are commonly grown and prunes are an article of trade.

The European plums have many unusually good qualities, including strong, vigorous, productive, hardy, upright trees with strong wood and branches capable of carrying heavy loads of fruit. Furthermore, they are not much subject to disease.

The fruit is not used so much for shipping long distances when fresh as some of the new Japanese hybrid plums. Some of the newer seedlings, however, such as the Splendor, Giant, Sugar, and Standard bear fruit which is shipped fresh in large quantities from California to New York and by sea to foreign countries every season.

For the most part the consumers of the large cities do not know that the big, luscious plums that they purchase in June and July are of the same varieties sold in the dried state as prunes.

The European plums have been used in the production of eight of my introduced prunes and have contributed to these the characters necessary for drying and shipping.

The European plums produce new forms readily from seed, so that it is scarcely necessary to cross them with other species to obtain seedlings with distinct new characters. Furthermore, it is difficult to make productive varieties when crossed with other species. My experience has been that they do not cross readily with the eastern or Asiatic plums, *Prunus triflora, Prunus simonii,* and *Prunus tomentosa,* nor very readily with any of the native American plums.

On the other hand, the common European plum crosses readily with the French species, *Prunus cerasifera,* the Cherry plum or myrobalan, often producing most valuable new varieties.

This French Cherry plum is a small, slender tree. It is usually quite productive, but no seedlings of large size or superior quality have ever been produced directly from it, and the fruit of its seedling is not only lacking in quality but in size and firmness of flesh.

Firm Sweet Plum Fruits

The surface dotting of the American varieties and the shape of the Japanese plum are shown in this attractive fruit, which is a complicated hybrid, the result of repeated crossing and selection. The native plums of America have had an important share, in producing some of Mr. Burbank's most prized varieties.

The only variety I have introduced which is a seedling of this plum is a cross with the Asiatic *Prunus triflora.* This hybrid is called Doris. There is blood of the French Cherry plum, however, in some hybrid plums including my well-known Shiro and a few others.

The European plums have also contributed largely to the production of new races of fruit trees that are highly ornamental. A whole race of plum trees beautiful enough for lawn decoration has sprung into being in my open air laboratory.

The French plum with purple leaves, *Prunus pissardi,* formed the basis for the development of these ornamental fruit trees. The methods used in developing these hybrids are the same as with the others, and results are similar, although the fruits have not proven so generally valuable as certain varieties raised solely for fruit.

The main use of the purple-leaved plum is for decorative purposes, but the fruits of the two varieties introduced are good enough for home use and in some cases are sold in near-by markets. This refers more especially to the very early purple-leaved plum, the Othello.

The story of the stoneless plums, which also owe their origin to European stock, has been told elsewhere and need not be repeated here.

The unique form of the apple plum, the delightful Bartlett pear flavor of the Bartlett plum, the appetizing color of the Santa Rosa, and the large size and remarkable shipping qualities of the Wickson would not have been developed had it not been for the use of the Japanese species *Prunus triflora.*

TRIBUTE FROM THE ORIENT

Indeed, the Japanese plum stands as part contributor to thirty-eight varieties added to American horticulture. These thirty-eight plums have been sent out from my farms, and few nursery catalogs list more than four or five Japanese plums other than these varieties, although several have been developed by other workers.

China, as well as Japan, has furnished material for the development of highly valuable plums. The well-known varieties, Maynard, Climax, Chalco, Santa Rosa, and Formosa, and many other newer seedlings, have in their make-up the blood of *Prunus Simonii,* the Apricot-plum of China.

This fruit takes its name from Eugene Simon, who introduced it into France from China in 1872. It was distributed in this country about 1881. It is peculiar in shape, being a large, flat, tomato-shaped plum, with dark brown, hard flesh, purplish-red skin, and a small stone.

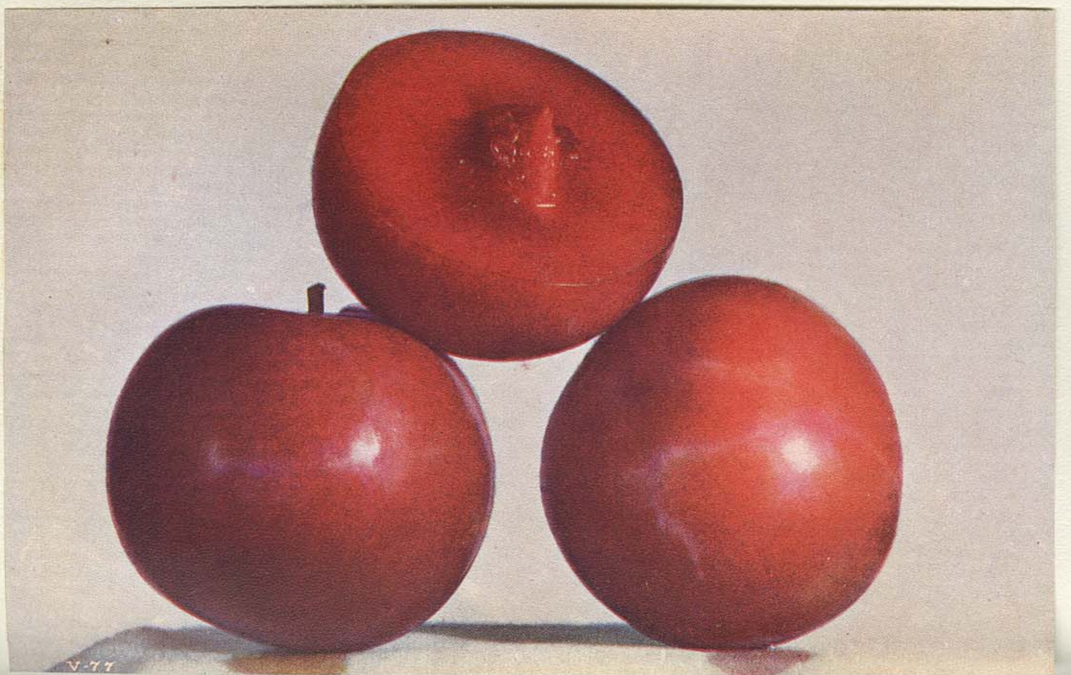
The fruit is sometimes eatable, and sometimes classed as good when grown in the hot, dry climates of the interior valleys of California. Its merits and defects were outlined in an earlier chapter. Here I will only add that it is by no means necessary to have a perfect fruit to begin your experiment. I have in many cases developed the very best of new fruits from two nearly worthless ones.

In selecting the Simon plum for these experiments, its value for plant improvement was considered and not its value as a market plum.

As a result of its use, its small stone, delightful aroma, and desirable tree characters have been imparted to a new race of plums, several of which have already added thousands of crates a year to the shipments of the principal plum growing sections.

Others even more promising are still in the test orchard awaiting final approval.

Such, then, are the materials that have been utilized in the development of new fruits in my plum orchard. I have used the native plums of the Middle West, the worthless wild plums of the bleak coast of Labrador, the plums of the Pacific slope; those which our forefathers brought from Europe; a worthless, wild, half-stoneless plum; plums from Japan, some with red flesh; other



Globe Plum Fruits

It will be seen that the flesh and the skin of this plum are almost uniform in color. This is a very unusual characteristic. The plum is a complex hybrid, and the red flesh betokens a Satsuma ancestor. Although named, this plum has not as yet been introduced.

Japanese and Korean varieties with large bright colored fruits and delightful flavors; the apricot plum from China, the purple-leaved plum from France and the cerasifera, which has been grown mostly for grafting stocks.

Although some of these species are insignificant in themselves, their characters by combination and careful selection have had a share in making fruits of the rarest qualities.

And the work, notwithstanding its notable results, is only at its beginning.

The Mystery of the Bud

In completing this outline of the methods of plum development, let us now consider a little more in detail an aspect of heredity which concerns equally all our other cultivated orchard fruits, and which must seem mysterious to everyone who gives the subject a moment's consideration. I refer to the familiar but extraordinary fact that whereas the bud or cion of a given tree will reproduce the fruiting qualities of the parent with the utmost fidelity, yet the seedlings grown from the fruit may have the widest diversity.

It has been pointed out that you need not hybridize the orchard fruits in order to get new varieties. The seed of almost any plum tree, for example, will give you seedlings a plenty that are different from the parent tree.

That the germ plasm of a single tree may thus contain the potentialities of a hundred different types of future fruit, is a mystery to which we have referred, but to which we may recur without apology.

When we further reflect that the branch in question, which carries this amazing heritage, perhaps grew from a single pea-sized bud inserted on the trunk a few seasons ago; and that the tiny bud in question must have contained, pre-determined within its seemingly insignificant substance, all the potentialities that will be revealed in all the different "varieties" of its progeny, the mystery becomes still deeper—if comparison be permitted between the various aspects of a subject every phase of which lies almost beyond the bounds of human comprehension.

But even though we cannot hope fully to understand, much less to explain, the mysteries of heredity of which the case of the bud furnishes a familiar yet striking example, we cannot help pondering on the matter. And as nowadays we are accustomed to associate function with structure everywhere in nature, seeking a physical basis for the observed phenomena associated with life processes, it is natural that here as elsewhere attempts should have been made to visualize the conditions that obtain in the germ plasm of the plant, and to picture in imagination its actual mechanism.

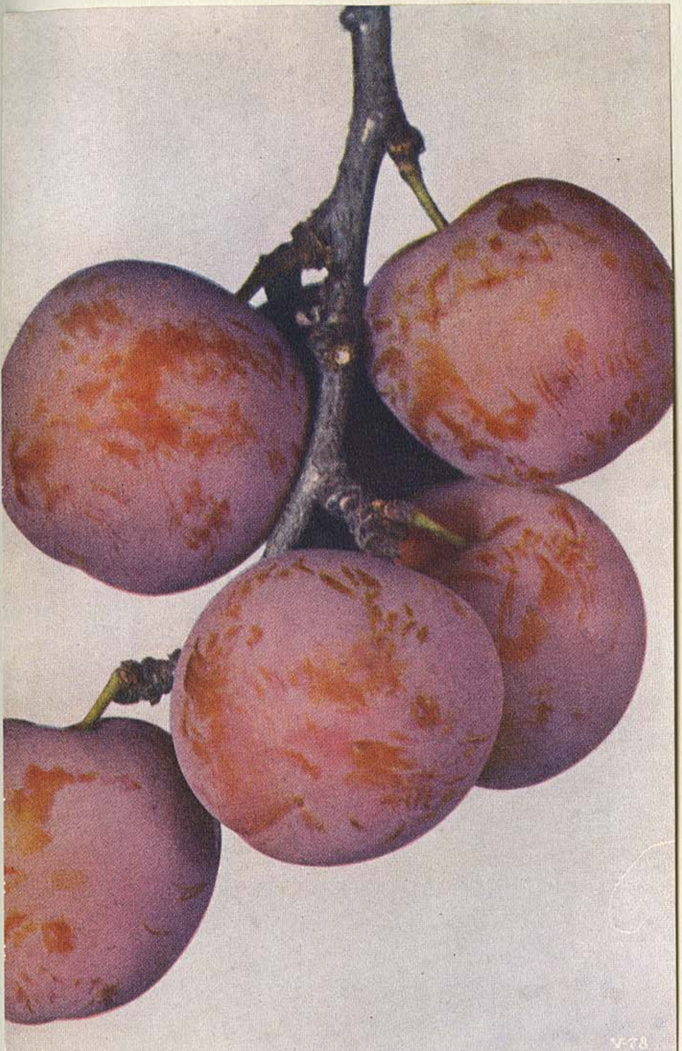
In our age the telescope, fortified by the weirdly penetrative spectroscope and aided by the photographic plate, has enabled the astronomer to reach out into unthinkable realms and to record not merely the direction and speed of light but even the chemical composition of stars so distant that their light, traveling 186,000 miles per second, requires scores of years to reach the earth.

With the aid of the same instrument, the universe is proved to be peopled with dark stars, definitely revealed to us even though forever invisible; the structure of the universe as a whole is coming to be understood, and the course and direction and speed of groups and streams of stars by millions have been tested and charted.

In such an age it is not strange if the worker who turns his eyes in the opposite direction, and attempts to penetrate the mysteries of the microcosm of the plant or animal cell should have found means to pass beyond the range of vision of the microscope and reveal something of the intimate nature of the events that are taking place in the world of molecule and atom and electric particle.

Aid from the Microscope

In point of fact the invasion of the world of the infinitely little by the modern biologist has



Early Crimson Plum Fruits

This particularly realistic direct color photograph print shows a plum which bears unusually early, and which reveals in its characteristics a combination of the wild California, European, and Japanese plums. The strains of the different ancestors are blended in very complex combinations, through repeated crossing.

been no less wonderful than the exploration of the world of the infinite vastness by the astronomer.

And perhaps it should not seem strange to any one who has a philosophical conception of the underlying harmonies in nature, that the conditions revealed in the microcosm of the living cell should suggest in many ways an epitome of those made manifest in the macrocosm.

Such, at all events, is the message that the modern biologist and physicist bring us from the world of infinite littleness. Making the first stages of their invasion with the aid of a microscope, they show us that all living tissues, vegetable or animal, are composed of cells, and that within each cell there is a vitally important central structure called the nucleus.

This structure lies at the heart of every germ cell through which a living organism propagates its kind.

The pollen grain of the plant, for example, is the carrier of such a germinal nucleus. The pollen grain itself is a structure of almost microscopic size, yet it is colossal in comparison with the infinitesimal fleck of germinal matter that lies at its center. Yet the modern microscope can so magnify this fleck of matter that something of the mechanism of its vital parts becomes visible.

The microscopist tells us that within the germinal nucleus there are to be seen sundry films of matter, arranged to form a sort of skeleton, which are readily stained under his manipulation and which he therefore names "*chromosomes*", colored bodies. He observes that the nuclei in the cells of different plants and animals have these infinitesimal chromosomes arranged in different characteristic groups, differing in number in different species but always the same for each and every cell of plants or animals of a given species.

The enlarged vision of the microscopist enables him to assure us that when two germ cells of the opposite order come together—when, for example, the nucleus of a pollen grain blends with the nucleus of the plant ovule—there are various characteristic dividings and interlinkings between the two sets of chromosomes within the two nuclei.

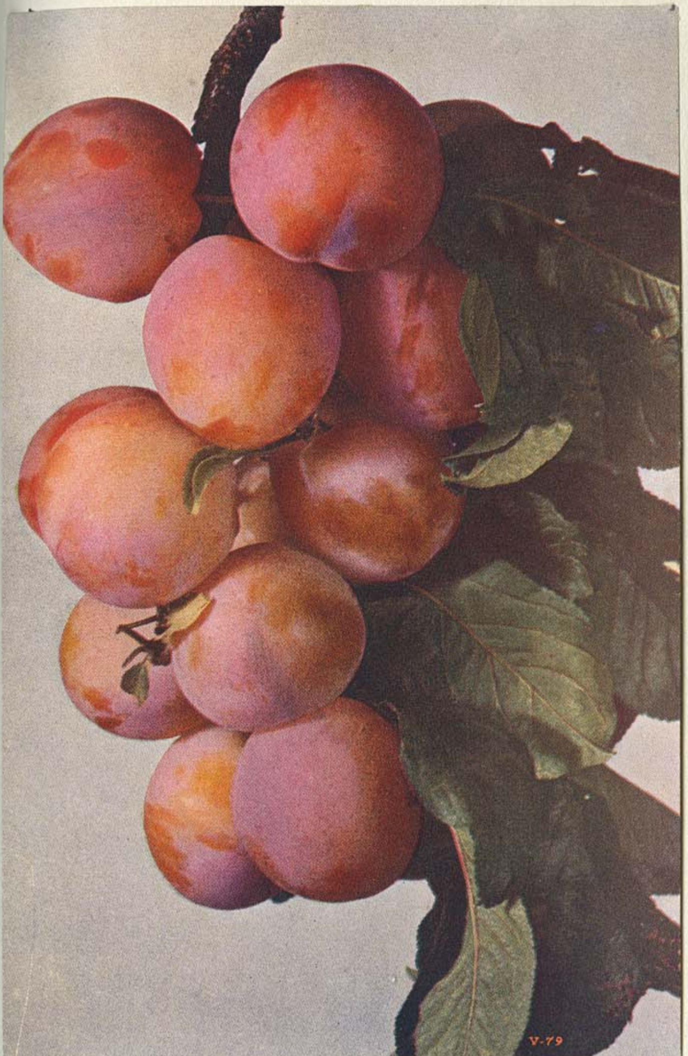
In the blending and rearrangement of these minute structures, he believes that he is witnessing the underlying processes that bespeak the blending of hereditary potentialities and their re-combination to determine the future possibilities of the new organism that is thus brought into being.

All this is very wonderful. But it brings us after all only one stage nearer the confines of the mystery. The chromosomes within the nucleus, which all biologists nowadays regard as the tangible carriers of hereditary tendencies or capacities, are few in number, and small as they are, we are forced to conclude that each of them must be the carrier not of a single potential trait or tendency but of a multitude of such potential traits or tendencies.

Our practical experiments in plant breeding have shown us that we deal often with a dozen or more tangible characters that are grouped against each other in opposing pairs—definitive qualities of size or color or flavor of fruit and all the rest—and it requires but a moment's thought to see that each of these "unit characters" is in reality made up of a multitude of minor characters.

Heredity carries all of these definitely from one generation to another; so their potentialities must be represented within the structure of the chromosomes; and there are by no means chromosomes enough to supply one for each hereditary character.

So we are obliged to assume that each chromosome is in itself a complex structure, and that within that structure there are subordinate structures—like the individual bricks and boards and nails and rivets that go to make the structure of any piece of human architecture—that determine by their quality or their arrangement the specific potentialities of the future organism. Each chromosome, in other words, must be thought



The Home Chestnut Plum

Like all Mr. Burbank's recently developed new varieties, this is of complex ancestry. It is less celebrated than many other varieties that have been developed at Sebastopol, but it has qualities that make it an admirable fruit for the door yard and home garden.

of not as the tangible conveyer of any particular "unit character", but as a receptacle in which several or many factors or determiners of diverse unit characters—size of flower and color quality of leaf and fruit and all the rest—are assembled.

Further Aid from the Physicist

But unfortunately the powers of the microscope do not suffice to reveal these unit structures within the chromosome.

What they are like, must for the present remain only a matter of conjecture.

But that they are definite mechanical structures of unthinkable smallness, represented by chemical atoms in specific combinations, we can not doubt. And in revealing to us the size and character of these atoms, the modern physicist gives us aid in supplementing the vision of the microscopist and in helping to make it seem at least a possibility that the definite factors of heredity have a physical basis within the microscopic chromosomes.

The conclusions that give this assurance are based on various almost infinitely delicate tests that are made in the modern physical laboratory.

Summarizing these in a few words, it appears that the physicist and chemist are now able to make definite computations as to the size of the molecules and atoms that make up the structure of all matter. And the figures they present, when they have taken a census of the atom, are such as to give us full assurance that even so small a structure as the minutest chromosome within the nucleus of a plant cell contains molecules and atoms in such numbers as to make possible an infinite complexity of arrangements and therefore an infinite diversity of resulting qualities.

Thus we are told that the smallest particle of matter visible under the magnifying influence of the most powerful microscope is of such dimensions that 50,000 of such particles placed in line would be required to cross the space of one centimeter or about two-fifths of an inch. If we calculate the cube of this number we find that 125 thousand billion such particles could be crowded into the space of a cubic centimeter. But it further appears that, according to a definite measurement made by Professor Rutherford, more than 20 billion times that number of helium atoms would exist in the form of gas in the same space.

And the commentator I am quoting adds: "Of course the molecules of gas are widely separated. So it follows that the smallest particle of solid matter visible through the most powerful microscope contains many times 20 billion atoms."

"Many times 20 billion atoms" in the smallest particle of matter that the microscope reveals! Vastly more than that number of atoms, then, in each individual chromosome of the group lying within the nuclei of pollen grain and ovule—since these are by no means at the limits of visibility. And each atom has itself specific individuality. Each group of a thousand atoms or so might make up a molecule of a different type of protoplasm.

So here is material for millions of kinds of protoplasm, were so many needed.

Here within the infinitesimal germ cell, revealed to us in part by the microscope of the biologist and for the rest made manifest in imagination by the revelations of the physicist, is material enough to supply tangible carriers for all the conceivable hereditary factors that come to make up the most complex organism of any plant, or for that matter of any animate creature whatever.

The Germ Cell A Complex Organism

Let us make the illustration specific. Suppose that the chromosome in the nucleus of any given pollen grain—say that of a plum blossom—were of the very smallest size visible under the microscope. Suppose, also, merely for the sake of illustration, that the hereditary factors for unit characters that it bears are of a thousand different types—representing all details of size and color and foliage and growth and leaf and blossom and fruit of the future tree. We know that the chromosome really does bear these potentialities;

The Turkey Egg Plum

Where hundreds of new varieties of fruit are in evidence each season, it is often difficult to find names appropriate to designate them. Someone suggested that this handsome plum is shaped like a turkey egg; so the name was appropriated. Names aside, this fruit is luscious and palatable, as a glance at the picture will suggest.

I am merely assuming their number at a thousand individual units for the sake of illustration.

In our former views, when we considered the transmission of complex qualities by the infinitesimal pollen grain the thing seemed utterly inscrutable and mysterious. But now with the aid of the new facts that the physicist has supplied us, the mystery is somewhat clarified. He shows that the smallest visible bit of protoplasm must contain at least twenty billion atoms.

So there would be enough of these atoms to supply no fewer than twenty million to make up the structure of each individual hereditary factor.

Now twenty million bricks, of ordinary size, piled solidly together, would make a mass 100 feet square and 300 feet high.

So the structure of each hereditary factor of all the thousand in our infinitesimal speck of germ plasm may be as complex as any building that could be made with such a pile of bricks as that—and more complex, no doubt.

Add that each individual atom in our germ plasm structure is no crude brick but is conceived by the best informed students of physical science to be "at least as complex as a piano", and we gain a yet clearer conception of the possible intricacies of the mechanism of each of our imagined thousand hereditary factors.

In this view, then, the germ cell may well be an organism as complex and of as definite a system of architecture as the full grown tree into which it will ultimately develop.

The leaves of a tree—even the leaves of a forest—are a meagre company compared with the census of the atoms within the nucleus of a single germ cell.

An Amazing Microcosm

Nor need we limit our view to the germ cell that produces a single plant. Let us consider for a moment the bud from which the branch grew on which are produced, according to our illustration, plums, the seeds of which may give rise to some hundreds of different "varieties" of fruit.

Do the analyses of miscroscopist and physicist make comprehensible the fact that the original bud of the plum tree can contain potentialities of so many different complex structures?

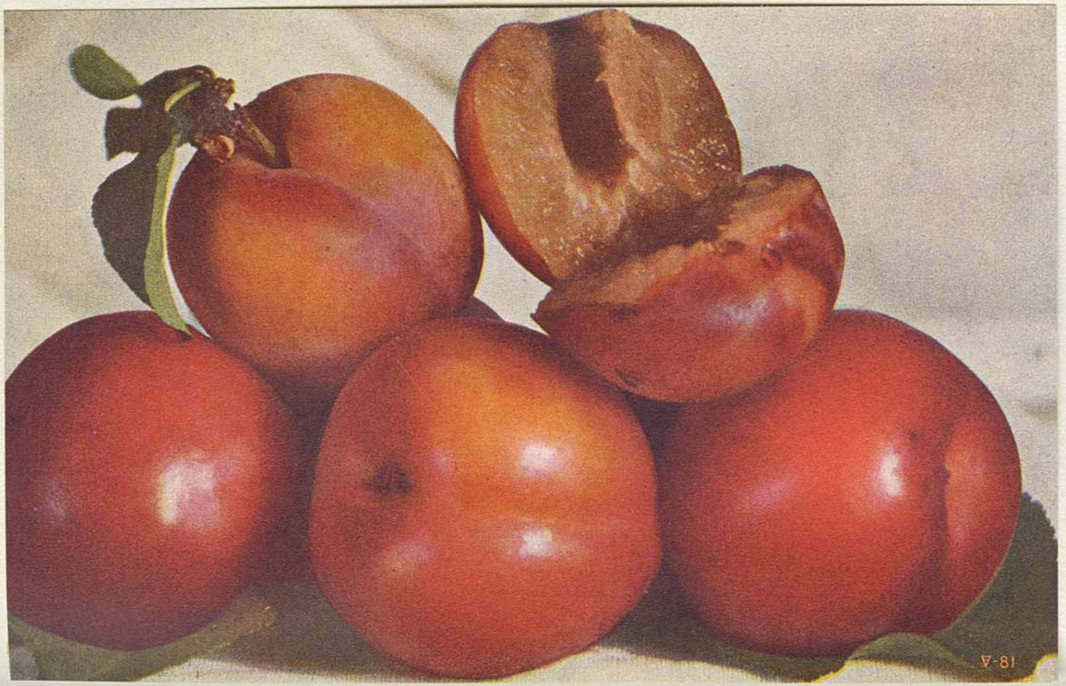
Another glance at the figures of the physicist will supply an answer that would have been bewildering were it not for what we have just seen as to the complexity of the germ plasm. It appears that, according to the estimates of Professor Rutherford (based on accurate count of the atoms given out as so-called alpha particles in the radiation of radium) the mass of an atom is so inconceivably small that the number of atoms making up a portion of matter as big as our plum-bud (which we may assume to have the bulk of about a cubic centimeter) is represented by the figures 68 followed by twenty-four ciphers—68 "octillions", if the figures must be read.

So the number of atoms that are aggregated in the tiny plum-bud is vastly greater than the total number of people that have lived on the earth since the human race was evolved.

To attempt to give tangibility to the idea of the smallness of the atom, we may borrow an estimate made by the late Lord Kelvin. It may be computed that if the tiny plum-bud were imagined to be enlarged in size until it became as big as the earth, each component atom being increased in the same proportion, its entire structure would then be made up of units (magnified atoms) of about the size of footballs.

If we then reflect, further, that according to the definite analyses of other physicists, with Sir J. J. Thomson of Cambridge at their head, each atom is itself a complex structure—the very simplest atom, that of hydrogen, being composed of at least 1,700 particles called electrons which are in reality the unit particles of electricity—we shall gain a still more enlightening view of the complexity of our plum-bud microcosm.

It has been estimated by a French physicist,



The Bully Plum

Sometimes the chance remark of a visitor suggests the name for a new fruit. So it was with this plum which brought forth a slangy but expressive ejaculation that seemed highly appropriate, and was retained. No one who looks at the picture will doubt that this is really a "bully" plum.

Becquerel, that the size of the individual electrons that make up the atom is such that they may be thought of, not as piled solidly together within the structure of the atom, but rather as infinitely separated by comparison, like a swarm of gnats flying about in the dome of a cathedral.

It is a little difficult for anyone not accustomed to this particular use of the imagination to follow the conceptions of the physicist. But we may accept his findings as authoritative, for they are the result not of one man's work alone but of tests that have been applied by many workers.

Making the application to our plum-bud, then, it appears that its bulk is such as to give us assurance that it contains (although it actually is no larger than the smallest pea) a number of atoms so great that if the atoms were conceived to be all gathered into 8,000 different groups (each group representing a different variety of future plum), there is material enough to supply at least eight million billion atoms in each group! And each of these atoms is itself a complex structure made up of several thousand electric corpuscles.

Now we know that each particle of protoplasm, the physical basis of all life, is composed of atoms of carbon, hydrogen, nitrogen, and oxygen in complex combinations. A single molecule of protoplasm may contain a thousand or more atoms.

But even allowing a thousand atoms to each molecule, we have ample material for the construction of something like eight million billion molecules for each one of our 8,000 groups of potential plum trees.

Obviously there is abundant opportunity for the combination of such material into complex groups, quite adequate to account for the different qualities of our various plums—be they never so divergent as to form or size or color or flavor.

The Bud as a Walled City

In this expanded view, then, it is no more wonderful that a pea-sized plum-bud can contain within its germ plasm the potentialities of hundreds of varieties of future plums than that a city can comprise hundreds of houses, no two just alike, all built of wood, brick, stone, and metal in different proportions and combinations; just as the germ cells are all built of the atoms of carbon, hydrogen, nitrogen, and oxygen in different combinations.

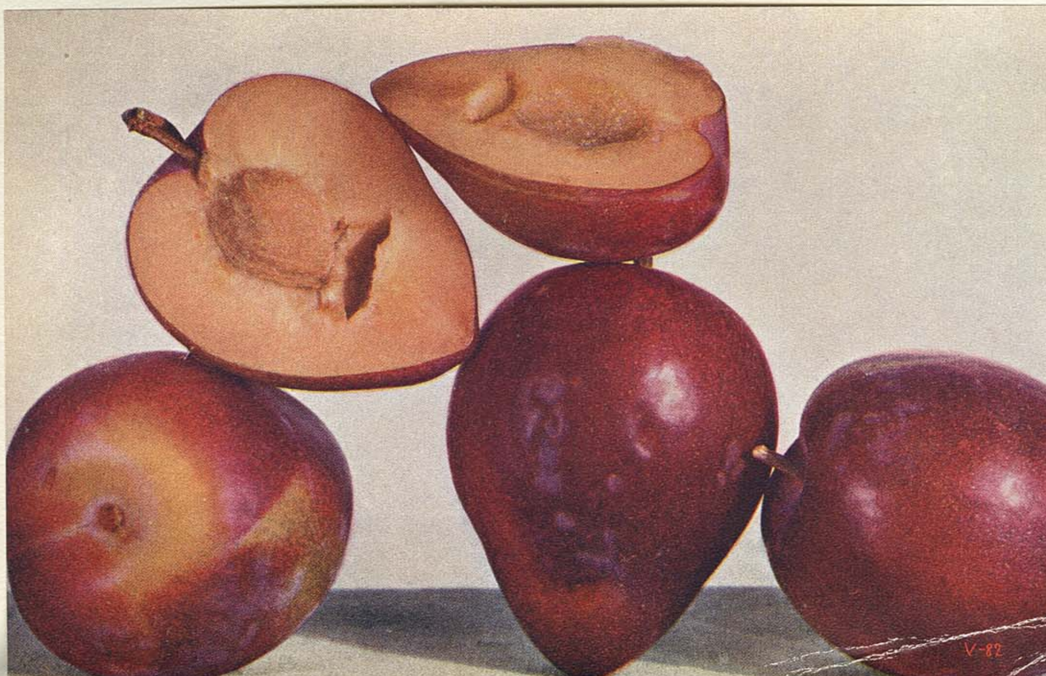
There are far more bricks (atoms) available to build each different type of germ plasm in our plum-bud colony than are required to build the largest structure in the man-made city.

The real wonder, as I said before, lies in the fact that each infinitesimal aggregation of molecules of protoplasm has the capacity to take to itself stray atoms that are brought into its neighborhood, shape them into its own structure, somewhat as a brick-layer shapes the bricks into the walls of a building, and thus increase constantly in size.

It is this capacity of the germ plasm to gather material and utilize it in expanding its structure—together with the further capacity to move in response to environing forces—that is the underlying mystery of the entire life-process, including the interesting aspects of it that we see manifested through heredity.

In a word, a fruit-bud is a walled city tenanted with a multitude of complex structures, and the mere size of the bud, in our clarified view, has nothing whatever to do with the wonder of its composite architecture.

The phenomena of the germ cell have hitherto appeared peculiarly mysterious simply because our blunt human senses deal ordinarily with masses of matter of a more tangible size. Now that the microscopist and the physicist have opened the way for us into the microcosm, we see that mere size is of no great significance in the matter, and that there is ample opportunity within the nucleus of the smallest germ cell for an organization of molecules and atoms that for all practical purposes may be at once as complex and



Big and Handsome but Nameless

This big flat plum is of very mixed ancestry. In shape it suggests the Kelsey, which was doubtless one of its ancestors. Note the hollow under the seeds, from the breaking of the flesh, which is a characteristic and an interesting peculiarity of this plum.

as definite as the visible structure of the mature plant in which the germ cell sprang or of that other mature plant into which it will develop.

—The work, notwithstanding its notable results, is only at its beginning.