Observations

...on the...

Colors of

Flowers and Leaves.

E. Williams Hervey.

OBSERVATIONS

ON THE

COLORS OF FLOWERS.

BY

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INTRODUCTION.

Color in Nature, and especially in the vegetable world as seen in leaf and flower, is one of the most pleasing objects that greet the eye.

Many questions naturally arise regarding its origin and the purposes it subserves, its modifications and many changes. These offer a somewhat novel subject for enquiry. There is very little literature on the subject, and a portion of what exists is open to grave criticism.

Chemists have informed us of the nature of only a few of the pigments and where they may be found, whether fixed in minute bodies called plastids, or free in the cell sap.

Grant Allen has written very entertainingly on the sequence of color and Hermann Müller has discoursed on insect selection; the writer however, not being wholly convinced as to the soundness of the theories of these authorities, recalling moreover Agassiz's injunction, which he copied from a blackboard in the Penikese school: "Study to translate what actually exists," "Study nature, not books," decided to investigate for himself. Herein he presents the results of his researches, including a general survey of color in flowers, leaves, etc., as seen by an ordinary observer, reviewing also some of the more obvious facts and comparing them with the conclusions of the above mentioned and other writers. Some of the ways in which flowers become variegated will also be pointed out, and in brief there will be presented a general conspectus of color as found in vegetation.

Eliphalet Williams Hervey.

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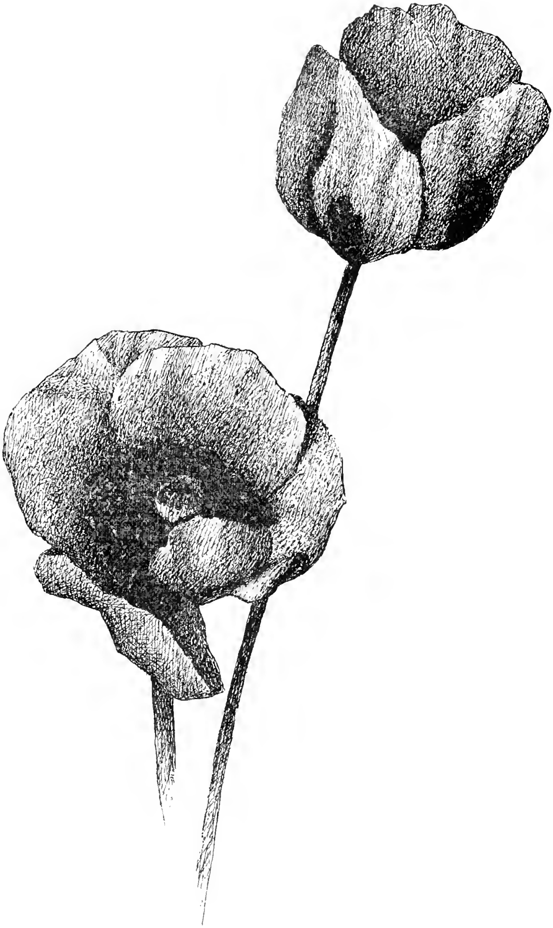

OBSERVATIONS

ON

THE COLORS OF FLOWERS.

SEQUENCE OF COLORS.

CHAPTER I.

It has been thought that as flowers are morphologically modified leaves, that green is the primitive color; others favor yellow, making purple and blue later developments.

Let us first consider the relation of green to other colors. It is the most prominent of all hues; we find that it is not confined to foliage, but that a very large and important portion of the Floral Kingdom existing at the present day is wholly green, or has green as its ground color, and that this color is not restricted to small, weed-like plants which may be degraded specimens of more highly developed ancestors, but it is also found among the choicest plants of gardens and conservatories.

Neither are these green flowers limited to primary forms, but they are found in every stage of advancement from the simplest to the most complex. The green color of the bud of course, as every one knows, as a rule precedes all other colors, and when in this green state it is generally impossible to say what color will follow, for however bright the future color may prove to be, for the time being, it is completely concealed, but green in its more permanent forms also yields directly to any hue.

We will glance for a moment at a few prominent green flowers. Some of the most conspicuous of these found in our conservatories are the *Cypripediums;* there are at least a dozen species having as pure a green color as the general foliage of plants, except that one or more petals may be relieved by a slight blending with another tint which Nature adds to lessen their homeliness, and at the same time to make them more attractive to the insects which visit them and assist in their fertilization.

C. longifolium is wholly green.

C. insigne: the green dorsal sepal which stands conspicuously erect is tipped for a third of its length with pure white.

C. Harrissianum: the veins of the dorsal sepal, which is largely white, and also of the slipper or tubular lower petal, are turned to a dull purple.

C. Lawrenceanum: the dorsal sepal has become quite white by the fading out of the green, except that there remains a few streaks with the purple veins.

There is moreover a variety of *C. callosum* in which the whole flower is of the purest white, saving the green veins.

C. Charlesworthii: the whole dorsal petal has changed from white to a beautiful pink purple.

C. Sedenii and C. Calurum have all the petals of a rose color, only a trace of green remaining.

The green portions of these flowers by age become yellowish, for orchids as a rule remain fresh for a month or six weeks. Green flowers often become yellowish-green or greenish-yellow and finally pure yellow; and among the Cypripediums are found pure yellow varieties.

One can therefore trace from the foundation green, a white, a purple, a rose, and a yellow, and an infinite number of shades and tints. The purples and reds are evidently separate and independent colors, breaking through the chlorophyl green.

Yellow often results from the disintegration or dissolution of the chlorophyl itself, which is largely composed of yellow with some blue. White results from the loss of color, as seen when either yellow, green, red, purple, or blue or other color fades and disappears from the petal. This white may be pigmental or the white of the original color of the tissue, the chlorotic white, as seen in the embryo of the seed, and commonly in the earliest growth of roots and stems. A common garden bean when split open will show not only the thick white cotyledons, but a second pair of delicately veined leaves white as marble, which on germinating change to green. One-half of all so-called white flowers are no whiter than this primitive white tissue.

There are differently constituted whites as well as yellows. This last mentioned white color is not produced by a pigment; there is no coloring matter, but the whiteness is an optical effect similar to that seen in snow which dissolves into colorless water. It is caused by minute bubbles of air in the cell walls which reflect white light. There does not appear, however, to be any dividing line between a translucent, structural white, as seen in the embryo, the Easter lily, etc., and a pigmental chalky white as seen in the rays of a daisy, which latter is occasioned by numerous small granular bodies in the cells of the tissue known as leucophytes.

Lest the examples of Cypripediums might appear to be exceptional, we add a list of other green flowers both showy and inconspicuous.

Zygopetalum, green with darker markings of brown

Lycaste gigantea, olive-green, lip maroon and orange.

Do. ciliata, green, lip white and buff yellow.

Cycnoche, four species, green suffused with purple.

Angraecum sesquipedale, light green, spur ten inches long

Galeandra, several species, green with lips white or rose.

Cattleya bicolor cœrulea, green, lip sky-gray.

Cœlogyne pandurata, pale green, lip yellow-green.

Eucomis, eight or more species, green.

Selenipediums, ten species, green shaded with reddish-brown.

Epidendrum Pseud. Epidendrum, apple-green, lip orange-red.

Catasetum, Orchis, Cirrhopetalum, Cymbidium, Platyclinus, Masdevalia, Oncidium, Brassia, etc., all have green species.

The following sections will be recognized as native plants:

GREEN.

Gymnocladus Canadensis, two shades of green, flower has a delicious spicy odor.

Xanthoxylum, Ptelea, Rhus, Vitis, Ampelopsis, Euonymus, Scleranthus, Smilax, Chrysosplenium, Habenaria, Physalis, Arisæma, numerous species of *Chenopodiaceæ, Ambrosia, Amarantaceæ, Salicornia, Ludwigia, Ribes, Helonias*, purple changing to green, and *Cobea scandens* of gardens green changing to purple, *Liriodendron Tulipifera*, etc., etc.

GREENISH-PURPLE.

Scrophularia, Menziesia, Aristolochia, Aplectrum, Trillium sessile; Veratrum, green turning brownish, purple within, *Tipularia, Clematis*, etc.

GREENISH-WHITE.

Hydrastis, Polygonatum, Synchrys, Conobea, Pyrola, Anemone, Comandra, Triglochin, Goodyera, Celastrus, Smilacina, Echinocystis, Polygonum, Aralia, Solea, Polygala, Iva; Ornithogalum, green and white, *Galanthus*, several species of a green color; *G. Elwesi* is white marked with green, *G. virescens*, outer petals pale green shading down to pure white, inner petals entirely green. *Habenaria lacera* is pale green, except that the lip fades to white.

If green be the earliest color of flowers, one would naturally expect to find that color among the simplest forms, as in *Ranunculaceæ*, and it is found that many are so, as five species or more of Clematis are green or greenish, *Anemone cylindrica* greenish-white, *A. Virginiana* greenish, *Thalic-*

trum purpurascens greenish and purplish, *Myosurus* greenish, *Trollius* greenish-yellow, *Helleborus*, several species, greenish or wholly green, *Knowltonia* greenish-yellow, *Isopyrum* greenish-white, *Hydrastis* greenish-white, etc.

This change from green to white is common on the margins of green sepals, as in *Nymphæa odorata*, *Stellaria*, *Buda*, *Plantago*, etc.

Polygala sanguinea has three sepals green, the original color, and the two lateral sepals purple. *P. polygama* has three sepals green with rose-purple edges, the other two being rose-purple like the petals. Dutchman's Pipe has the curious green corolla shaded and dotted with purple.

The large white involucre of *Cornus Florida* is like most real flowers, green before becoming white. Indeed, in Clematis several species described as purplish are lacking the clear color because they are dulled by green!

In *Pæonia Brownii*, of same family, the brownish-red of the petals doubtless results from the mixing of chlorophyl-green and red, and the brown-purple of *Xanthorriza* from the mingling of green and purple.

We find positive evidence, therefore, that some of the earliest and simplest members of *Ranunculaceæ* are still green, and that others have green as a foundation color, from which white, purple, red and yellow may in any order originate.

GREENISH-YELLOW.

That a green flower may become yellow in a manner analogous to a green leaf becoming yellow, is too well known to require comment. In some instances the yellow is apparently a direct product of a previous green, resulting, as in foliage leaves, from the disintegration of the chlorophyl and the disappearance of the blue element. This yellow is regarded by some chemists as an entirely distinct pigment and has been named Xanthophyl. Of course the yellow developed directly from white in the case of *Lonicera longiflora*, must be of a different character.

The transition from green to yellow may be traced in all stages. A short list only is added of native plants: *Prosartes, Uvularia, Dioscorea, Agave, Medeola, Sassafras, Clintonia, Physalis, Nicotiana, Frasera, Sedum, Penthorum, Gonolobus, Shepherdia, Trollius, Myosurus, Liriodendron*, etc.

The leaves of many healthy plants turn from green to yellow, as seen in numerous garden shrubs and vines which are wholly yellow or variegated in various ways, as a green leaf with a yellow margin. Fruits turn from green to yellow, as the banana, lemon, etc.

Autumn leaves are also largely yellow, and most flowers of a yellow color are preceded by green, as in *Nuphar, Hypoxis, Narcissus*, lilies, etc., but there appears to be a yellow of a different quality not derived from green, as seen in roots, bulbs, early shoots, and when a white flower, as *Lonicera longiflora*, changes to a clear yellow.

GREEN, YELLOW AND BROWN.

We have already alluded to the brown and brown-purples of some of our native plants; but among tropical plants, and especially the orchids, one is surprised at the number of flowers having these colors. Very often the brown is associated with yellow; at times the flowers appear to have yellow as the ground color, and to be merely blotched or barred with brown, while in other species the flowers may be wholly brown or brown with yellow markings. A few descriptions will illustrate these combinations of color:

Epidendrum oncidioides, red-brown marked with yellow.

E. ochraceum, orange-brown, lip yellow.

Phalænopsis Luddemannia, chestnut-brown, with pale yellow transverse streaks.

Oncidium Batemanianum, light yellow, blotched with chestnut-brown.

O. Baueri, yellowish-green, spotted with red-brown.

O. barbatum, yellow, blotched with chestnut-brown.

This genus has upwards of three hundred species, nine-tenths of which are yellow and brown.

Vanda tricolor, light yellow, spotted with red-brown.

Miltonia cuneata, brown, tipped with pale yellow.

Masdevallia, *Phaius*, *Coelogyne*, *Calanthe*, *Schomburgkia*, *Zygopetalum*, *Paphinia*, *Catasetum*, *Trichocentrum*, *Dendrobium*, *Lycaste*, *Houlletia*, *Darlingtonia*, etc., have more or less species of these colors, to which should be added *Odontoglossum*, with upwards of sixty species and varieties of brown and yellow.

If there be a law of progression in colors, as has been maintained by one writer, where ought the various shades of brown to be placed? Should they precede or follow yellow? Might they not be formed from yellow as a base by the addition of other pigments, or are they entirely independent of it? Although the two colors are so frequently associated with each other, the writer is of the opinion that, primarily, they were distinct and independent, but that yellow also may be, and in fact often is, produced from brown by oxidation or other chemical action. An evidence of this is seen in *Oncidium longipes*, where five of the six segments of the perianth are chestnut-brown, but the lip is a rich golden yellow. The lip of orchids is the most changeable in color, and as a rule has a different hue from the other petals, and indeed is often variegated with several colors. *Crotons* are foliage plants remarkable for the changing colors of their leaves. If the recent leaves are first green, they are liable later to turn to a bright yellow along the veins and in spots and patches; with more age, the yellow areas become scarlet, and at the same time, and doubtless by the same pigment or chemical agency, the lighter green of the lower surface of the older leaves changes to a chocolate brown. What was green becomes directly brown. Thus brown is formed without yellow, for no yellow has been developed there. It is quite evident in this example that some form of red, mingling with the yellow, produces the scarlet color, and it is found that the same red with the green produces the chocolate.

A test was made of ordinary pigments by selecting Hooker's green No. 2 and crimson-lake, which, mixed in proper proportions, gave a chocolate identical with the color of the Croton leaf. We would not presume for a moment to limit the power of Nature to produce a brown by one method alone, her resources being unlimited, but in the present instance it seems to be a satisfactory origin of the brown, for the color is first met associated with green, an earlier color, and not with yellow, as may also be seen from the following:

Epidendrum macrochilum album, green ground, covered with red-chocolate, lip white.

Phajus Manni, deep, bronzy-brown, bordered with green, lip white.

Angræcum caudatum, brownish-green, lip white.

About ten species of Cypripediums, known as Selenipediums, are various shades of green and reddish-brown, green being generally the ground color. Seven or eight species of *Zygopetalum* are green, marbled with brown or purplish-brown, lips white or purple.

Oncidium Lucochilum, green, barred with chocolate.

Brassia lanceana longissima, green, blotched with brown.

Vanda Parishi and several other species are greenish-yellow spotted with brown.

Catasetum macrocarpum, greenish-yellow, covered with chocolate-brown.

Cymbidium canaliculatum, brown with green margins.

Euonimus Europeus, occasionally seen in lawns, has flowers perfectly green in color, while *E. atropurpureus*, the Burning Bush, much more common, has flowers of a chocolate-brown; the latter color might be formed from the first mentioned by merely the addition of red, and the brown colored *Calycanthus* was doubtless also produced in the same manner.

In *Gaillardia* the central florets are always green to dark purple-brown.

Nuphar advena, Yellow Pond Lily: the three outer sepals often have a reddish-brown band or blotch on the upper side, appearing even in the bud, through the green color, before any yellow is developed. In some specimens the sepals are almost wholly of this chocolate color, which may have been the original color; at all events it is perfectly obvious that the brown color is earlier than the yellow.

When green and brown are the primary colors, by the changing of green to yellow, an exceedingly common color change, we obtain yellow and brown: then Nature by some secret art often transmutes the brown into yellow, one of its component parts, by eliminating the others, with the result of a wholly yellow flower. Thus as regards the relations of yellow and brown to green, it is found that the one is as close as the other, that brown in many instances is the older color, that when brown is a self-color on the first departure, then yellow must rank as second.

In *Chrysanthemums* the central, tubular florets are yellow as is commonly the case in Composites: the rays in the wild flower are usually white, a color which in this instance evidently was preceded by the yellow color of the disc flowers, from which the rays were developed. In examining a semi-double Chinese flower, one may occasionally see among the tubular florets the ligulate form in various stages of development, short or long, flattened out partially or wholly, but whenever on the disc this altered flower is seen among the tubular ones, and in whatever stage of development, the color is found to be changed to white!

A change of form is often the occasion of a change of color. These transformed florets, now all white and strap-shaped, not infrequently become tinted a flesh color, a pink, or some form of purple or perhaps blue. This sequence of colors might be farther expanded to embrace the following: yellow, white, flesh color, pink, rose, carmine, crimson, pink-purple, lilac, blue-purple, violet and violet-black. But this series does not comprise all the well-known hues of this many colored flower. There are, for instance, varieties of Chrysanthemums as large and as highly developed every way, yet having the entire head composed of yellow ligulate petals. Whence then comes this yellow variety? Simply from the fact that Nature is not confined to one inflexible law in regard to the order of development of color, whether in flowers of simple or of complex construction.

If one examines the central florets of a semi-double yellow flower, it will be seen that upon the change of form to ligulate, no change whatever is effected in its color, and thus the entire flower in its transformed character from tubular to ligulate remains yellow, not losing that color as in the former series, but on the contrary is very apt to add to it some form of red or even of purple, resulting in many of the most beautiful secondary and tertiary hues known to flowers. This series would embrace: yellow, straw, orange, scarlet, salmon, purple-brown, maroon and black, and intermediate hues with an infinite variety of tints and shades difficult to describe. That this last series of color is not confined to high classed and cultivated flowers can be shown by going back to simple *Ranunculaceæ*, than which none of the polypetalous division are more primitive; and among the genera, Clematis may be regarded as perhaps the simplest. Here are but a few yellow flowers, none wholly yellow in North America, yet *Clematis reticulata*, *Walt.* is said to be pale yellow inside, reddish outside. *C. coccinea* is scarlet. *Aquilegia Canadensis*, sometimes yellow, is generally scarlet, except at the tip and within the petals, where it is yellow; *A. flavescens* has "sepals sometimes scarlet tinted outside."

Trollius has two species, deep orange-colored.

Potentilla Wm. Rollisson is orange-scarlet, a simple flower of *Rosaceæ*. *Ranunculus*, or buttercup itself with all its claimed simplicity, adds red in *R. Asiaticus d'Olanda*; in cultivation it is a magnificent double flower of a bright scarlet color!

It will be observed that this change of color is in the same direction in the simple *Clematis*, *Trollius* and *Ranunculus*, etc., as in the more specialized Columbine and in the highly developed Chrysanthemum, and that the colors do not pass through white to pink, etc., which fact will be especially referred to farther on.

It may also be added that the simpler Clematis has more purples and blues than the higher developed Aquilegia, or at least as many, the latter having ten yellow or scarlet species to only two purple in North American species. The list of flowers belonging to this series, many exclusively so, is immense. Among the number are the following, in several of which the red pigment may actually be seen flushing from day to day the yellow surface of the petals: *Cuphea*, *Corezema*, *Manettia*, *Libonia*, *Gesneria zebrina*, *Canna*, *Lantana*, *Tropæolum*, *Tulip*, *Poppy*, *Tritoma*, *Escholtzia*, French Marigold, *Lonicera sempervirens*, *Lachenalia Nelsonii*, *Rosa lutea*, var. Copper Austrian Brier is yellow externally, but inside a brilliant orange-red. *Taraxacum* (Dandelion) and *Leontodon*, have the outer row of ray petals, commonly a reddish-purple on the lower surface. In upwards of one hundred species of Aster, the central yellow florets change directly to a reddish-purple.

Polygala sanguinea and *P. cruciata*, have an exceedingly interesting color change not noticed by any of the Floras: The conspicuous color in the heads of these flowers, usually a rose-purple, belongs to the sepals, but the small true flowers are first yellow, then orange, and finally a rose-purple, very much like the sepals in color. All these colors may be clearly seen in the same head in a bright, clear day!

Castilleia coccinea, flowers, or rather the bracts, yellow and scarlet. "Garden and Forest" states that flowers of the yellow American Hamamelis have been found in New York state with bright red petals. From the foregoing it will be seen that yellow to red is a very common and natural succession of color, especially if the red be a vermilion or scarlet. *Kniphofia* or *Tritoma*, the Flame Flower, retrogrades from scarlet to yellow, the young flowers at the top being scarlet, and the older at the lower end of the spike being yellow.

In view of the above well-established facts regarding the order of color change, it is truly astounding that Grant Allen should make a statement so glaringly erroneous as the following, which ignores nearly one-half our choicest and best known blossoms:

"As flowers advance in type they pass from yellow, which is the lowest color, through white, pink, red, and lilac to purple and blue, which are the highest. And when through any special cause they begin to retrogress, they pass backward through the same stages in inverse order"!

Grant Allen recognizes two compound colors, lilac and purple, in his scale, but utterly ignores others, such as orange, scarlet, brown, brown-purple, green and other of the second series above mentioned, and his sequence is one only of two which are equally important, not mentioning others of less occurrence.

CHAPTER II.

Certain yellows evidently are the product of a preceding chlorophyl green. Chemists inform us that the coloring of chlorophyl is composed mainly of yellow and blue pigments, which can readily be separated.

This process takes place naturally in leaf and petal, the blue portion being absorbed by the plant, or in some other manner eliminated, while the yellow element remains. This may be illustrated by the Chinese primrose, which, of whatever hue, has a central green eye. This green spot often remains unchanged, but usually it becomes modified, in color varying from yellowish green to pure yellow, the yellow color being confined strictly to the space previously occupied by the green. It is obvious therefore that this particular yellow was occasioned by the decomposition of the chlorophyl. The same is true in most cases of both green petals and green leaves, viz., that the yellow depends for its existence upon a previous green color. If one observes the ripening leaf, even before there is any frost, say as early as the middle of August, he will find that some of those of *Rhus copalina*, for instance, have become already of a yellow color, other leaves on the same bush will be scarlet, while others still may be partly yellow and partly scarlet. A similar color change is seen in maples, *Croton*, *Coleus*, *Achyranthes* and in green petaled flowers. Which color ought one to pronounce the most primitive? According to Prof. Vines, "the green and the yellow coloring matters of plants are deposited in corpuscles of a protoplasmic nature, but the others, especially the red and blue, are dissolved in the cell sap. It is to the presence of coloring matters in solution in the cell sap that the colors of petals are principally due." The red and blue colors then are quite independent of the yellow. They may develop before the chlorophyl has dissolved into its components, or they may appear while the decomposition is taking place or afterwards, or the yellow principle may vanish with the chlorophyl and so never develop. The red coloring matter suffusing the green or the yellow petal or leaf produces a scarlet or a darker shade, precisely as the mixing of artists' pigments would do. Therefore it is apparent that when a chlorophyl green is the foundation, the first color to follow is not restricted to yellow, but may be red, purple, or blue.

There are other yellows, however, or at least of a different origin, which are developed from a pure white foundation. These are seen in *Lonicera longiflora*, garden bush, pole and Lima beans, many orchids, and in a less degree in tuberose, jasmine, etc., which become yellowish by age, and in Fungi.

We know furthermore, by the examples heretofore given of Cypripedium and Angræcum, that some greens do not become yellow at all, but they gradually and sometimes very slowly indeed, as in *Lapageria alba*, fade evenly away to a pure white ! *

Therefore not only a yellow and a green color, but for that matter any color, to use a popular expression, may fade out to a pure white, as we may have occasion to show.

The writer has not yet been so fortunate as to have seen the original statement of De Candolle regarding color. If his oft quoted "xanthic and cyanic series" referred to species of flowers, each of these divisions would contain the most heterogenous assembly of flowers imaginable, and such an arrangement could hardly be conceivable of a botanist of his intelligence ; he doubtless referred merely to the evolution of color as a separate and independent feature of flowers, such a division being not inappropriate, for, indeed, with comparatively few exceptions, all hues might be comprised in these two series to which we have already alluded ;

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* See Lapageria alba and others in the list, Chapter IX.

the xanthic comprising green, yellow, orange, scarlet, etc., etc., all containing some yellow, and therefore making the designation quite appropriate, while the cyanic or blue series, beginning as in the xanthic with green and yellow, would diverge at this point and continue through white, red, crimson, purple and violet to blue; or white might immediately follow green, in which case yellow as a rule would be excluded from the series.

Numerous browns, brown-purples and similar shades would not be in either direct line, but might be considered as early digressions from the regular gamuts.

Although the progression of each series is given from the lighter to the darker tints, it should be remembered that the reversed order would be just as natural and just as primary, as Nature has no hard and fast rule regarding color. Each series also is stated in a definite sequence, not because it is an invariable rule, but because broken links of the chain comprising two, or occasionally three colors, may be found, which united will make a complete series.

To illustrate, there are many species in *Borraginaceæ*, having flowers which expand of a pink or light crimson color, but quickly and regularly change to purple or blue; and white flowers are very apt to become pink, while the white color itself frequently can be traced to a previous yellow; so that the order is yellow, white, red, purple. This succession of colors may occasionally be noticed in a single flower, as in the Chinese primrose; it has a green eye, changing more or less distinctly to yellow, the other part of the flower has become white quite likely, but not necessarily, from a previous yellow like the eye, the latter being the honey-guide relic which will be particularly discussed in the second chapter. This same white flower often turns crimson and in fading becomes a blue-purple. But while this order appears to be very common, as a matter of fact every color may spring directly from white. Scores of species are known only as white or blue, white or red, white or yellow, each of the latter colors proceeding directly from white or retrograding to white: or these three primary colors may, as we have shown, originate immediately from the chlorophyl green, or actually precede it!

CHAPTER III.

The *Ranunculaceæ* are placed first in order in our Floras, we imagine for the reason that the flowers of this family are very simple in construction, especially so if we except some peculiar shapes of petals in *Aquilegia*, *Aconitum* and *Delphinium*, but even in these as well as in all the others, all the parts are separate and distinct. Hermann Müller calls a flower simple which is without any consolidation ot either the essential organs or floral envelopes.

Grant Allen, in elucidating his color theory, selects from among this family the common yellow buttercup (Ranunculus) as a typical example of a simple or primitive flower and maintains that it is prevailingly yellow "because it is an early and simple type of flower."

But before accepting his conclusions one should be fully assured as to the correctness of his premises; we therefore would like to be informed in the first place, if it really is "the simplest and least differentiated member of the group," as he puts it, and if there is no member equally as simple and yet having a different color.

Can one believe that there are no species of that family *even more* primitive in character? Take for instance *Clematis Virginiana*, the Virgin's-Bower; this flower has not even developed any petals, it is so primitive, and the number of its white sepals is but four, instead of the more common number five. A double Clematis growing in the writer's grounds throws some light on the color of this flower and on the cause of its having but four sepals. It was remarkable in having its leaves near the flower which was terminal, white like the flower. The lower leaves were opposite, those higher up in whorls of four, or two pair brought together, while near the flower a whorl of twelve leaves, that is six pairs, was completely merged into sepals. The four outer had long petioles with blades, mostly green, but containing some white, a second inner row of four had more white on the blades with shorter petioles, while within these the blades and claws, wholly white, were of the same length as the sepals or real flower. Some of the stamens had the anthers unrolled into small petals, supported by long filaments: thus there was a complete gradation from foliar leaf to petaloid stamen. It was obvious that the white color from leaf to stamen resulted from the same cause, viz., the lack of chlorophyl. If any color could in reality be more primary than another, the white or greenish-white of *C. Virginiana*, being at least nearer to the fundamental tissue color, is entitled to that honor

From the above example of an abnormal Clematis we learn that the four sepals are merely a whorl of four leaves simply reduced in size, and not being any longer vegetative in character have dispensed with their chlorophyl, and now white, may assume some other color as purple or blue, if such color should be for their advantage. As a matter of fact, the different species are almost wholly white or purple, there being very few indeed of a yellow color.

There are perhaps a dozen species in cultivation of a white color. The anthers, at least in some of them, are not even yellow, but as white as the filaments and sepals, and moreover, so slightly differentiated from the filament as scarcely to be detected by the unaided eye. The pollen also is white!

It is not necessary in these flowers to consider the question whether original petals are derived from stamens or not, for we know that the colored sepals of Clematis never were stamens! If we compare Clematis with Ranunculus we find that the former in the absence of true petals is certainly more primitive, or at least more simple, than the Buttercup, which is a complete flower, being furnished with both whorls of floral envelopes, and the thick, glossy petals still farther advanced by the presence of scale-like nectaries at their base.

A little more developed than Clematis, are *Anemone patens* (Pulsatilla), and *Atragene*, both of which make a feeble but vain attempt to produce petals by their "gland-like, abortive stamens answering to petals," and by "enlarged filaments more or less petaloid."

Still higher perhaps in the scale of development is *Cimicifuga*, which actually has a few diminutive petals, which with the numerous stamens are white!

We might allude to the frail, purple-flowered *Anemone nemorosa* as another blossom much simpler than Buttercup, and also refer to the fact that of this genus *A. Robinsoniana*, *A. apennina*, *A. blanda*, are of a sky-blue color! But we are not obliged to go out of the Ranunculus genus itself to find real Buttercups having white, red, or scarlet flowers as well as those of a yellow color.

R. Andersonii, Great Salt Lake vicinity, is pink!

R. Asiaticus has yellow petals with reddish tips, stamens with the anthers and the pistils brown!

R. Asiaticus var. d'Olanda, a cultivated variety, is a magnificent double *scarlet* flower as large as a double Dahlia! Some of these flowers show a little yellow at base of the petals, thus proving that the color was formed directly from yellow by the addition of red.

R. Anemonoides is white tinted with pink!

R. Lyalli is pure white, stamens yellow!

There are varieties of *R. Asiaticus* which are purple! yellow, orange, and variegated white, yellow or red; thus all colors except blue are already found among Buttercups and it would not be so very astonishing if a blue one should some day be discovered.

A partial list of *Ranunculaceæ*, showing their colors:

Helleborus colchicus, bright purple, stamens yellow.

Nigella Hispanica, blue, stamens blood-red.

Cimicifuga racemosa, every part of the flower is white, including filaments and anthers.

Clematis caerula, violet, stamens deep purple.

Do. Virginiana, white, stamens white.

Hepatica triloba, blue, filaments and anthers white.

Do. angulosa, blue, filaments, anthers and pollen white.

Ranunculus Lyalli, pure white, stamens yellow.

Do. Austinea, pure white, stamens yellow.

Do. Asiaticus, various colors, stamens brown.

Do. bulbosus, etc., every part yellow.

(Atragene), *Clematis alpina*, bluish-violet, stamens yellow.

Thalictrum Cornuti, white, filament and pistils white or greenish.

Isopyrum, *Actæa alba*, Clematis of white flowered species, have filaments and anthers white.

Anemone Virginiana, every part white.

Anemone nemorosa, white or purple, filaments and anthers snow-white.

Do. Italian, scarlet or purple, anthers and stigmas dark purple, almost black.

Trauretteria, all parts white.

Nigella, *Xanthorrhiza*, *Aconitum*, blue or purple, and *Anemone Virginiana*, white, have green or greenish stamens!

Delphinum Ajacis, purple, filaments and style whitish, anthers black-purple.

Do. triste, dark, dusky brown.

Anemonella thalictroides, white, filaments white, anthers yellow.

Aquilegia Canadensis, scarlet and yellow, filaments pale green.

Aconitum Californicum, blue-purple, filaments and anthers green.

Hydrastis Canadensis, greenish-white, filaments and anthers white.

Helleborus viridis, purple, tubular petals very small, perfectly green.

Caltha, yellow, white or pink.

Clematis, white, scarlet, purple, greenish, and a few yellow.

Helleborus, purple, greenish-purple and white.

Aconitum, purple, blue, white, yellow.

Anemone, white, greenish-white, purple, pink, sulphur color, blue, yellow.

Adonis, yellow or red.

Ranunculus, yellow, white, pink, scarlet, or partly purple!

Delphinium, scarlet sepals and yellow petals, purple, blue, white.

Among a dozen species of American Aquilegia, three-fourths of the number are yellow, notwithstanding their high development.

Aconitum has many blue flowered species, but it also has at least thirteen species or varieties of a yellow or cream color!

We have shown that the prevailing color of numerous species unquestionably simpler than the buttercups, are white or purple, with several reds and many blues. The remarkably developed Aquilegia is mainly yellow, and while Delphinium and Aconitum have in the American species the most blues, there is really very little difference in colors between the species of the highest and lowest of the Crowfoot family, or say between Aconitum and Clematis.

There are to be found among the *Ranunculaceæ* an unusually large number of species having only colored sepals, except that at the same time there is apparently an attempt to produce real petals, with the result only of modified stamens of the outer row, which do not grow at once as in the case of double flowers into perfected petals, but remain half transformed and diminutive.

They represent at least a transition state, and being the nearest approach to true petals, ought to be of a golden yellow if it be true that all petals were originally of that color, but in reality they are generally white, also the stamens from which they develop are white!

We have discussed the *Ranunculaceæ* at some length, for the reason that great stress was laid on the yellow buttercup by the author of "The Progressive Color Theory," as showing an example of a simple flower having "the golden yellow" color said to be peculiar to "almost all of the earliest and simplest types of *existing* flowers," which are seldom white and *never blue*!!

CHAPTER IV.

It might be interesting to notice a few more statements of Grant Allen, who endeavors to show why the buttercup is yellow, the stitchwort white, etc., viz.:

1. "All flowers it would seem were in their earliest form yellow; then some of them become white; after that a few of them grew to be red or purple; and finally a comparatively small number acquired shades of lilac, mauve, violet or blue, and when through any special cause they begin to retrograde, they pass backward through the same stages in inverse order." "Almost all the members of the most advanced families are purple or blue."

2. "The *Violaceæ* are a whole family of bilateral flowers highly adapted to fertilization by insects; and as a rule they are deep blue in color. This is the case with four of our British species."

3. "The highest mode of adaptation to insect visits is found in larkspur, *Delphinium ajacis*, which is blue, white or red; and still more developed in monkshood, *Aconitum napellus*, one of the deepest blue flowers we possess."

4. "*Aquilegia vulgaris* is blue or dull purple, but readily reverts to white or red."

5. "The *Corolliflorae* betoken in their shape high modification; yellow is a comparatively rare color, while purple or blue become almost the rule."

6. "The *Borraginaceae* are another very advanced family of Corolliflorae, and they are blue almost without exception."

7. "Most early and simple flowers are yellow because the stamens are generally yellow, and when they developed into petals they naturally retained at first their original coloring."

8. "In ox-eye daisy and May-weed the rays have become white, and this I think establishes the fact that white is a higher development of color than yellow."

9. "It is not remarkable that the pinks should never be yellow, as the five principal carpels have completely coalesced into a five celled ovary."

10. Progressive coloration is said to follow the modification of flowers from the simpler forms to those highly specialized. Among the former are buttercups, potentillas, the *Alsineae*, and *Alismaceae*, as Alisma and Sagittaria; and among the latter, violets, peas, composites and orchids, harebells, heaths and labiates.

We answer in the same order:

No. 1. Has already been for the most part fully answered. In *Ranunculaceae* there is not the slightest evidence that the numerous purples and blues have ever been yellow, and as may be seen from a foregoing list, the stamens are by no means prevailingly yellow, and from a list a little farther on it will be proved that purples and blues are no more common in orchids, *Leguminosae*, *Compositae*, *Scrophulariaceae*, etc., than in *Ranunculaceae*, etc.

No. 2. Every one knows that in our Northern States white and yellow violets are common, there being four or five white flowered species and three yellow flowered species, with several other yellow kinds in California.

No. 3. Delphinium has two or more species with yellow petals, and Aconitum thirteen species and varieties yellow or cream color!

No. 4. Our New England Aquilegia is scarlet tipped with yellow; it is not a reversion, but a progression from yellow to scarlet. California has two or more species wholly yellow!

No. 5. We have only to point to the immense number of yellow disc florets of this form of flower in Composites, to the squash, cucumber, *Gerardia*, *Mimulus*, *Verbascum*, *Calceolaria*, *Oenothera*, *Lonicera*, *Allamanda*, *Bignonia*, etc., etc., all yellow!

No. 6. We count in Lowden, whose list is very incomplete, thirty white species and twenty yellow flowered species!

No. 7. The stamens in *Ranunculaceæ* are very largely white or purple.

No. 8. In *Cineraria*, the cultivated species are mostly crimson, purple or blue and never yellow, and the centre florets are of the same color! These rays in various varieties are in all stages to pure white. *Sericocarpus conyzoides*, central florets pink-purple, rays white. Nearly every color under favorable circumstances becomes white

No. 9. The great majority of species have their carpels more or less united; we will only mention a few: *Nuphar* ovary, eight to twenty-four cells, yellow; *Oenothera* pod, four cells, yellow; *Hypericum* pod one celled, styles three yellow, etc., etc.

No. 10. We have shown that buttercups have various colors, and we can add that Potentilla has beside the common yellow also rose, white, scarlet and dark crimson hues, and in P. palustris a purple color!

In regard to *Alismaceæ* we quote as follows:

"The common arrowhead is one of the earliest and simplest threefold flowers of separate sexes, with a white corolla of somewhat papery petals. The water plantain, another form of early threefold blossom, both sexes combined, has delicate pinky-white petals and a number of small one-seeded carpels exactly as in the buttercup, which occupies in part the corresponding place among the five-fold flowers. Save that the petals are now pinky-white, while those of the original ancestors *were almost certainly* yellow, we might almost say that the marsh-weed in question was really the earliest petal-bearing plant of which we are in search."

When Grant Allen writes on the history of certain plants and does not treat specially of their color features, his observations are at variance with his favorite theory, as seen in the colors of Alisma and Sagittaria. By his theory, as the Alisma is one of the earliest and simplest flowers, it ought to be yellow, but it is really white or even pink, without the slightest trace of yellow. This discrepancy is noticed by its author and is remedied by hypothesis: by guessing that sometime in the long past, it might be 80,000 years or so, the flower "almost certainly was yellow"!

It is indeed very unfortunate that not a single example of any existing flower could be found in all the great endogeneous class of plants to illustrate the theory!

If all petals and stamens were first yellow, why not the pistils and the base of the pistils, which later becomes the fruit, as this is but a part of the flower which continues to develop after certain other parts wither and decay.

Doubtless this idea would strike every one as absurd, but it is quite as reasonable as that every flower was originally yellow.

The development of color in fruits from the green state to maturity is a very interesting study, and the methods are as diverse as one can conceive.

CHAPTER V.

CHANGES which take place in the individual flower, proving that THE SEQUENCE OF COLOR IS NOT uniform.

Viola tricolor, yellow to purple or blue, and purple to yellow.

Æsculus and *Catalpa*, honey guides yellow, change to rose-purple.

Pelargonium, scarlet varieties are apt to be rose-color in bud.

Aster umbellatus, white: central florets yellow to pale green.

Do. corymbosus, white: central florets yellow to rose-purple.

Of the large family of Asters, one hundred and fifty species, more or less, the central florets are usually yellow at first, but change regularly by age to some form of purple.

Strophostyles angulosa, the green bud expands a clear pink color, changing, except the diminutive tip of the keel, entirely during the day to a creamy yellow or light buff in the evening.

Phaseolus vulgaris, common garden varieties either white or purple and the Lima bean, change color to yellow, especially the wing petals.

Helianthus cucumifolius, yellow: central florets with yellow tube, the lobes only, dark, red maroon, chlorotic chaff among the florets tipped with crimson.

Cassia nictitans, yellow; stamens yellow at base, upper half is crimson, changing to purple and the anthers purple!

Cleoma, a variety with slender white petals on long purplish claws, filaments purple, the petals have a tendency to become a lemon-yellow.

Globe Amaranth, the head is composed mainly of the prominent dark crimson bracts: the minute flower is first white, but changes to the same crimson.

Zinnia has large, coarse textured outer petals; some varieties of these at first lemon yellow, become orange, then scarlet, and with age crimson!

The central florets do not change their yellow color. Certain other varieties begin with white which is then followed by quite a different series of color, similar to those shown in Chrysanthemums.

Prenanthas alba, white, has a light green involucre or sepals which change to purple.

Chrysanthemum tri-color is variable, the rays being yellow at base and red at the tip, or yellow at base, then red above and the tip white, while the disc florets are purple-brown.

Cheiranthes Cheiri, certain varieties at first lemon-yellow, change directly to pink.

Phaseolus vulgaris var. multiflorus. The inner petals of a very young bud of the Scarlet Runner bean are pink and white; when half grown and when expanded they are orange-scarlet.

Euphorbia polygonifolia and *E. maculata*, white, on expanding change to pink.

Saponaria officinalis, frequently expands white, afterwards changes to pink and fades finally to purple.

Polygonum aviculare, the green sepals have a white border changing to pink.

Arctium Lappa, burdock, not infrequently opens white and changes to rose-purple.

Gaillardia, central florets green, tipped with purple-brown approaching crimson on the outer row. The rays also tubular, though much elongated and with modified lobes, are greatly changed in color from the central florets, as the tubes are dull scarlet and the lobes bright yellow! This is a good example of different manner of color development and change in the same compound flower. The yellow here is secondary to the red!

Cakile Americana, commonly at first white and its filaments green, both change to purple, and the green sepals with age become yellow.

Rhexia Virginica, rose-purple, the yellow filaments change to scarlet after expanding, also the lower half of the yellow anther.

Sisyrinchium angustifolium, blue, the upper portion of the yellow filament changes to blue, while the lower part remains unchanged!

Polygala polygama and P. cruciata have their true flowers pale yellow, changing through orange to rose-purple!

Cobea scandens, pale green the first day, the inside of the lobes become purplish on the second day, and by the third day the entire bell-shaped corolla has become a beautiful purple!

Erigeron Canadensis, the outer rows of minute white flowers turn purple.

Lindelofia, *Symphytum*, *Anchusa*, *Ompholodea*, *Mertensia*, *Pulmonaria*, etc., change from pink or red to blue.

Myosotis laxa, in bud white, becomes first pink, then light blue. The different species all have a yellow eye.

Gerardia maritima, petals purple expanded, are of a pale yellow in a half developed bud. Anthers and pollen snow-white.

Lycopus Virginicus, white; in the bud or just before expanding is a pale yellow; at least those growing in dry soil and sunny places; also *Alyssum maritimum*, white, under certain circumstances has been observed to be pale yellow in bud.

Aster vimineus, white, and several other white species change to pink, lilac or rose-purple.

Primula Sinensis, Chinese primrose, has varieties first white, changing through pink to crimson or purple and fading to blue-purple.

Lonicera longiflora, pure white changes to pure yellow! and several other species of different colors become decidedly yellowish with age.

Loniceras have a strong tendency to yellow as seen by the following descriptions: cream colored, yellowish-white, greenish-yellow, greenish-yellow tinged with dull purple, yellow tinged with red, scarlet outside and yellow within, scarlet, whitish with a purple tube fading yellowish, at first snow-white but finally changing to golden yellow!

Composite flowers, having different shaped flowers in the same head have different color changes: *Bellis*, the daisy, *Chrysanthemum*, etc., change the central, tubular, yellow florets to white, ligulate ray petals, which often become pink or in some genera purple or blue: other genera change the tubular to ligulate without change of color as in *Rudbeckia*, *Coreopsis*, *Baldwinia* and *Helenium*, but do change the central florets to brown or brownish-purple; in others the yellow rays change to some of the following colors: brown, brownish-red, maroon, copper colored or dark red-purple as in *Coreopsis coronata*, *C. Harveyana*, *Helenium elegans* and *H. nudiflorum* and in several species of *Gaillardia*, *Dysodia*, *Psathyrotes*, *Troximon*, *Lactuca*, *Nabalus*, etc.: in *Erigeron bellidifolius*, the central florets turn a rusty color; in *Sericocarpus conyzoides* the central florets are never yellow, but pink-purple usually changing to white, while *Cineraria*, at least in ordinary varieties, has both rays and centre of same color, viz.: crimson, lilac, purple or blue, and never yellow! Asters have rays of different colors from their centres, which last commonly change from yellow to a vinous purple.

Even when the two kinds of flowers in the same head have similar colors, the variegation in some species is exactly reversed, as in *Gaillardia* and *Coreopsis*, the purple-brown color being at the tip of the yellow corollas of the centre and at the base of the rays! *Hieracium aurantiacum* goes from yellow to orange. *Pyrethrum uliginosum*, rays white, has central florets of a green color, the minute lobes only are tipped with black!

Florists' varieties of Chinese Chrysanthemums, Dahlias, etc., have innumerable hues.

CHAPTER VI.

WHERE yellow flowers may be found:

Helleborus, several species absolutely green, and *Nigella Nigellastrum*, flowers brown and green!

Aquilegia has several handsome bright yellow species, and notwithstanding that this flower is highly specialized. *A. viridiflora* is green flowered!

Delphinium has one section consisting of species with calyx and petals of different colors, the petals being wholly or partly yellow.

Aconitum, in section of fibrous roots, thirteen species or varieties are yellow or cream color, only six purple, but in section of tuberous roots are mostly blue or violet.

Anemone and *Hepatica*, very simple flowers, mostly blue, purple or white.

Clematis, chiefly blue, purple or white with very few yellows generally of a dull color.

Ranunculus, mostly yellow, has many whites, also pink and purple.

Paeonia, though of the *Ranunculaceæ*, appears to have no yellow flowered species!

Caltha, commonly yellow, has species rose tinted or bluish.

All of the above belong to Ranunculaceæ.

Malvaceæ: Abutilon, eight species cultivated are yellow or orange.

Malva, twelve yellows and many purples.

Hibiscus, twenty yellows and twelve purples.

Sida, fifty-eight yellows and one purple

Amaryllidaceæ: *Alstromeria*, *Bomarea*, *Zephyranthes*, *Narcissus:* this last has fifty-four species either white or yellow, some with highly developed cups or trumpets, also the others very handsome, preponderating colors yellow, orange or scarlet. Hypoxis same order, all yellow.

Liliaceæ: *Blandfordia*, *Hemerocallis*, large, beautiful, chiefly yellow, larger and handsomer than *Funkia*, white or purple, also *Lilium*, *Erythronium*, *Uvularia*, *Tulipa*, *Kniphofia*, etc.

Bignoniaceæ, Bignonia flowers tubular, ten cultivated yellow species, also Tecoma, etc.

Scrophulariaceæ: Veronica has eighty species wholly purple: this genus has its color ascribed to it on account of high development: but high development is wholly valueless with regard to color, with *Verbascum*, *Celsia*, *Gerardia*, *Pedicularis*, *Linaria*, *Verbascum*, *Mimulus*, *Gratiola*, and many other genera of the same family, largely yellow and superior every way. *Calceolaria* with yellow or xanthic hues is more highly modified.

Ericaceæ: some of the largest and handsomest, as in Rhodendron, are yellow.

Hypericaceæ: Hypericum, sixty-six yellows and one red!

Onagraceæ: Oenothera, a large family, is almost wholly yellow.

Primulaceæ: Primula, a dozen species yellow colored, tubular, salver shaped, etc.

Lysimachia and Steironema, all yellow.

The smallest flowered species have the darkest hues!

Cruciferæ: the flowers are about equally divided into white, yellow or purple colored.

Geraniaceæ: Pelargonium, thirteen yellow species. Impatiens and Oxalis, Tropæolum, etc

Rubiaceæ: Palicourea, a genus of one hundred species with elongated tubes, mostly yellow or white, never blue! *Rondeletia*, many yellow and white; yet *Houstonia* of this family has thirteen species and varieties, small flowered, all blue or purple. *Bouvardia* has some yellows.

Labiatæ has many yellows in *Sideritis*, *Galeopsis*, *Galeobdolon*, *Stachys*, *Phlomis*, *Leonotis*, *Teucrium*, *Hyssopus*, *Salvia aurea*, *S. glutinosa*, *S. indica*, *S. officinalis*, etc.; on the other hand *Mentha* and *Thymus* bear small, purple flowers and not a single yellow one! On the whole, purple and blue far exceed all others.

Irideæ: Gladiolus, Iris, Ixia, etc.

Caprifoliaceæ: Lonicera, a dozen or more yellow flowered species.

Caryophyllaceæ: yellow flowers are scarce, but Silene has three species, Saponaria one, and Dianthus one, and doubtless there are others.

Cucurbitaceæ: largely monopetalous, and even bell shaped are quite generally yellow as in pumpkin, cucumber, watermelon, etc.

Borraginaceæ: flowers largely purple or blue, or changing from pink to blue, yet *Amsinckia*, *Onosma*, *Lithospermium* section *Batschia*, all yellow or orange!

Rosaceæ: Rose, the Queen of Flowers, has yellow species and other genera yellow.

Compositæ: native composite flowers have fifty per cent. more yellow flowered than purple flowered species! This family probably has more yellow flowered species than all others of the family put together.

Umbelliferæ: have for the most part white flowers, next those of a yellow or green color.

Leguminosæ: the flowers are recognized at once as highly modified and specialized, with butterfly shaped corollas mainly, yet upon an enumeration of the species in London's Encyclopedia there were found to be 548 yellow species to 372 of all other hues put together!

Lentibulariaceæ: Utricularia, largely yellow.

Violariaceæ: violets, about as many yellows as white or violet, there being two yellow flowered species in Massachusetts.

Liliaceæ: Aloe, all colors, yet forty-three out of ninety-nine species are green!

Verbenaceæ: Verbena, a large family almost wholly red, purple or blue, but the flowers are small or only mediocre; Amasonia, however, corolla with elongated tube, sub-bilabiate, has four species yellow or sulphur-colored!

Orchidaceæ: There are very few native orchids of a yellow color, but many of a green or greenish color, a few rose or brown, but no blues! while exotics are pretty evenly divided among purple, red, yellow, white or green, with many of a brown color and very few blue! The prominence of green flowered species of both small and large size is quite noticeable, and yet this family is in the highest rank of specialization and modification.

Alismaceæ: has Butomus and Alisma rose colored, Sagittaria white.

Naiadaceæ: ranking lowest of all, *Aponogeton*, no petals, but large bracts white or pink, anthers purple-brown.

We are obliged to omit many other Orders for want of space, but if one could see a complete list of yellow flowered species he would incontinently abandon the idea, if he ever had such, that yellow flowers are confined to simple or primitive types. We think, however, that the general list of Orders above given will be ample evidence as to where these species are to be found.

White is designated as a low or primary color, yet as in the case of yellow, it is found all through the floral world: *Viburnum*, *Cornus*, *Andromeda*, *Saxifraga*, *Arenaria*, *Cratægus*, *Capsicum*, *Clerodendron*, *Umbelliferæ*, the magnificent *Easter Lily*, trumpet-shaped, nine inches in length, *Pancratium*, *Convallaria*, *Nymphae*, *Yucca*, *Gordonia*, *Stuartia*, *Camellia*, *Exochorda*, etc., magnificent Orchids and Chrysanthemums, etc., etc.!

We think that enough has been said to make it perfectly clear that the statement: "that almost all the members of the most advanced families are purple or blue," is very inexact.

COLOR STUDIES.

CHAPTER VII.

Myosotis, Forget-me-not, presents a succession of four colors. The stamens and eye are yellow; the five minute rays extending from the eye and completing the star-like centre are white; the corolla, at first a clear pink, changes gradually to deep blue. The order is yellow, white, pink, blue; but if one examines a bed of Myosotis critically he is likely to notice exceptions to this sequence.

The yellow anther never becomes white, but changes directly to brown! The nectary changes to white only; not uncommonly an entire plant bears pink flowers, changing if at all to white; and such flowers as do become blue are apt to change again, but to white also.

Thus all three colors under certain conditions become white. The common white variety is derived from the blue, and with a lens, frequently remnants of the blue may still be detected. It will be observed that these colors do not retrograde in the same order as they advance.

While many examples of a sequence similar to above are to be met with, there are certain yellows that change directly to blue, no white or red intervening, though usually some white, as in Pansy. The yellow anthers and pollen of crimson Tulips with a yellow centre become blue; and these yellow centres themselves change through green to a dingy blue, which in the variety *T. Gesneriana* is a permanent pure blue which sometimes appears as a blue star on a round yellow eye!

On certain yellow Pansies, not the lightest yellow, but those more of a Cadmium yellow, is frequently to be seen a dingy or olive green blotch which finally disappears, leaving the flower of a clear color. If one will examine the half or even two-thirds developed bud of the same plant, he will find that its color is then partly or wholly violet, and that the commingling of this with the developing yellow occasions the greenish blotch. Sometimes a flower may be found entirely and evenly colored a greenish yellow from the same cause. Furthermore, if one picks open the bud of a purple-brown or reddish-brown and yellow variety, which is not a rare combination, he will find it also to be purple. These brown varieties fade finally to yellow. Anyone therefore can satisfy himself of the fact that violet or blue purple precedes yellow in Pansies by analyzing the colors, selecting of course suitable varieties. The writer has often found a bud pure violet and an expanded flower of the same plant pure yellow!

The yellow Pansy as it exists today was undoubtedly once of a purple or violet color, as is clearly shown by the darker face markings almost invariably to be seen and by the violet spur.

Native violets, both white and yellow, show vestiges of the earlier violet color, and the wild, violet colored violets have no yellow at all! Similarly to Pansy, many varieties of yellow Iris, Wallflower, etc., may be traced to an older purple or blue, the intermediate colors being reddish-brown or terra-cotta.

Antirrhinum majus, Snapdragon; the colors of its different varieties can be traced from purple, through crimson, brown, cardinal, terra-cotta, yellow-brown to pure yellow.

Cnicus horridulus, the common yellow thistle, varies from cream color to pale yellow, while the anthers are a lively red-purple, and in striking contrast with the other parts of the flower. The corollas extend below into a long, thread-like tube of a weak, pearly white color, in fact the fundamental white tissue which in the ultimate analysis is the basis of all color, as not only yellow, but red, purple, and blue in similar circumstances gradually fade away into this primitive tissue-white. It is more than probable that this pale yellow was not the original color, but that the latter was more like the anthers and the tips of the bracts, which last in bud are of a pronounced red-purple. The corolla, once purple, faded to white, from which fundamental color the yellow is now forming. Another indication that this yellow is not the primary color is found in the fact that it does occasionally occur of a purple color. The writer has found a single plant bearing rich, glowing purple flowers in a field where every other plant bore the ordinary yellow blossoms!

Boletus subtomentosus, a mushroom, its flesh yellow, changes immediately to blue on fracture!

Ixias are of a great variety of color in cultivation, but all have a dark centre or eye varying in hue from dark purple to bright crimson, according as they are affected by the general color of the petals. This purple eye indicates that the original color of the flower was either purple or some combination of red and blue; yet there are yellow varieties and certain varieties at first yellow, excepting the eye, change to white and afterwards become crimson, the three distinct colors being seen on the same raceme, viz., yellow at the top, white lower down, and the lowest or oldest flowers crimson! But in some varieties the crimson shows in the green bud before any yellow color develops and the flower becomes wholly crimson. Another strain of Ixias adds red to the yellow, producing scarlet of various tones and certain varieties of the latter change from scarlet to crimson! and finally with age become a purple.

Gaultheria procumbens: The calyx is wholly a waxy white, like the cylindrical corolla, but the two minute bractlets are red! At length the calyx which forms a part of the berry becomes green, and finally changes to scarlet!

Lobelia Cardinalis, to an ordinary observer, is simply a scarlet flower of one hue throughout, but on closer inspection, one finds the petals and filaments scarlet, anthers dull blue or blue-black, tipped with a snow-white fringe, pollen yellow, style greenish partly tinged with red, stigma has two crimson lobes surrounded by a fringe of white hairs, and calyx green, more or less stained with dark purple. These minutie are best seen by the aid of a magnifying glass.

Centaurea Cyanus, the corn flower or bachelor's button, is common in gardens. Select a light colored flower, pink or white; the scales of the involucre are green with a black fringe; with a magnifying glass find five colors.

CHAPTER VIII.

STRIKING CONTRASTS OF COLOR IN THE SAME FLOWER.

THE green calyx is often found to be reddening or purpling at the same time that the corolla is some other color, as white or yellow. This incipient change of color continues in some species until a clear bright color is established, contrasting strongly with the color of the petals. This fact is of itself sufficient proof that original colors develop in different ways.

Examples of diversity of color in the different whorls of the same flower are numerous, even among our native flora; we will refer to a few of these, but give a more extended list of exotics. It is often the case that the outer whorl of calyx is so much more developed that the inner is completely hidden from view, as in Masdevalias.

Delphinium variegatum, sepals purple, petals white.

Do. nudicale, sepals red, petals yellow.

Polygala sanguinea, sepals purple and green, petals yellow.

Helianthemum Canadense, sepals tinged with red, petals yellow.

Senecio aureus, tips of green sepals dull purple, flower yellow.

Leucothoe racemosa, calyx and bracts dark red, corolla white.

Prenanthes alba, involucre purplish, petals cream color.

Nuphar advena, sepals green, brown within, petals yellow.

Anaphalis margaritacea, involucral scales snow white, true flower is diminutive, and of a yellow color.

Billbergia vittata, flowers indigo-blue, tubular calyx carmine.

Iris Kolpakowskiana, falls red and yellow, uprights blue.

Clerodendron Balfouri, calyx inflated pure white, flower deep crimson. The calyx changes to pink with age. Stamens always pale green.

Phajus Bernaysi, sepals and petals china-white on outside and pale yellow within.

Streilitzia reginæ, a gorgeous flower with large orange sepals and ultramarine blue petals!

Abutilon vexillarium, calyx bright crimson, the partially protruding petals yellow.

Aechmeas fulgens, flowers scarlet tipped with blue, and bright scarlet bracts.

Cereus Lemairi, and other species, have pure white petals and bright yellow sepals.

Cerinthe retorta, flowers lemon yellow, tipped with deep purple, floral leaves, several pairs extending down the stem rich purple.

Do. aspera, flowers red-purple, tipped with yellow, floral leaves blue, tipped with yellow!

Fuchia procumbens, deep yellow tube, dark purple lobes and light blue stamens.

Bougainvillea, three large pink leaf bracts, enclosing three inconspicuous narrow linear flowers, reddish outside and yellow within the lobes

Iris Tingitana, sepals blue-purple with yellow tips, the three inner petals are blue-purple.

LEAVES OF BEAUTIFUL COLORS.

Anœctochilus, has species with broad orange and green stripes: green veined in regular lines, and covered with a network of gold.

Coleus, varieties innumerable, including crimson, crimson and yellow, purplish-crimson, dark maroon, yellow, tinted rose, etc.

Aspidistra elatior, has a variety with alternately striped green and white.

Begonia Rex, leaves deep green, banded with a broad silvery zone, or deep bronze-red centres; spotted with white, or brown-purple, nerves red, etc.

Caladium, green blotched with white; carmine-red bordered with white; uniform golden-yellow, etc.

Codiæum, Syn. Croton, green with infinite variegations chiefly with yellow, which frequently changes directly to a fiery scarlet or crimson, and the lower surface to purple-brown.

Dracæna, green, marbled and banded with various shades of yellow, and margined and veined with red.

Pandanus Candelabrum, var. green, with bands of pure white.

Panicum variegatum, white striped and pink tinted.

Arundo donax, green, striped with white.

Aphelandra leopoldi, green, variegated with narrow, white feather veins.

Strobilanthes Dyeranius, lilac-purple with pinnate green veins.

Many trees in our lawns have variegated leaves, especially in maples, beeches, etc., and numerous shrubs.

In some of the preceding the leaves are far more attractive than the flowers.

Coleus displays in its many varieties the two series of Xanthic and Cyanic coloration. Commencing with a deep purple breaking through a green leaf, one series leads through crimson and pink to white, and the other retaining the yellow element of the chlorophyl goes through scarlet and orange to yellow and finally to white.

Even in a plain green leaf of Coleus one may change to yellow and another without yellow directly to white. A blue or purple color is by no means obliged to wait for a yellow to precede it! It breaks forth when and where it pleases; it is perfectly obvious that many times the yellow is not at all in the series.

The same remark applies to all ripening leaves, whether autumnal or of mid-summer; some plants have exclusively but one series, some only the other, while many, like the Coleus, combine both kinds.

In *Plantago lanceolata* the tips of the green sepals, and in Dandelion the tips of the involucre, become an inky purple.

An example showing the constitutional nature of color is furnished in a purple variety of Norway maple. In the seedling plant the first pair of leaves is green, but the stem and second pair is reddish-purple, and this last color slightly modified may be seen in the full grown tree, in its winter buds, leaves, leaf-stalks, peduncles, sepals and style. The flower therefore, instead of being wholly green as in the common variety, is of a brick-red color, although the petals retain their greenish hue. There is no doubt as to the sequence of color here from the cotyledon leaves of a green color to the next pair purple! One may go a step farther and examine the stem of the yellow flowered *Caltha palustris* just below the surface of the ground, and find it colored a beautiful purple, which color developes *before* the chlorophyl-green!

Another example of the flower color pervading the whole plant may be seen in *Phytolacca decandra*, the pokeweed; its peduncles, bracts and petal-like sepals are a pink-purple: the entire stem becomes red, and the berries change from green through red to black.

CHAPTER IX.

FLOWERS CHANGING FROM GREEN TO WHITE.

Mollugo verticillata, is white in every detail, except three green streaks on the outside of the sepals.

Allium, the common onion, is white with a remaining green stripe through the centre of each sepal.

Ornithogalum umbellatum, is white above, and green with white margins beneath.

Euphorbia marginata, has its upper leaves and bracts green with snowy white, petal-like margins.

Parnassia Caroliniana. White petals show the basal color in the pretty green veining, and at the tip.

Polygonum arifolium, *P. Hydropiper*, *P. acre*, etc., sepals change from green to white.

Habenaria tridentata, Petals light green, become white.

Sarracenia Drummondii, has its trumpet-shaped pitchers green below, with the upper portion white with purple veins.

Cypripedium Lawrenceanum, green clouded with dull purple, has a white dorsal sepal.

Lapageria alba, is a wax-white, lily-like flower, with a calyx at first as green as the general foliage. The flower continues in bloom fresh and fair for six weeks, during which time the sepals very slowly fade out to as pure a white as that of the petals!

Angræcum, primarily of a green color as in A. sesquipedale, in the course of ten days becomes ivory-white.

A. superbum, greenish-white as to five segments, the lip becomes pure white.

A. caudatum, olive green, large clawed lip pure white, its spur nine inches long!

Nicotiana acutifolia, green outside, white within.

Cornus florida, the bracts forming an involucre to the diminutive flowers continue green till fully developed, say two inches in length, then become pure white.

Comandra, green at the base of the petals has the upper portion white, or but faintly tinged with green.

Green leaves of *Panicum*, *Pandanus*, *Begonias*, *Geraniums*, *Tradescantias*, etc., have varieties with marginal borders or surface markings of white.

FLOWERS CHANGING FROM WHITE TO YELLOW, OR DARKER HUES TO YELLOW.

Lonicera longiflora, pure white, changes in a day or two to pure yellow; also other species of this genus, of different colors, as cream, pink, etc., change to yellow.

Phaseolus, Lima bean, and common garden white varieties, change to yellow.

Angraecum citratum, white, changes to citron-yellow.

Odontoglossum Harryanum, brown and yellow, front lobe of lip pure white, changes to yellow.

Coelogyne Dayana, white, becomes tinged with yellow by age.

Platyclines glumaceum, wholly white except minute yellow lip.

Sobralia leucoxantha, white, lip golden-yellow.

Nephelaphyllum pulchrum, green, lip white.

Dendrobium thyrsiflorum, white, lip orange-yellow.

Lycaste Skinneri, alba, white, lip primrose-yellow.

Cattleya citrina, yellow, tip of lip white.

Thunia Dodgsoniana, white, lip bright yellow.

Bollea Lalindei, bluish-purple, lip golden-yellow.

Mina lobata, Bud crimson, changes through orange to pale yellow as it expands.

Colutea arborescens, Bud reddish-brown, through orange or salmon to a clear yellow.

Alamanda nerifolia, Bud dark red-purple, becomes a lemon-yellow.

Viola tricolor, Bud deep purple, occasionally changes to yellow.

Lilium Nepelense, red-purple, upper half of petals yellow.

Tuberose, Jasmine and many other white flowers fade to a yellowish color.

Numerous existing yellow flowers are known to have been derived from purple ancestors by the still remaining purple eye; examples may be seen in *Hibiscus Trionum*, *H. esculantus*, *Gossypium*, *Coreopsis*, *Lysimachia*, *Calochortis*, etc.

CHAPTER X.

SAP.

The color of a flower is not generally influenced by that of the sap: Dandelion, *Lactuca*, *Sonchus*, Hieracium, Nabalus, etc., have white sap but yellow flowers: *Chelidonium* has orange colored sap and yellow flowers: *Sanguinaria*, orange-red sap and white flowers: *Asclepias*, white sap and purple flowers: *Apocynum*, milk-white sap with stems, petioles, peduncles and calyx of a reddish color, corolla white and rose, or wholly pink.

The orange-red color of the root of celendine gradually changes up the stem to the exact yellow tint of the flower at the end.

The change of the same colored sap to white in the flower of Bloodroot seems remarkable, and yet yellow to white is a common sequence in flowers, and white to pink or purple is also common.

POLLEN.

Not only the more conspicuous parts of the flower, but the very pollen-grains have every conceivable tint; the most common are cream color, yellow, white, purple, blue, green, snuff-brown, and chlorotic or colorless.

Agapanthus, a purple lily, has very blue anthers and very yellow pollen; Red Azalea has a black-purple anther containing white pollen; Calla Lily has a bright yellow spadix and snow-white pollen; Cannabis sativa, anther green, pollen pure white; Prenanthes alba, anther black, pollen pale yellow; Lobelia cardinalis, anther blue-purple, pollen sulphur-yellow.

In examining the color of the pollen of one hundred different species of flowers, the greatest number was found to be yellow, but nearly as many white, and one-half as many purple, the others scattering, all being in about the same ratio as found in the colors of the petals, though often varying from them.

We will merely allude to other minute organs having different colors developing in different ways, as hairs, glands, etc., viz.: The hairs growing on the lower side of the green leaf of Cineraria and other plants are often purple or red, and the white glandular hairs on Azalea viscosa have little red knobs on the ends!

ROOTS.

While green is generally more primary than yellow, it is not always the original or most primitive. Any color may precede and be entirely independent of chlorophyl-green, as may be seen in examining roots, bulbs, root-stalks and sprouting stems, also fungi, all of which have colors arising directly from the structural or chlorotic white of the embryo, without any special order of development.

Familiar examples: Beet: roots, stems, etc., red; Carrot, reddish yellow; Parsnips, from cream color to pale yellow; Turnips, with purple tops and yellow turnips with purple bases! Onions, of all colors: Radish, pure crimson: Medeola, Indian Cucumber-root, white: Coptis, Goldthread, bright yellow, etc., etc.

Likewise many petals show color in their earliest stages, especially such as are well protected with sepals, as the Red Rhododendron, etc., without any development of chlorophyl.

DOUBLE FLOWERS.

Whenever stamens change to petals as in double flowers, whatever the color of the anther previously, the new growth caused by the unrolling of the anther and filament which may be of different colors, immediately takes a new departure in color. Frequently a part of the original anther with its original color will remain attached to the incipient petal, as a blue anther cohering to a crimson petal in Tulips. The prominent green stamens of *Nigella Damascena* change directly to a clear blue color, etc., etc.

Why does the color change so completely unless there be special needs for special organs?

Double, so called, English Anemone, has a tuft of green leaves in the centre of the flower, why do these turn white like the petals when they get their growth, or similar leaves of pink flowering Almond change to pink, or both leaves and stamens of white Spiræa become white?

PIGMENTS.

Yellow, green or orange pigments are found in variously formed granules in the cells of the tissue: blue, violet, and rose-red are dissolved in the cell sap. Chlorophyl, contained in the green granule, can be abstracted by the use of alcohol, and by other chemicals separated into two substances, one of a bluish-green color, and the other a yellow which has been termed Xanthophyl. There is also another yellow substance found in the green parts of plants known as etiolin. Xanthophyl and etiolin may be derivatives of chlorophyl by oxidation or otherwise. The red coloring matter has been named erythrophyl.

There are at least two kinds of white color, one a pigment named leucophyl, the other caused by the absence of all color and generally referred to as chlorotic; this kind of white is only an optical effect of structure, but the two kinds grade into each other without perceptible dividing line.

Different pigments, as those fixed in the plastids, and others free in the cell sap, often exist at the same time, one kind then naturally modifying the hue of the other. With such a condition, viz., of different elements associated at the same time in the same flower, one can easily conceive that a plant widely distributed might under different conditions in one case develop the purple element which is free in the cell sap, and in another, the fixed yellow xanthophyl, or erythrophyl substance, so that the difficulty of assuming that the colors of different species of the same genus were all derived from one primary color of one original ancestor would be eliminated.

These pigments are found mainly near the surface of the flower petal, just beneath the cuticle, sometimes in the skin itself. In a white Crocus variegated with purple, if the transparent cuticle is peeled off, it carries the purple color with it, leaving the remaining tissue white; not infrequently however, the pigment extends quite through the tissue from side to side, continuing even down the peduncle and stem, as in Arethusa and certain Begonias. The yellow Crocus is tinged quite through the entire tissue, also Buttercup, Laburnum, purple Iris and red Pæony. Various kinds of acids are found free in the cell sap, or in combination with alkalies, and the varying proportions of these elements play an important part in establishing the colors of flowers; the effect of these will be described later.

As hinted above, there is no good reason for supposing that there was an original color in any genus from which all the colors of the other species were derived. There was a time doubtless when plants did not bear the bright colored flowers of the present day; they were first apetalous and probably as unsightly as our present pond weeds; then long before they had differentiated into the present species or had even begun to develop petals, there may have been a marked difference in the colors of the essential organs, scales or involucres, in different plants widely dispersed, as is seen at the present day in our apetalous flowers. Take for an illustrative example the oaks, and suppose they should find it for their advantage to have bright colored envelopes for their naked flowers. We find them already varying much in the color of their leaves, scales and stamens; compare the black oak, white oak, live oak, etc., the leaves of one unfolding green, another brick red, another a pinkish purple; the anthers of white oak simply green, tending to become yellowish, and those of scrub oak a bright scarlet. Would it not seem entirely natural for each species to develop its own special color? and if it should, then the yellow and the scarlet colors which might appear would be contemporaneous, one as primitive as the other.

Iris has yellow, also purple or violet colored species similar to the Pansy, which has both colors and commonly no red intervening. Our New England *Iris versicolor* and *I. prismatica* are violet with some green, and the more southern European and Asiatic species are yellow.

Suppose one should enquire, Which of the two is the earlier or primitive color? Probably Grant Allen would say, the yellow of course. We would say, however, that it does not follow as a matter of course for these reasons: in our native Iris, the broad green claws of the three outer segments are prettily veined with purple, while the broader blades or tops of the falls are pure, rich violet. We have shown hereinbefore how a purple color often naturally breaks through the chlorophyl green, in leaf or flower as in Cypripedium, Coleus, etc., or may even precede the chlorophyl green itself, as in purple foliage shrubs, trees, etc.

We have also shown that it is just as natural under suitable conditions for the green color to dissolve into a clear yellow.

In our example, the violet exists in the cell sap, and the chloroplastids are tinged with green at the same time. It is a question simply as to which shall prevail, and that will depend upon chemical conditions at present not sufficiently understood. In our Iris the violet prevails.

The green upper portion of the claw fades away, leaving a few white streaks extending into the violet blade; this is a common sequence: green to white: with age that portion of the sepal at the height of the declined style becomes somewhat yellowish, that is, a very small part of the long green claw has transmuted its chlorophyl to Xanthophyl, and that is all the yellow there is in the flower, the inner segments or petals being of the same green and purple, with faint whitish streaks only.

The yellow species upon examination will be found to have always more or less of purple-brown on the claws, this color being a purple or violet modified by the yellow. Some species are wholly of this mixed purple-brown, as shown in Iris fulva. It appears, therefore, that the two pigments really exist in all the species, and one is just as likely to be as prominent as the other, according as climate or other circumstances favor.

The reason why yellow is more common than red or blue I apprehend, is because the ordinary yellow is dependent upon a previous green generally present in the flower bud, and when this recedes its yellow constituent is apt to remain. I have not infrequently seen a white, lavender, or red-purple flower, when the petals first peep out of the calyx, to be more or less yellow temporarily.

In observing the colors of the common garden Sweet Pea one frequently remarks a variegation in the same flower: the banner being of one hue and the wings and petals of another. The banner is the outer petal which enfolds and protects the others in the bud, and consequently is at first somewhat green in the early state. As a consequence while this banner is never really yellow, yet the chlorophyl green in dissolving often leaves a trace of it sufficient to affect the subsequent colors, which from this cause are frequently of the xanthic series, while those of the wings and keel are of the cyanic series. I have never observed them to be in the reverse order! Of course the banner may be pink and the lower parts white, or the flower wholly white, but when the xanthic colors do appear they are invariably uppermost.

Flowers for the most part have their peculiar, stable and uniform colors, as in the wild rose, buttercup, strawberry, etc.; the number in which important variations have occurred is, however, considerable; and while different species do not always have different colors, yet if a plant is found with an entirely different hue, the probability is that if it persists and multiplies that it will also show other characteristics, as differences in shape of leaf, or habit, sufficient to entitle it to the rank of variety or incipient species.—But why one flower is yellow and another blue is a difficult question to answer categorically. One might as well enquire why one plant produces gum, another sugar, a third oil, others acids or alkalies, and a hundred other special products. Of course one does not expect to find as important changes in the physical conditions and chemical properties of the plant to produce the ordinary color pigments as the former products.

Green is *par excellence* the color of growth and vegetation, whether in leaf, flower or fruit; hence while growing and until they reach their normal size, flower buds and fruits alike are green, and naturally from this chlorophyl-green, with additions, or from its derivatives, or from pigments entirely independent of it, develop finally the numberless hues of flowers and fruits; for this reason we have in this essay given green a prominent place as a primitive color, while not overlooking the fact that the greater part of all colors under certain circumstances might precede this green and also that more primitive than all is the fundamental structural or chlorotic white.

CONCLUSIONS.

We find that among the Ranunculaceæ, yellow is not by any means the prevailing color. In Clematis *yellow* is comparatively a rare color.

Very many existing yellows are known to have been preceded by entirely different colors. Brown-purples and similar hues formed *of green and red* are earlier than yellows.

Simple or primary yellow does not regularly change through white to red or purple; an exceedingly common sequence being yellow to orange, vermilion or scarlet, or to brown; or through green to blue, or directly to crimson. Even in the Buttercup, there is a change of yellow to scarlet! Not infrequently green and purple, green and brown, green and red, green and white, green and violet, etc., appear before any yellow color develops. One with a trained eye for color can scarcely look at a flower without detecting a difference in the development of its hues; the anthers perhaps diverging into one series of color, the petals into another, the pollen often different in hue from the anther containing it, and possibly the sepals different from either, as in Lobelia Cardinalis; it frequently occurs that the very hairs *are of a different* color from the stem or leaf from which they grow. Size, shape, or construction, as a rule, has no effect on color, neither simplicity nor complexity.

Nature is highly democratic in her feelings; she bestows the royal purple or cerulean blue as freely upon Clematis, Hepatica and Anemone of the simplest family as upon Aster, Hyacinth, and Gentian of the highest families, and, conversely, she distributes the golden yellow on the whole in as great a proportion among the higher as among the simpler species.

HONEY GUIDES.

CHAPTER XI.

FLOWERS usually have but a single, uniform color, depending upon the species; there are, however, many which are variegated with more or less regular spots, streaks, dots, and "eyes," of a different color, usually in strong contrast with the predominating hue.

When these additional colors are confined to a single petal, they generally point to the spur of the flower if it has one, or to the nectary or depression containing the sweet secretions; they are known as "honey guides," or "pathfinders," for the reason that they have been supposed of use in guiding insects to the nectar.

Examples of the guide-markings may be seen in the following flowers:

Mimulus ringens of a lavender-blue, has a yellow spot at the throat.

Pontederia cordata, pickerel-weed, violet-purple, has a two-lobed yellow dot on the middle of the upper three-lobed petal.

Lespedeza polystachya, cream-color, has a purple spot on the standard.

Sisyrinchium angustifolium, blue, has a yellow eye.

Solanum dulcamara, violet-purple, has ten round green dots, two to each petal, surrounding the column of stamens.

In garden Balsam of many varieties, the honey-guide is a mere yellow dot of the size of a pin head, and is found on one of the sepals!

Tropæolum or nasturtium, yellow or orange, has purple-maroon veins or wider stripes, mostly on the two upper petals.

Of a similar nature is the scarlet-maroon eye of yellow Coreopsis, the purple centres of white Phlox, Althæa, Hollyhock, etc., the crimson zone on a white ground in some varieties of Sweet William, the yellow "eye" of scarlet Tulip, the large black spots on the petals of oriental Poppy, the different colored lips of Orchids, and the golden bands, and red, glandular dots of *Lilium auratum*, etc., etc.

Were these different colored markings a part of the original design of the flower, or have they been added to a plain self color, and if so, by whom and why?

Christian Conrad Sprengel's attention was called to this subject in 1788. He first noticed the yellow ring round the mouth of the corolla of *Myosotis palustris*, L., and "he conceived the idea that this might serve to guide insects on their way to the honey. On examining other flowers he found colored dots and lines and other figures at the entrance to the nectary or pointing towards it, and was accordingly confirmed in his idea of path finders or honey guides."

W. E. Shuckard in his book of British Bees says: "Flowers, within themselves, indicate to the bees visiting them the presence of Nectaria, by spots colored differently from the petals. The honey marks surely guide them."

Grant Allen writes as follows regarding these honey guides: "We can hardly resist the influence that they have been developed to guide the bees to the proper place for securing the nectar."

Prof. M. I. Newbigin in a recent work says: "Their meaning and origin are still very doubtful."

Alice Lounsberry, in her "Guide to the Wild Flowers," refers to the "Road that is plainly marked out for the bee, by a deep, rich veining" to a gland of nectar.

G. Henslow remarks: "It has been observed that the 'spots' are more persistent than the base color of the flower. Whenever they occur as guides or pathfinders, which have been determined by insects, they have become hereditary."

John H. Lovell in the American Naturalist for June, 1899, writes as follows: "In a species of Dendrobium the sepals and petals are white, tipped with purple, and the lip is bright orange with two crimson spots. This is probably due to the marked tendency of the species to variation."

C. Darwin's reference to honey guides will be found farther on. Of these seven writers of repute, only one hazards the opinion that they "have been determined by insects," but not a hint is vouchsafed of the manner in which they were determined, nor by what kind of insects. Neither have I ever seen or heard of any explanation regarding their origin; I shall therefore offer the following as an original elucidation of the subject.

For our first example in illustration, let us take a common yellow garden Tropaeolum, otherwise Nasturtium.*

The plant is either climbing or dwarf, with round peltate leaves, and the long-spurred flower has many varieties. We

* The pen and ink sketches are by Joseph E. Landers.

will select as best adapted for our purpose a flower of a yellow color with a longitudinal reddish-brown stripe on each of the upper petals. These are the honey guides and they in this example really point directly to the nectary. The question to be solved is how they got there.

Did the Creator design them expressly for the benefit of nectar-loving insects, or did the insects paint these petals themselves with their own saliva, same as a grasshopper will stain your fingers if you hold him for a moment? It is of course remarkable that insects should be so cared for as to have a special sign-board directing them by the shortest route to the sweets they so much crave!

If this particular variety was the only one to be found, our task would be harder, but as we examine the numerous sorts, we will be very likely to run across a dark colored flower with no honey guides, and whose color is exactly the chocolate or Indian-red of the markings on our yellow example. In the place where the honey guides ought to be, the color is of the same as the general hue, only a trifle richer and deeper. This richness of color is occasioned by the irritating influences of the bees in traversing the same route to and from the nectary, thus stimulating the flower to send more of its peculiar pigment to this point, same as a little friction or a pinch will bring the blood to the cheek and cause a rosy tint.

The next step in the process is to change the general color of the flower to yellow. How this is effected by Nature it is unnecessary to explain just now; suffice it to say that the fading of a color to a lighter tint is one of the most common occurrences in color-change; we have only to look around and observe the yellow roses fading, some to a clear white on the same shrub, and the pink ones also fading out, and scores of other flowers blanching on their own stems; blue Houstonia and Myosotis, the pink English daisy and apple-blossom, changing to white, etc., but in our Tropaeolum the flower never becomes perfectly white;

it does, however, change to much lighter tints, some as pale as cream-color. In our search every gradation is found, but in every case the deeper and therefore more permanent shade of the honey guides remains, only somewhat modified in color. Thus we get back to our yellow example with its Indian-red honey guides, the remaining vestiges of its original color! In this same example there is very likely to be found smaller spots on the three lower petals; these are less marked for the reason that the smaller insects, which are careless and don't stop to read the clearly lettered guide-board of the upper petals, foolishly alight below, where they are debarred from getting at the nectar by a sort of *cheval-de-frise*, or erect, fringe barrier; but the silly insects stimulate just the same, though in such less degree that the three spots not infrequently wholly disappear, while the two upper, more thoroughly made, will persist. We have in these lower spots a hint that honey guides do not always guide!

Example 2.—We will briefly describe another example.

One variety of the slender Spanish Iris is of a beautiful blue, with a golden-yellow spot on each of its three outer segments. It is more wonderful to behold than the Nasturtium, but, as we have fully described above the principle of honey-guide decoration, all its mystery disappears.

As in Nasturtium, this flower has many varieties. The typical flower is entirely yellow, with no markings except a little more of a Naples yellow tint in the place of a honey guide, but practically no guide at all; it might be added in this connection that the bees get along just as well in the yellow flower with no guide, as they do in the blue flower with the brightest possible sign to arrest their attention: it all depends upon habit!

But to return to our subject. The general yellow in this case fades completely to white, except the markings, which remain as in Tropaeolum; hence there is a white variety with a yellow honey guide; then begins a tinge of blue on some of the white varieties, which gradually deepens and spreads up to the very limits of the golden yellow spot, without encroaching one hair upon its territory. Notice two points: the flower change is from white to blue, just as is seen in Pansy, with not a bit of red intervening; also that sometimes the change is so immediate that it is from yellow to blue, no white even being noticed.

Anything that arrests the attention may be a valuable guide for certain purposes; the stamens of the fragrant, full-clustered, little white Rosa multiflora are at first of a bright yellow, by the second day or before they turn a dark brown, so that the yellow and the brown centres are quite distinct in the same cluster. The bees always take the yellow centres and pass the others by.

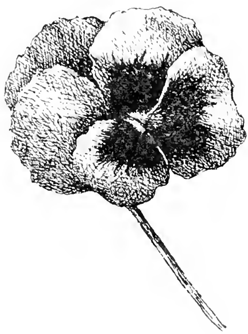
Example 3.—In violet-purple *Pontederia*, pickerel-weed, the bumble-bee always flies directly towards the two-lobed yellow dot on the upper petal, against which he presses his head as he sips the nectar.

In this instance it is the insect's head and not his feet that causes the irritation, preserving most likely the original color of the flower, the dark purple being the more recent. It is quite possible also that butterflies are concerned in this particular marking, for the prominent little feelers between their eyes touch at exactly this place as they extract the nectar!

Example 4.—In *Galanthus*, the snow-drop, and *Leucoium*, the snow-flake, we have examples of green colored honey guides; in the former of these flowers which are both white, the three short inner segments are green on the inside where the insects enter; in *Leucoium* the bee clings first to the drooping tips of the sepals which are green colored, before he turns up into the flower. These green tips, all the rest of the flower being white, were caused by the bee in the same manner that the yellow spot of Iris and the Indian-red of Tropaeolum were produced, but the original color of Leucoium was green!

Example 5.—The widely scattered dots on *Lilium auratum* were not accounted for by the writer until a humming-bird moth was seen to hover over the flower, and suck in succession the nectar from each red, glandular vesicle!

Example 6.—*Trillium erythrocarpum*, painted trillium, is a beautiful white flower, painted with a crimson eye with fine radiating lines. The eye is also of the nature of a honey guide. It is the remnant of a former crimson flower and preserved to us by the insects!



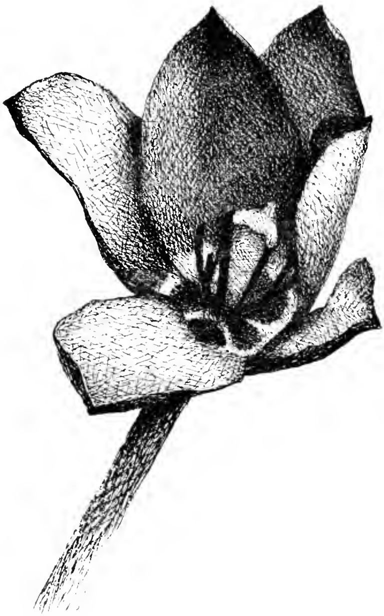
Example 7.—*Viola tricolor*. A yellow pansy has three dark maroon or brown-purple spots; the two upper smaller, the lower large and two lobed. A violet pansy has only a very small yellow eye at the centre.

The ordinary yellow variety with the maroon spots was undoubtedly derived from the violet variety.

Example 8.—Eschscholtzia has an orange, self color, but its lemon yellow variety has four orange spots corresponding to those on oriental poppy. The lemon yellow is a recent color, the flower retaining the orange markings of the original.

Example 9.—Gloxinia, Digitalis and Catalpa: The original purple or crimson fades to white on the outside of the tube, retaining the color naturally longer within, but it finally breaks up into numerous purple dots. The two additional streaks of yellow in Catalpa may be a more recent color produced when the flower became bi-lateral and the ridges formed, necessitating the insect to take that course.

Impatiens fulva is similarly marked with purple dots equally distributed over all the lobes.



Example 10.—In the preceding examples we have shown how a bee can assist Nature in variegating a flower with another color. We are able to demonstrate farther that a bee not only assists, but actually produces color, and that the same bee may be instrumental in developing three or four distinct colors in the same flower! We will endeavor

to illustrate this idea by taking for an example the common yellow variety of garden Tulip.* The purest and most original specimens are yellow in every detail: perianth, stamens, stigma and also the very grains of pollen. From this lemon-yellow tulip are derived a great variety of charming hues and many pretty variegations. We shall not undertake here to explain the chemistry of these color changes, but we will point out the rolé of the insects in this magical transformation.

Variegation 1.—As one of the ways colors run, and not by any means a necessary sequence, as this very example will clearly prove, we find individuals of this flower which have changed to pure white except a yellow area at the bottom of the chalice which still retains the original color, so that we have a white flower with a yellow eye. Why does this yellow eye remain, is it of the nature of a honey guide? If so, it certainly does not guide, for there is never a drop of nectar in the cup: it is rather a delusion and a snare! In watching the bees, one finds that they do not alight on the petals, nor do they force an entrance before the bud has widely expanded, but when it is invitingly open, the bee is able to fly directly into the opening and alight upon the stigma or the anthers which alone afford the nectar. For this reason there are no guiding honey guides. The insect does not always retain his foothold, and the inner segments of the perianth being erect, and smooth as glass, with a slight concave bend near the middle, if he trusts to these he is sure to fall to the bottom, from which it is no easy matter to escape. Not only bees but other small insects, clamber up to fall again, and are finally exhausted and smothered in the pollen dust accumulated at the bottom. Their struggles for life preserve to us the golden eye, a remnant of the original hue! I have found in one flower a bee, bug and ant. This is a cold, hard-hearted flower and dangerous to insects.

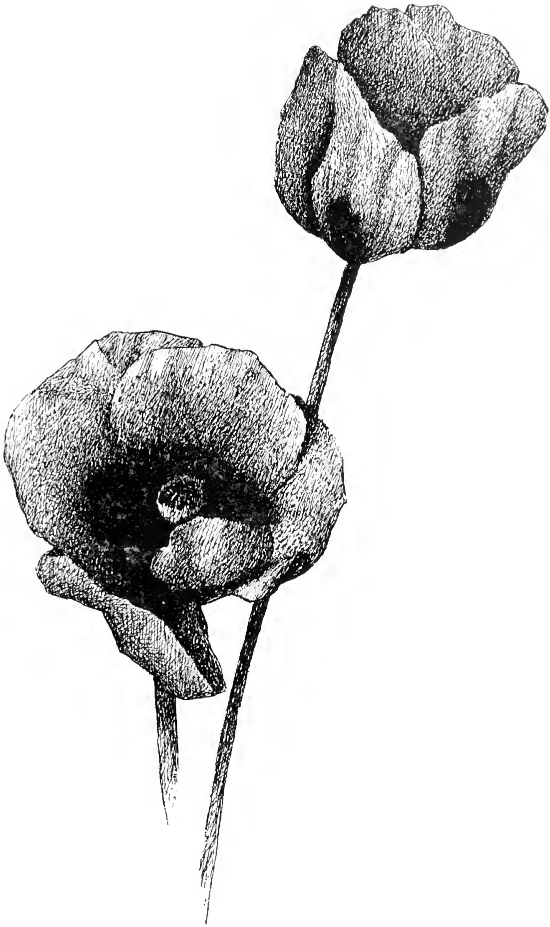
* The illustration is a wilted Tulip, to show marking at centre.

Variegation 2.—There is a slight tendency to blue, manifested in the anthers of the same original type, which by the stimulus of constant visits of bees is increased and the color deepened, so that besides the original yellow and the white, one may occasionally see an anther which has turned blue, and the darker the flower, that is, if it be a scarlet for instance, the surer one is to find a blue anther, and not only this, but the yellow eye changes to blue, and the same bees which were responsible for the yellow eye are also responsible in a measure for the dark cobalt-blue of T. Gesneriana and for the black pollen dust changed from golden yellow.

There is a very attractive variety of tulip known as the Kaiser Crown, of yellow and scarlet colors; its peculiarity is in the two ways of variegation. The scarlet which suffuses the yellow foundation color runs on the outside, from base towards the tip; on the contrary, that on the inside is the reverse, that is to say, the scarlet color extends horizontally on each petal, forming a central scarlet zone in the yellow flower-cup. The former is the natural method; the latter is the result of insect agency, and is,

Variegation 3.—The same bee while giving his undivided attention to the anthers, owing to the proximity of the erect petals, is apt, in going the rounds of the stamens, to rub his back against them, with the result that just where it touches is left a more or less distinct scarlet band within the petals at the exact height of the anthers! This feature being noticed by the Dutch florists was doubtless seized upon and hence the beautiful variety.

This singular zonal marking cannot be seen in every yellow flower. It is more apt to be found in one which has a tendency to a scarlet or red color, seen perhaps on the outside, and the stimulus of the insect awakens it within. In like manner and by the same agency, the writer has seen a white tulip with a *crimson* zone on the inside, the "eye" still remaining yellow and the anthers blue,



making four distinct colors! Q. E. D.—These last colors are accounted for by the disappearance of the yellow pigment, which leaves a white basal color and changes scarlet to crimson. The yellow eye of a white tulip is apt finally to fade to white. I have also observed a similar red zone in a white Roman Anemone.

Prof. M. I. Newbigin mentions what appears to be a mystery to him concerning honey guides, viz.: the fact that they occur sometimes where there are no nectaries. No examples are given, but the professor might have had in mind a flower like the Oriental Poppy.

Example 11.—This scarlet poppy* is one of the largest of flowers known, being quite seven inches in diameter, and on each of its four broad, flaming petals, near the base, there is a black spot one inch in diameter. As Prof. N. remarks, there is not the slightest evidence of any nectar anywhere on the petal and apparently none in any other part of the flower. What then are the spots for, and how were they produced?

Of course, we have no record of the history of the flower and of what colors it flaunted long ago in the garden of Eden, so one must theorize somewhat, and our theory is just what has been stated regarding the tulip; evidently the flower has changed from its original color which was some shade of purple, and the bees or some other Eastern insect visited the flower just as they do now for the nectar that the *anthers* afford, precisely as the bees visit the anthers of the rose in these days. As they revolved around among the numerous stamens of the same inky hue as the spots, in clinging to the outermost, their backs rubbed against the walls of the petals at the precise place of the spots, which is central on the pètal and slightly depressed. The stamens are weak and inclined to droop, so that the weight of the bee throws him, or if he loses his hold, he falls on to

* The illustration, p. 65, represents a small variety of Oriental Poppy.

the depressions. This constant irritation of the cuticle at this one point deepened the color and retained it, when every other part of the petal was transmuted by chemical agency to a flame-like hue! Of course the prominent, black honey guides are of no value as real guides, they serve to decorate the petal and that is all; and this is all that half of the spots or guides are good for!

They may, however, be of some utility for a purpose to be referred to later.

Example 12.—*Liriodendron Tulipifera*, Tulip-tree, is a stately tree, bearing cup-shaped, green flowers encircled on the inside with a remarkably rich orange band, which color strikes through to the outside.

The flower is two inches across, with long stamens reaching nearly to the top of the six upright petals, and its three sepals, quite similar in size and shape, but lacking the orange color, become strongly declined.

The general appearance of the flower is that of a tulip, and the orange band recalls a similar band in the garden variety of tulip, before referred to, though differing in tint. When I first examined the flower I immediately remarked that the orange band was low down in the flower, while according to my theory it ought to be directly opposite the anthers, so that the bee, as in the case of the tulip and poppy, would come directly in contact with the spot or marking on the petal; this clearly was not the case in Liriodendron, and for a moment I was puzzled. I was able, however, shortly to discover the reason of this difference. One cannot examine the actions of insects quite so handily on a tall tree as he might wish, but happily there were a few low branches and I was not obliged to climb it. Greatly to my surprise the bees flew right past the anthers into the space between the stamens and the orange band, and instead of facing the anthers, they faced the petal and confined themselves strictly to the orange zone, not going above or below it! All the surface of this zone they diligently licked over, making a complete circuit of the corolla. The position of a nectary and at the same time of a genuine honey guide so much above the bottom of the chalice is very unusual indeed; it is the only example I have ever met.

There was nothing discerned by the naked eye to attract the bees but the color; with a lens however the orange band was seen to be minutely and obscurely punctate, and the pollen falling from the extrorse anthers upon it, mingling with the secretions, formed a delicate ambrosial nectar. This nectar originally was the first thing to attract the bees, then their stimulating influences evoked the color! I have had suspicions all along my researches, that insects did to some extent awaken a new color; they were aroused in the Kaiser Crown tulip, where it was the only scarlet color on the inside, and produced by bees, but the pigment was in the "blood" of this flower, for it showed naturally on the outside, but in Liriodendron there is not a particle of orange color elsewhere!

This pigment no doubt exists in the petals undeveloped, for with age the green color becomes somewhat yellow; but this elegant band of gold on a green ground would never have appeared without the aid of insects, and in this instance, therefore, I should say that it was not a vestige of the past, but a new creation!

Example 13.—*Sisyrinchium augustifolium* and *S. anceps* are two common New England flowers, small but interesting. They are blue flowers having a yellow centre. Each blue petal has a diminutive yellow spot at the base, and these six together form a small star-shaped eye; the base of the style to the exact height of the eye is also yellow, but higher up is blue. This flower was undoubtedly in the remote past of an entirely yellow color, perianth, stamens and style. Possibly it emigrated from the tropics, where its congeners are still mostly yellow. It may have taken thousands of years to reach New England, and the change of climate probably changed its physical character sufficiently to alter the relative proportions of acids and alkalies, or even to develop a new element requisite for producing the blue pigment. At all events, the tell-tale eye stamps it as of foreign parentage, and we know from the foregoing illustrations why the eye is yellow, and why one-half of the style is also yellow and the other half blue!

Example 14.—The little Lobelia of a blue color, frequently seen in hanging baskets, has for honey guides a pair of diminutive white streaks at the throat, slightly diverging. It is visited by a little bee a third of an inch long, and just strong enough to force open the palate and enter for one-half the length of its body, dragging its hind legs exactly over the guides. These divergent little streaks therefore are not exactly footprints, but impressions of the insect's legs as it lies flat and outstretched sipping the nectar!

Charles Darwin points out "a striking case of correlation of color with a special organ," viz.: "In many Pelargoniums the two upper petals in the central flower of the truss often lose their patches of darker color: and when this occurs, the adherent nectary is quite aborted, the central flower thus becoming peloric or regular," etc. Well, that is precisely what one would expect, no nectary no honey guide!

Darwin was a very busy man and he would not have been long in finding out all about the nature of honey guides if he had only turned his attention to that subject, but one would judge from the quotation that he had not done so.

Grant Allen in The Strand Magazine for April, 1899, referring to white flowering plants, remarks as follows: "A curious coincidence is, that none of them have any streaks, spots, or lines on their petals. The reason is simple. Such streaks or lines are *always* honey guides to lead the insect straight to the nectary"!

Anything that arrests attention may be useful as a guide for insects. A large proportion of the markings on flowers, as we have seen, do not guide to the nectary. Some do so point, but of these many are in the tube, and of no value when the insect has got so far towards his object. Nevertheless, while many of the spots, dots, bands, etc., are not guides to the nectary, they serve as signs or advertisements to insects that such flowers are especially nectariferous. Probably there is no flower with these markings but that has nectar somewhere in the blossom. They are always confined to those parts only of the flower which come in contact with insects. It is the contact which causes them.

Other useful guides are found in the rapid change of colors. Weigelia rosea opens white, and changes to deep rose-purple: after a time there are but few white flowers and many purple on the shrub. The honey bees visit only the white ones.

A bumble-bee will fly among a bed of Columbines, perhaps all white: he goes close to the flowers, looks into this or that, and passes on to others, finally entering some. If the ones he visits are examined, they will all be found to have bright lemon-yellow anthers, while the ones he rejects, though looking just as fresh, are not so, all their anthers have turned to black. Even a change of color in the spots themselves, to which we have previously referred, serves a like purpose, as it indicates that the flower has passed its virgin freshness, and with it its nectar has dried up.

Real double flowers have no insect visitors, partly double do, and the markings may continue on these for a time by heredity.

The honey guides on Polygonatum, Solomon's Seal, and Lucoium are green: on Phlox Drummondi and Cineraria, white at the centre frequently, while Convolvulus sepium has white, radiating streaks: they are Indian-red in Tropæolum; yellow in tulip, iris, freezia, pontederia, etc; purple or violet in pansy and white violet, etc.; cobalt blue in Tulipa Gesneriana: and violet-black in oriental poppy.

In Rhododendron, Azalea, Geranium, etc., the special markings are on the upper petals, for the reason that the stamens on that side are shorter and deflexed, also for the reason that the nectary which the insects themselves have made are on that side, and chiefly because the insect alights there.

In *Weigelia rosea*, *Gladiolus*, orchids, etc., the marks are on the lower side of the tube or lip, as being the more natural resting place, when the stamens do not interfere, if the flowers are declined or horizontally disposed.

Upright flowers, as tulips and poppies, have similar markings on each petal, as the insects have equal access from any point.

When the petals are rather narrow as in Freezia and some orchids, the markings extend over to the adjoining petals on each side, probably because the spread of the visiting insects' wings comes in contact with these side petals, or the insect does not confine himself to narrow limits; in Rhododendron, the corolla being gamopetalous, the numerous dots extend over three lobes.

In addition to the examples noted of honey guides or special markings, are Melampyrum, Calopogon, Pogonia, Lysimachia, Aesculus, Ribes aurea, Oxalis, Gloxinea, Apocynum, Veronica, Coreopsis, Hibiscus, Gossypium, Calochortis, Digitalis, Cladrastis, Laburnum, Catalpa, Cyclamen, Baptisia, French Marygold, etc.

Generally speaking, special markings like those described above, indicate that the flower has changed color. The markings are usually relics of the previous color of the flower, but not always so, as they are often modified by the new pigment, and sometimes their hue is completely changed. In a comparatively few instances the markings appear to be recent. They are always the result of actual contact with the insects at these precise spots.

A few writers have noted the fact, without any explanation, however, that night blooming flowers have no honey guides or other special markings.

The author of "Field, Forest and Wayside Flowers," in describing the difference between day and night blossoms, says of the red campion, Lychnis githago, a day bloomer: "A few clearly-drawn, dark lines, running from the edge of the blossom to its centre, are a floral signal-code telling the butterflies where the nectar which they seek is stored," etc.

The evening-lychnis of a white color, "has no lines to indicate the whereabouts of its nectar, for these would be undistinguishable in the dark, and therefore useless," etc. "But a very small object, if it be white, can be seen in the darkest hours of a moonless night."

This of course is not a very satisfactory reason why night bloomers have no dark markings. We are not altogether certain that a winged insect which could see a white flower by twilight, might not notice a red or purple spot on the petals; certainly there would be a sharp contrast of light and shade. But we think this lack of guide markings can easily be accounted for in another manner.

We have shown that they are incident to a general change of color, usually of a dark tint to a lighter one, commonly first to white. Among night blooming flowers there are no dark colors, no red, purple or blue. If dame Nature ever produced them, she long ago corrected that mistake for, at present, they are only white, pale yellow, or pink. Such flowers as Azalea viscosa and Oenothera biennis have adapted themselves to night shadows and their colors, white and yellow, are the very best for nocturnal insects, therefore they never change, and there can never be any red or purple spots, simply because there are no flowers of these colors!

There is, however, one twilight bloomer at least, and there may be others, having guide markings, I refer to Convolvulus sepium. It is a pink flower, funnel form, of the size and appearance of a Morning Glory. The wide tube is white, with five white rays extending up through the centre of each lobe to the border of the limb, so that the effect is that of a five-rayed star on a pink ground. The white star is the honey guide, its white color being the original one and the pink more recent. The flower blooms in the morning twilight, long before the roses, and lasts but for a day. The white guide markings were produced when the flower became pink, and are very appropriate and suitable for twilights. There are varieties of the flower wholly white.

Besides the crepuscular and nocturnal bloomers, there are diurnal bloomers which keep open house all night. Privet is visited by four or five different kinds of moths and probably clethra by as many more; and one of the kinds which visit privet, *Oenothera*, and *Azalea viscosa*, I have seen visiting the scentless purple larkspur at dusk when I could scarcely distinguish the flower from the leaves! and what is of farther interest was the fact that a few white flowered varieties in the clump were passed by! *Datura Tatula* is said to bloom towards evening (it is of a pale violet-purple), and if so, there is no doubt but that moths would find it with its strong odor as readily as larkspur!

Apocynum androsæmifolium, a day bloomer, is a bell-shaped flower one-third of an inch long, of the palest pink, with fifteen deep rose-colored lines running straight to the centre of the flower. Two different kinds of moths were noticed at dusk sucking its nectar, not counting diurnal insects.

Honey guides are useful characters in distinguishing species. Of the two New England yellow-flowered species of *Oxalis*, viz., *O. stricta*, *L.*, and *O. corniculata var. Dillenii*, Trelease, the latter can be distinguished at a glance by the honey guides. They are very diminutive, consisting of four or five straight pencil lines near the base of each petal, forming a small circle around the centre of the flower.

When an animal seeks a brook or spring for water, he is apt to take the shortest practicable course. If he goes and returns several times, he is likely to make a path. Figuratively speaking, the special markings on the petals of flowers are the foot-prints of the bees and the butterflies. When they follow the same route for nectar, they leave a trail; where the butterflies walk around the stamens of a pink they leave the impressions of their tiny feet in the shape of a circle; when a bee rubs his back against the petals of a poppy he makes a similar shaped spot on each; and when with his tongue he laps the nectar on the petals of the tulip-tree, he paints a golden band; when he falls to the bottom of the cup-shaped tulip, he in his scrambling describes a disc of blue or yellow.

Bees and butterflies work unconsciously as Nature's agents in flower decoration; some of the markings prove to be of utility in guiding the insect descendants of those who made them; some, in regular flowers where the lines from every side point to the centre, are of no especial value; others neither direct nor have any connection with the nectaries, but all, being footprints of nectar loving insects, may possibly indicate to the more intelligent of their kind that the flowers are especially nectariferous.

VARIEGATION OF LEAVES, ETC.

Special markings are not peculiar to flowers; the variegation extends to leaves and stems. Notice the pale crescent on Clover leaf; the purple zone on *Pelargonium zonale;* the mottled leaves of Erythronium and *Chimaphila;* the brown-purple spot on *Euphorbia maculata*, and the more brilliant markings on leaves of tropical plants, referred to elsewhere. As the upper and lower surfaces of petals are sometimes of different colors, so leaves are found with one side differing from the other; some species of Oxalis, Tradescantia, Begonia, Nymphaea, Cineraria, etc., are reddish-purple beneath and green above; certain species of Quercus, Populus and Vitis are white beneath. On trunks and stems of trees and shrubs the green or brownish basal color is often prettily variegated with numerous white dots as in birch, willow, alder, sassafras, benzoin, etc.; pale gray blotches appear on some maples, and larger white patches on Platanus, while the whole trunk of canoe and white birch with age becomes a staring, chalky white.

SEEDS.

The colors of seeds take a range nearly equalling that of flowers, every hue being found from the white of pumpkin to black of watermelon. The garden bean, perhaps, presents the greatest variety of colors and variegation in its different kinds; it is quite astonishing, as these seeds do not receive the direct rays of the sun, being enclosed in a pod, and yet they are often prettily marked. Indian corn is red, yellow or blue.

The order of development of seed colors as in flowers, is not uniform. Notice a few examples from small seeds:

Stellaria media: the transparent ovule first becomes white, then orange, brown, and black in succession.

Sonchus oleraceous, goes from white through lemon-yellow to brown.

Oenothera biennis, from white to brown; no yellow.

Baptisia tinctoria, from green, through purplish-brown to black-purple.

Asparagus, from a translucent green directly to jet-black.

The colors of different berries beginning usually with green, show many beautiful transitions before reaching their final hue. The gradations of Asparagus berry for instance, are green, olive green, Indian red to scarlet. Others change from green, through red to blue, purple, or black; green directly to white; green through yellow to scarlet; and white through green to scarlet (Gaultheria), etc.

CHAPTER XII.

ARE THE COLORS OF FLOWERS THE RESULT OF INSECT SELECTION?

Prof. Hermann Müller, in his book on "The Fertilization of Flowers," ascribes their color to the selective agency of insects, which having preferences for certain hues, have visited such more frequently, and consequently have promoted their increase by cross-fertilization. We quote from him as follows:

"In *Rosaceæ*, whose honey lies concealed and which are fertilized by a motley crowd of short-lipped insects, the flowers are for the most part greenish-yellow, yellow, or white in color. In *Comarum palustre*, *Potentilla atrosanguinea* and Sanguisorba officinalis, they are dark red or purple, probably owing to the influence of carrion-feeding flies, etc. *Rosaceæ* visited for pollen have white flowers when the chief visitors are small, short-lipped insects."

"The uncommon color of *Scrophularia* must be referred to the peculiar taste of its visitors, the wasps. It has round brownish flowers with widely open mouth."

"Bright red colors of pinks seem to have been produced by the similar tastes of butterflies."

"Flowers fitted for short-lipped insects are usually white or yellow."

"Insects with longer tongues and acuter color sense gradually caused the production of flowers with more varied colors."

"*Globularia* is blue. This is the only instance in the German and Swiss flora of a blue color being *produced* by the selective agency of *Lepidoptera*" (butterflies).

"Hundreds of honey bees visit both *Melilotus officinalis* (yellow), and *M. vulgaris*" (white).

"*Linaria vulgaris*, flower yellow, excludes short-lipped bees from the honey, and flies and beetles are prevented from entering the flower by the tumid lower lip which completely closes the tube; by these characters the flower becomes exclusively adapted for the most diligent of fertilizing agents, the long proboscisid bees."

"*Antirrhinum majus*, purple, our largest bumble bees can enter bodily. It is fertilized chiefly by bumble bees."

"*Digitalis purpurea*, humble bees are the only fertilizers"; flower purple.

"*Oenothera* biennis, honey accessible to long-tongued bees, and also adapted to nocturnal Lepidoptera," flower yellow.

"*Galeobdolon luteum*, yellow, exclusively by bees," seven species.

Clematis recta, white, seven species bees out of nineteen species insects.

Stellaria media, white, six species bees and five diptera.

Chelidonium majus, yellow, seven species bees and six diptera.

Ranunculus acris, yellow, twenty species bees out of sixty-two total species.

Cnicus arvensis, purple, thirty-two species bees out of eighty-eight total species.

Taraxacum officinale, dandelion, yellow, fifty-eight species bees out of ninety-three total species.

If one analyzes the foregoing quotations, it will be seen that Müller says distinctly that the colors of certain flowers are due to the peculiar tastes of their insect visitors, who by their selective agency have produced them.

That some plants have changed the colors of their flowers, and that others are in process of change, we have already shown; our object now is to ascertain, if possible, whether bees have a preference for certain colors and are able at their own sweet will to change one hue for another, or whether the plant itself, for its own advantage, owing possibly to changed conditions, initiates, carries on, and completes a change in which the insects are only valuable assistants.

As a means of solving the question, we have taken note of the principal visitors of a hundred different kinds of flowers, more or less.

We find that it is a difficult question to determine positively, owing to different conditions in different localities; the species vary, the seasons vary, and the insects vary; competition varies, and the daily weather varies; but we are able to say what flowers certain insects have visited and in which they appear to delight. Our attention has been directed principally to the larger kinds: bumble bees, honey bees, wasps, hornets, butterflies, etc., while not entirely neglecting the minor insects. We will anticipate our conclusions by saying that taking a general survey of the subject we cannot find any marked preference of any kind for any one color.

In the Fall of one season, when goldenrod and Joe-Pye weed (Eupatorium) were at their height, these flowers bloomed abundantly along the side of a road leading through swampy woods. Bumble bees were present in great numbers, visiting both of these flowers, one kind yellow, the other purple. An actual enumeration was made, and the number of bees on one kind was substantially the same as on the other. The following year, in a different locality, there were bumble bees found on Joe-Pye, but scarcely one on goldenrod. The only way I could account for the difference was by supposing that the bees of the woods, being remote from fields, were restricted to woodland flowers, while in open fields they would have a greater choice of kinds.

Symphoricarpos vulgaris was discovered in Eastern Massachusetts. The Floras do not give the plant as growing in New England, so that likely few, if any others, could be found within two hundred miles. The flowers were monopolized by hornets to the exclusion of every other insect. There were more hornets assembled than I had seen together at one time. The flowers were small, inconspicuous, bell-shaped and perfectly green. Would it be safe to say from this incident, that hornets prefer a green color and a bell-shaped flower? If they do prefer it, and our Symphoricarpos is not to be found within two hundred miles, what are the thousands of hornets to do at this season of the year? it blooms in August. Evidently they must be content with other colors, green flowers being scarce, or confine themselves to killing insects.

I have seen hornets on garden leeks having a similar shallow, bell flower with colors from green to purple; also on the small green bell flowers of *Gaylussacia frondosa*, but as a matter of fact I have seen more hornets on other colors than on green. Referring to my memoranda, they were found on Symphoricarpos, Eupatorium, Clematis, Rhus, Helianthus, Linden, Rudbeckia, Clethra, Monarda, Asclepias, Solidago, Ribes nigra, Spiræa salicifolia, Gaylussacia frondosa, etc.

On the other hand, I have examined numerous other green flowers without ever seeing a hornet.

I infer, therefore, that the hornets were especially pleased with Symphoricarpos, on account of its abundant nectar and the ease and convenience with which it could be obtained.

I, of course, do not pretend to an exhaustive research in regard to hornets. Doubtless if my observations were continued, other green flowers would be found to be frequented by hornets, and at the same time the list of colored flowers would be extended.

We do not find in studying the habits of the larger winged insects that any particular color exercises such a fascination as to attract especially to the neglect of others of a different hue. Müller maintains that white and yellow flowers are frequented by inferior fly-like insects, but that the nobler honey bees and bumble bees have a preference for purple or blue. Of course any bright color in contrast with the green foliage would arrest attention, but examples of green flowers being freely visited by swarms of insects are too numerous to warrant the assertion that color is essential, and especially a particular color for particular species. There is not the slightest doubt, however, that bees do distinguish between colors and that they profit by the distinction, as when they select, *not from taste*, but for their advantage, a white rose with yellow stamens rather than a white rose with brown stamens, or a white Weigelea rosea in preference to a pink one.

Moreover they have no choice in the matter, for if they wish the freshest and best supply of nectar they must take the first color in these changeable flowers, in one case yellow, in the other white, etc.; in Lathyrus maritimus and numerous others they are obliged to take pink which is followed by blue, and in Ipomœa, morning-glory, and Brunella, violet followed by pink!

Again, while bees as a rule visit one kind of flower at a time and then of course those of the same color, if the kind of flower is plentiful, in case it is not they go from one kind to another indiscriminately, as we have seen bumble bees fly from Brunella to Baptisia, from Impatiens to Arctium, Nabalus to Clethra, and Brunella to red Clover. Later in the day they take another sort of flower which they follow, and as the season advances the same bees, or same kind of bees, follow in succession five-sixths of the different flowers as they appear, of whatever color.

We will notice some of the flowers visited by bees and some of their preferences for certain kinds of flowers, not preferences for mere color.

PURPLE AND BLUE.

Brunella and Pontederia are visited mainly by bumble bees, some honey bees and butterflies; these also visit Viola, Iris, Lupinus, Delphinium, Aconitum, Mentha, Asclepias, Cnicus, Eupatorium, Echium, and other Borragenaceæ, all purple or blue, but the same bumble bees visit the red clover (Trifolium), which is of a distinct pink-purple, just as freely, while honey bees, on account of their smaller size, are obliged to take the white T. repens, or rose-tinted T. hybridum, which have shorter tubes. Honey bees are constant visitors of Myosotis, blue: bumble bees visit less frequently; on the other hand bumble bees visit pansy, a larger flower, purple or yellow, more freely than honey bees.

Wistaria, blue, has pea-shaped flowers which exclude many kinds of insects; bumble bees, but more especially *Xylocopa*, an insect quite as large as the largest bumble bee, with a smooth black abdomen, seeks them before they are fully expanded and pierces the short tubular calyx from the outside for the nectar, and when fully blown they also visit the interior. Honey bees suck the nectar from the minute holes made by the former. Bumble bees often employ this device to get at the honey in other species of various colors. I have seen them pierce the tubes of Delphinium, Rhododendron, Azalea viscosa, Weigelia rosea, various varieties of Petunia, Aquilegia, Vaccinium corymbosum, Impatiens fulva, Phlox, Foxglove, Leucothœ, and Linaria vulgaris, even in bud. All hues are represented in these flowers: red, blue, yellow, white and green! These flowers do not appear to be perfectly adapted to bees, and they have considerable difficulty in reaching the nectar, yet they do not turn their backs on them to seek purple or blue flowers, although it is said, "blue is the special hue affected by bees." Honey bees do not attempt to enter these flowers except Weigelia rosea, they know what the bumble bees have done and without any honey guides they go straight to the minute holes on the outside of the nectary!

While bees are conspicuous on the purple flowers above mentioned, many of a similar color are not visited by bees at all and scarcely by any insects, as the large purple *Cle-*

matis, *Vinca*, *Ageratum*, *Sisyrinchium*, the smaller *Lobelias*, *Solanum Dulcamara*, *Agapanthus umbellatus*, and most probably other blue lilies, *Hydrangea hortensis*, *Tradescantia Virginica*, etc.

WHITE.

Among white flowers our native and garden varieties of Clematis are visited by numerous honey bees which lick the juices from the filaments and anthers, as the flowers have no nectaries. *Clethra*, white, is visited by many large size insects attracted by its fragrance as well as nectar, such as bumble bees, honey bees, wasps, hornets, ichneumons, drone flies, butterflies (yellow, black, or brown-eyed, etc.), humming-bird moths and other moths, and the ambush bug, etc. Of this promiscuous crowd the bees are always very much in evidence. Notwithstanding the attractions of this sweet flower, the purple Asclepias, the Canada Thistle, the crimson-purple Burdock, and the pale green flowered *Rhus copallina* attract just as well both kinds of bees, and about the same mixed assembly.

Ligustrum, the common privet, also white, with small tubular flowers, is visited while the day lasts and until the last corolla falls to the ground, by both kinds of bees and numerous butterflies and drone flies. *Melilotus alba*, a small, sweet-scented flower of the *Leguminosæ*, is much liked by bumble bees. One will rarely miss finding numerous heavy-bodied bees clinging to the slender pea-shaped flowers; the same may be said as to *Hydrangea paniculata*, *Cephalanthus*, *Deutzia*, etc.; on the other hand no bees ever visit *Sambucus Canadensis*, *Philadelphus inodorus*, *Solanum tuberosum*, or *Exochorda*, all very showy white flowers, having no nectar, but a plenty of pollen. Our white flowered cherry trees, pear, quince, and apple trees, the latter more or less tinged with crimson, are visited by throngs of honey bees and many bumble bees, which aid greatly in fertilizing the flowers, also *Prenanthes*, *Cephalanthus*, *Hydrangea pa-*

niculata, *Aster umbellatus*, *Nymphæa*, *Halesia*, *Æsculus*, white lilac, white foxglove, white rose, mignonette, etc., all white flowers, are frequented some by honey bees, others by bumble bees.

Bees do not care for the small, flat flowers of spiræa, strawberry, viburnum, cornus, sambucus, achillea, May-weed, etc., all of which are white. They also discriminate between flowers of the same family and same color: Rubus strigosus and R. occidentalis, raspberries, have diminutive white flowers much frequented by all kinds of bees, while the larger and showy R. villosus, high blackberry, has but a limited number, certainly many less.

It appears to one, at first, singular that bumble bees which are crazy for the white, fragrant flowers of Rosa rugosa, var. alba, will never alight on the white, sweet-scented and beautiful flower of the water lily, Nymphæa. I suspect that they do not like the water, and are afraid of wetting their feet; besides, there does not appear to be any nectar, and the limited amount of pollen is better adapted to small flies, yet honey bees enjoy these flowers.

Bees are so fond of white privet that I have often seen them (bumble bees) remain so long at the close of day that they went to sleep on the flowers and remained there all night!

RED OR RED-PURPLE.

Bumble bees are fond of red clover, which, as has been noticed, is of a very different color from Brunella and Viola. All of these flowers are more limited in kinds of visitors, on account of their peculiar shapes. Pink-purple foxglove, as well as all other tints, is visited by both kinds of bees: the bumble bees readily entering the tube, not regarding the very slender hairs almost invisible on the lower lip, which cause the more sensitive honey bees to turn and enter, if they can, by the upper side. No more bees visit the flaming red flowers of Pyrus Japonica than the pure white cherry blossoms, both of the same family and similarly constructed: no more a red rose than a white one.

Honey bees revel on hawthorn, while bumble bees rarely approach it. The scarlet or red tulip is mainly visited by honey bees.

Rhexia Virginica is visited by both bumble and honey bees. Bumble bees can usually be found on *Rhododendron*, *Æsculus*, *Robinia*, *Aquilegia*, *Weigelia rosea*, *Zinnea*, Gladiolus, Hibiscus, scarlet poppy, foxglove, balsam, rose, scarlet salvia, dahlia, malva, *Apocynum*, *Polygala*, *Gerardia* and *Elodes campanulata*, etc. These are mostly large flowers and tubular.

Spiræa salicifolia, flesh color, is frequented by bees and many other insects, while S. tomentosa, rose color and more showy, has almost none. No bees have been seen on Kalmia latifolia and K. augustifolia. It is said that bees do not frequent oleander (Nerium Oleander).

YELLOW.

Baptisia tinctoria, Cytisus scoparius, and probably all the larger yellow papilionaceous flowers are visited by bumble bees quite as exclusively as Wistaria, Brunella, or red Clover.

Goldenrod is much liked by honey bees and other small bees which can always be found on it, while bumble bees not so uniformly: wasps and hornets are also often seen on these flowers.

Taraxacum and *Ranunculus bulbosus* have many honey bee visitors, but a limited number of bumble bees. *R. acris*, with only a minute nectariferous scale, has no bee visitors.

Helianthus annus attracts more bumble bees than honey bees! also hornets and several other kinds of bees.

Asclepias tuberosa, yellow or orange, many bumble bees and honey bees, various kinds of butterflies, common flies, etc.

Pumpkin, squash, melon, and cucumber, all yellow, are fertilized almost exclusively by bumble and honey bees. Five or six honey bees may sometimes be found in a single pumpkin flower, scrambling over each other.

Oenothera biennis by bumble bees and other bees, a pink-and-white moth and another of a dusky color.

Impatiens fulva is visited by bumble bees who both enter at the orifice and afterwards bite holes in the sharp-turned, fish-hook spur from the outside, to get every drop! also by humming birds.

Hypericum and *Hypoxis* rarely have insect visitors; a few honey bees only have been seen on Hypoxis.

Ribes aureum, yellow, with a long calyx-tube, is visited by bumble bees.

Linaria vulgaris, yellow, is visited exclusively by bumble bees and another small bee.

Silphium asperrimum and *Heliopsis scabra* are two plants of about the same height, with yellow flowers, similar in appearance. The former is visited by many bumble bees, while Heliopsis has none. The florets of Silphium were longer and looser; those of Heliopsis shorter and more compact; these were the only visible differences. Heliopsis was not entirely forsaken by insects, however, for it had several kinds but smaller in size.

Sassafras has small greenish-yellow flowers visited by flies and ants. Bees do not visit them. If they alight casually and taste the nectar, they immediately leave in disgust.

Tilia, on the other hand, of a similar color but even paler, has throngs of bees and other insects which all together make a distinct humming sound!

Oakesia sessilifolia is of a dull cream color, flowers drooping, under overspreading leaves. The flower is often scarcely visible, and yet bumble bees will fly close to the ground, passing violets, potentilla, strawberry and other flowers, to find this *bonne bouche*.

Bees are also commonly seen on Helianthus giganteus, Marygold, Helenium autumnale, Actinomeris squarrosa, Laburnum, Berberis, Aesculus glabra, A. flava, Crocus, Tropaeolum, Canna, Gerardia, Cytisus, Linaria vulgaris, Solidago, Impatiens fulva, Cnicus horridulus. Ribes aurea, yellow, with long calyx tube, is visited by bumble bees, but they never visit the myriads of Potentilla Canadensis, same color, and rarely the more showy Forsythia. They also discriminate between dandelion and buttercup, and seek out Hypoxis from among Potentilla, Oenothera pumila and buttercup!

GREEN.

By the 1st to 15th of June many flowering shrubs, fruit trees, etc., are past blooming, and bright colored flowers are for a time rather scarce; then, many dull, green colored flowers appear, and one unfamiliar with the fact would be surprised to know to what extent these inconspicuous flowers are visited by bees. In several instances while walking through thickets, not noticing anything but green leaves, my attention was attracted by the humming of bees. They were found to be in great numbers on the perfectly green pistillate flowers of *Nyssa sylvatica* in one instance, and on *Gaylussacia frondosa* in another. These bees had left *Iris*, *Sisyrinchium*, *Cnicus horridulus*, *Kalmia*, blackberry, buttercups, etc., and for the sake of a green flower? Not at all. The nectar of the flowers just coming into bloom was undoubtedly the chief attraction. For several years I have observed the fondness of honey bees for the spicy-scented *Ptelia trifoliata*, and have awaited the time of its flowering to see the thousands of clustered green flowers about to blossom, visited by many honey bees eagerly watching their opening, and that as long as a blossom remained they continued their visits. *Ampelopsis Veitchei*, green with small flowers, often entirely covered by the large-leaved foliage, petals and stamens soon falling, yet they are much visited by honey bees!

In the first half of June the following green flowers bloom: *Petelia*, *Smilax*, *Gaylussacia frondosa*, *Vitis*, *Liriodendron*, *Gymnocladus Canadensis*, *Rhamnus cathartica*, *Nyssa sylvatica* and *Rhus Toxicodendron*, and all but the last are visited by honey bees. They are also very fond of *Rhus glabra*, *R. typhina*, *Ribes nigra*, English Ivy, *Ampelopsis quinquefolia*, *Asparagus*, *Andromeda*, *Salix*, *Norway Maple*, and, notwithstanding its disagreeable odor, *Ailanthus glandulosus*. The latter was visited by both honey and bumble bees, but bumble bees were rarely or never seen on the other green flowers excepting English Ivy, *Gaylussacia*, and *Andromeda*.

A recent writer observes that, "Thistles are purple to please the bees." If so, what insect was intended to be pleased with the yellow thistle? Certainly bumble bees appear to be greatly pleased with them and are by far the most numerous visitors.

One finds a marked difference in the habits of honey and bumble bees. The former take a much wider field of operation. They visit readily nearly every green flower except the veriest weeds, beginning with the willow in the Spring, and continuing until the English Ivy blooms in the Fall.

Bumble bees, on the contrary, visit but a few of this color, not even Liriodendron, preferring the brighter hues and tubular form, yet some of bright colors and favorites of honey bees are not frequented by bumble bees.

If any kind of bee has a preference for blue it is the bumble bee, but those flowers of a blue or purple color that he visits the most frequently are always visited also by many kinds of butterflies, which proves that those flowers are rich in nectar. Also when one sees the white cabbage butterfly, *Pieris*, and the green *Colias*, supposed to be especially fond of Brassica, delighting in Pontederia, Heliotrope, Brunella and other blue flowers of same family, it is quite evident that butterflies also have no preferences for color. I have seen the same kind of dusky moth visiting in the evening, *Oenothera*, yellow; *Azalea viscosa* and privet, both white; *Apocynum androsaemifolium*, pale pink; and a garden larkspur, var. candelabrum, blue-purple! One is not likely to know what its preferences were for color, but it certainly appeared to be enjoying itself as much on one as on the other.

It is the same story for the moths as for the bees and butterflies, wasps, hornets and ichneumons, they all seek honey wherever it can be obtained, color or no color; and quite a percentage of the smaller kinds are content simply to sip the honey-dew from the green leaves, never visiting a flower, as is easily proved by walking through bushes in a midsummer evening where there are no flowers, and seeing the millers fly up before you on every hand, to alight again on other leaves!

In a comparison of Alpine Gentians, Müller suggests the following theory of their evolution:

G. lutea is of a lower grade than the others and nearer the primitive form. From one branch of the original a campanulate form was evolved in its relation to honey bees. Finally the corolla became so narrow that Lepidoptera as well as humble bees were obliged to perform cross-fertilization. "The primitive color retained in *G. lutea* was gradually exchanged for blue by the influence of the humble bees."

When one notices bumble bees so hardly pressed in the "struggle for existence," that they bite the sticky tubes of white *Azalea viscosa* and the yellow tubes of *Impatiens* and numerous other sorts of tubes which it is impracticable for them to enter at the mouth, one can hardly believe that these same bees are all this time diligently developing blue flowers, and that wasps are developing yellow flowers when they seek blue larkspur from which to pilfer the honey in the same way, each one abandoning his supposed favorite color to obtain honey with difficulty from another which he dislikes! But in addition to the evidence before our eyes in our gardens and fields of no preference for a particular color, aside from favoring forms, Müller himself, besides the instances above quoted of yellow flowers being exclusively cross-fertilized by bees, states as follows: "The sulphur-yellow color of *Sempervirum Wulfenii* seems not to stand on the same rank as the yellow color of some Sedums, but rather to have been developed from a purple color by the selective influence of humble bees"!

"In several species of Lonicera fertilized by bees the colors are bright red"!

"In *L. caerulea*, adapted for humble bees, they are yellowish-white"!

Müller clearly is impartial in his examples when he gives his opinion that purple was developed from yellow in one instance by bees, and in two others, bees developed yellow from purple!

Lubbock experimented with different colored slips of paper pasted on glass, upon which he put a drop of honey, and put them on a lawn for the bees, transposing the colors from time to time, with the result that the bees showed a decided preference for blue.

Müller on the contrary gives a table of actual visits of bees to different colored flowers, showing that those of a yellowish-white received the most visits, and blue the least number!

We have seen that bees discriminate between flowers of the same color in the same genus, and between flowers of the same color in different genera, also between flowers of different colors. They actually prefer some small green flowers to some showy blue flowers, and *vice versa*; and it is clear that their preferences are for the flower and what it affords and not for mere color. When one sees honey bees leaving beds of red begonia and pelargonium or blue myosotis for white clover close cropped by a lawn mowing machine, then forsaking clover for green Ptelia when that comes into bloom, he is quite ready to declare that azure-loving bees only love an azure color when it is for their interest. I have even noticed bees to leave flowers for a time and be content with only leaves!

There was a humming sound of bees in a purple-leaved beech tree, and searching for the cause there was found to be on the under side of many leaves a white, woolly substance which concealed numerous green aphides, and that they were living on pellucid little drops of a gummy nature which also attracted the bees! Similar sweet secretions are found on the common *Fagus ferruginea*, elm, and in less degree on red maple. It is a wonderful faculty that bees have which will enable them to find such minute secretions on leaves, or on inconspicuous green flowers without perceptible odor. It is scarcely conceivable when one is acquainted with the habits of bees that will so diligently and indefatigably search for nectar, that they would hesitate on any particular color, because, forsooth, it was not the right tint!

Bumble bees are a sturdy race of insects, made to crowd, push, probe, and burrow; therefore they prefer a tubular or bell-shaped flower that they can enter, or a personate or papilionaceous flower that they can force, or a tubular flower not too long that they can probe. Naturally they do not care for small flat flowers or diminutive florets of composites, such as ox-eye daisy, erigeron, achillea, etc.

The minor insects, as might be expected, fly indiscriminately from color to color without preference, and the same is the case with butterflies. I have counted more than twenty different kinds of flowers which were visited by the same species of butterfly! And about the same number by wasps. There is probably not a single kind of flower but that is visited by half a dozen kinds of insects and probably the greater part are visited by many times that number.

In the case of the tulip we showed how the same bee produced three different colors at the same time by stimulating the petals to increased action. In like manner not only bees, but every other insect is doing his part to stimulate the flowers to produce more and brighter color. They do not select, they simply stimulate, and the flowers or plant does the rest. Regarding the prevalent opinion that bees have a preference for blue colors, the writer has experienced more difficulty in finding bees on blue violets, sisyrinchium, iris, etc., than on dandelion and buttercup. I have never seen a bumble bee on heliotrope and they do not visit larkspur with much zest, almost always biting holes on the outside. I have seen more ichneumons on *Asclepias Cornuti* than bumble bees: seven large, black, waspy ichneumons were seen at one time on a single umbel.

As between Antirrhinum majus, purple, and Linaria vulgaris, yellow, being similarly shaped, there is no preference whatever. Both are fertilized by the same bees, viz., bumble bees, and another undetermined species rather smaller than a honey bee, yellow or brownish on under side of abdomen. While the former could only enter half way into Antirrhinum, the latter pushed entirely into the flower which closed after him. He was able to turn around and emerge when he chose

One can count more confidently upon finding bumble bees on butter-and-eggs, silphium, baptisia, Helianthus annuus, etc., than on any of the above or Agapanthus, Funkia, Centaurea Cyanus, etc. Yet certain families of blue are much frequented by bees, as the Borraginaceæ, Labiatæ, Pontederia, etc.

When a number of favorable conditions combine in a particular family or species, then bumble bees appear to have a preference for the flower. These conditions exist in *Anchusa*, viz., size and shape: tubular flower one-third inch long; throat slightly closed by feathery processes, (the bees enjoy a little obstruction), a continuous supply of high grade nectar, and a bright blue flower! The bees visit these flowers over and over again without intermission from morn till dewy eve. Very similar conditions exist in all the Borraginaceæ, in Brunella and Pontederia, but when like conditions meet in white privet, or clethra, the bees are just as numerous; also in a different style of tubular flower as crimson or white foxglove. This last, of a totally different color from Anchusa, never lacked for bumble bees while a flower remained on the stem

Honey bees have absolutely no regard for special colors: they go readily everywhere that nectar is accessible, naturally taking shorter tubes to probe than the bumble bees. A green flower is just as acceptable to them as a blue one, provided it is nectariferous, their business being to collect honey, and if green flowers can furnish it, or even green leaves, they will be on hand.

Moths visit at twilight yellow, white, green, red and purple flowers equally! The same humming bird was seen to visit the following flowers in the order stated: Gaillardia, Digitalis, Campanula, Heliotrope, Lonicera, Gladiolus; all colors represented. They also visit Tecoma, Tropaeolum, Arctium, Impatiens, Tiger Lily, etc.

There are of course certain kinds of beetles and bugs that feed upon the foliage or flowers of a particular family as upon Asclepias, Solanum, etc., but these care not at all for color.

The only difference I find regarding white flowers may be explained by their size: Mayweed, erigeron, achillea, sium, daucus, etc., have the very smallest white flowers, and very naturally would be visited by flies, the most diminutive bees, and the smallest butterflies, as *Chrysophanus* and *Phyciodes*, and this is exactly the fact in regard to these flowers; but when the same colored flowers get to the size of clethra, privet, cephalanthus, garden cherry, blackberry, white pond lily, etc., which are no more specialized than the former, the bees are very much in evidence and also the larger butterflies.

There are a dozen kinds of bumble bees, *Bombus*, in

New England, and I have noticed considerable difference in the various species as to the flowers they visit. There are also over one hundred species that are classed as bees, large and small, in the same territory, and taking together all the flower-visiting kinds of insects, their number would be in the thousands!

In a pond I found a large quantity of Pontederia, pickerel-weed, while the border was lined with Cephalanthus. The pickerel-weed was visited by bumble bees and several pretty maroon or reddish-brown banded humming-bird moths and several kinds of butterflies, but by no honey bees! Cephalanthus was visited by many honey bees and a number of bumble bees, also butterflies. The white flower of Cephalanthus, just coming into bloom, was preferred by the honey bees to the blue of Pontederia!

At about the same time it was observed that there were scarcely any honey bees and but few bumble bees in a garden of twenty or more choice varieties of flowers, several of which were purple or violet. The apparent explanation was, that at a short distance from the garden there was a lawn containing a number of bushes of the sweet scented privet, which apparently had attracted all the bees of the neighborhood.

A little later in the season every honey bee deserted heliotrope and mignonette, which earlier had been especially attractive to them, for *Ampelopsis Veitchei*, a perfectly green and insignificant flower, almost concealed by broad leaves! They even appeared to prefer this flower when petals and stamens had dropped off. Bumble bees did not appear to have the instinct to find it. These examples from the pond and garden illustrate the competition of flowers and the changing tastes of insects, and also prove that there are greater attractions than color.

In relation to the color of a flower being adapted to its environment, I have remarked that scarlet tulips expand their cup-shaped corollas sooner after cold or cloudy weather than white or yellow of the same age in the same bed; and that the latter close earliest at the approach of a cold storm. This appears to be due to the difference of temperature in the flower; the white requiring most heat, the yellow less, and the red least. The pink *Cornus florida* blooms a little earlier than the white.

Newbigin states that "the red parts of plants absorb 1.82 per cent. more heat than green parts."

Another observation may be worth noting in this connection, viz.: I have remarked that in the Southern States there is a preponderance of yellow flowered species in several genera which are common to both the North and the South. Following is a partial list:

	Chapman's Botany.			Gray's Manual.	
Polygala,	5 yellow species,	17 purple.		2 yellow,	12 purple.
Crotalaria,	3 "	none "		1 "	none "
Aeschynomena,	2 "	" "		1 "	" "
Baptisia,	9 "	" "		2 "	" "
Agrimonia,	3 "	" "		2 "	" "
Waldsteima,	2 "	" "		1 "	" "
Rhexia,	1 "	" "		0 "	3 "
Nymphaea,	1 "	" "		0 "	none "
Aquilegia,	2 "	" "		0 "	1 scarlet, 1 blue.
Sophora,	1 "	" "		0 "	none purple.
Astragalus,	2 "	" "		1 "	" "
Rhynchosia,	6 " and 1 var.	"		3 "	" "
Thermopsis,	3 "	" "		2 "	" "
Cassia,	7 " and 1 var.	"		4 "	" "

The species described by Gray as greenish, cream color, Chapman calls pale yellow.

California furnishes yellow Iris, yellow Lupinus, *Eschscholtzia*, *Calochortus*, etc. *Delphinium cardinale* and *D. nudicaule* have orange or scarlet sepals or partly yellow petals, while Northern species are purple. It would not be at all improbable that some yellow-flowered species originating in Southern climates should on spreading farther North become flushed with red or purple.

AN INSECT WITHOUT TASTE FOR COLOR, AND WHICH PREFERS BLOOD TO SWEETS.

Phymata Wolffii, the Ambush Bug, is a common insect on the flowers of the field and garden. He is a deadly enemy to honey and bumble bees, large flies and butterflies. The appearance of a spider, so different from a winged insect, would seem to be enough to frighten away any of the latter and prevent their capture unless taken unawares in a web, but this demure, winged bug, only two-fifths of an inch long, dressed in quiet yellowish or greenish colors and marked on its back with a brown-colored cross, gives no warning of its sanguinary nature. It is quite innocent looking, and appears to have as good a right to visit the flowers as bees or butterflies. It sometimes hides under the petals, especially when they are small and clustered, but quite as frequently takes up a conspicuous position on the flower, where it remains perfectly motionless until the legs of the bee or other insect are in a favorable position, when they are seized by the diminutive but powerful club-shaped claw of the bug, stabbed in a vital part by the dagger-like proboscis, and their life blood sucked away. In one instance the bee's tongue was seized and by that he was held. It is not pleasant to see a noble insect like a bee, or a beautiful butterfly, or even a drone fly, sacrificed by this worthless thug with the sign of a cross on his back. It is needless to say that the murderer is not fastidious as to the color of the flower he visits: yellow, white, red or blue are all the same to him, provided there is a good supply of victims!

CRUELTY TO INSECTS.

The structure of the flower and the manner of pollination in Asclepias is as complicated as in orchids. The five deep wedge-shaped slits in the crown are veritable death-traps to some insects. While spiders have been seen to walk over them with impunity, bumble bees invariably get their legs entangled, but by a vigorous jerk they are able to pull them out, and often with the pollen masses attached. Wasps are more awkward, and twist themselves round and round, but finally escape; while flies and miller-moths often become hopeless prisoners and an easy prey to prowling spiders. Sometimes they succeed in their struggles for liberty by wrenching themselves from their pinioned limbs, which are left standing on the flower as monuments of a freed but mutilated body. A dozen flies have been counted on a single umbel, all securely entrapped by these cruel pollen pockets. Ten times as many honey bees as bumble bees visit this flower, at least in the vicinity of towns, and they appear to be very efficient fertilizers too, yet I have found several dead, held fast by a leg, when there were parts of five pairs of pollinia adhering to the others in one instance. This bee appeared to be doing good work, but being a trifle under size, he had not the strength to extricate himself.

This is an instance of lack of perfect adaptation of flower and insect, for while the bees generally suffer no great inconvenience in getting their supply of food, some, and especially the smaller kinds of insects, are maltreated, with no possible advantage to the flower, as they do not digest the insects, nor their severed members, like *Drosera* and *Rhododendron viscosum*. The above flower was *A. Cornuti*. Either the many kinds of visiting insects did not have any special taste for color, or else they were willing to sink their tastes and run the risk of sundered limbs!

Apocynum androsæmifolium has clusters of small, flesh-colored bell flowers. The almost sessile anthers connive over the pistil, meeting at the top, but separated below by a very narrow slit. Just opposite each slit at the base of the corolla is a fine tooth-like process which projects into the slit, almost closing it but not quite, as there is left the width of a hair between it and the anthers on each side.

Very small insects creeping in the bottom of the flower get their legs caught in this narrow space and are held fast. If they have strength to pull away from the tooth, the leg then goes into the slit, from which there is no escape. The only advantage to the flower in this and the previous example, would seem to be to punish intruders; but the latter flower has honey guides inviting all, if that is to be construed as their object, which the writer does not allow; certainly there is no sign to the small fry to "keep out."

Azalea viscosa, *Cnicus muticus*, Nicotiana, several species of *Silene*, etc., which have viscid secretions on or near the flower, are more considerate, as these give warning to the ants not to trespass, but quite a number of small winged insects are hopelessly glued down. In the case of Azalea with its glands, the insects may perhaps be digested as in *Drosera*, but it does not appear to be the case in the others. The insects entrapped are quite diminutive and the numbers comparatively small, so it would seem that the loss of nectar taken by them would be only a trifle, but a trifle saved for more efficient fertilizers may in the long run be of much importance to the flower. Who knows!

But an insect's life is subject to calamities; what with traps, pitfalls, smothering, drowning, starvation, assassination by other insects, and takings off by birds, etc., the bees and the butterflies have their full share of trials and tribulations, which are rarely noticed except by the close observer of Nature, whose sympathy is often aroused.

AGENTS AFFECTING COLOR.

Dilute nitric acid changes purple or blue flowers and leaves as violets, heliotrope, vinca, and leaf of coleus, etc., to a red color; yellow flowers of oxalis and daffodil to brick-red; other yellows as in tulip, lantana, alamanda, cattleya citrina, to a blue-green.

It affects differently the different petals of *Cytisus canariensis*, changing the "standard" to green and the wings to brick-red. Some yellow flowers are not at all affected by the acid. A yellow pansy quickly turns to a bright green, followed by brick-red; white flowers turn from pale to chrome yellow.

Salsoda changes some purples to bright blue, others to bluish; certain whites to lemon yellow, others to yellowish-brown; some yellows, as in Lysimachia, to brick-red; this last evidently contains some red, for it may be detected with a lens. The soda brings it to view.

Potash does not affect the yellow color of tulips, dandelion, or alamanda, but changes the lemon-yellow of oxalis to blood-red; it has no effect on the standard of Cytisus, but changes its wings to a dull orange or amber color, and Lysimachia to brick-red; a purple crocus to green; some white flowers to lemon-yellow, others to bright red. A scarlet pelargonium, it is said, changed by an alkali to yellow, may be restored to its original color by an acid.

The purple vegetable dye, litmus, changes to blue with an alkali.

Acids and alkalies are properties of plants: various kinds are free in the cell sap, and color is naturally influenced according to the proportions of each.

Ordinary atmosphere changes the color of a certain mushroom from yellow to blue when fractured, and the yellow sap of Baptisia becomes an indigo-blue by simply agitating it in the air.

Ozone changes vegetable colors.

Certain minerals, as iron, change colors.

The action of the sun on the chlorophyl-green of stems and leaves will often change that color to red or purple, while the opposite side is unaffected

Too strong sunlight will often destroy color or cause it to fade to white, while a proper amount deepens it.

Water will dissolve out certain purples, changing them to white as in violets.

Field scabious (Knautia) of two shades of purple, is said to change to a bright yellow when exposed to the smoke of tobacco!

A proper amount of sunlight is necessary to evoke color. Insects deepen and intensify the natural hue by the stimulating effects of their friction.

Insects may change the color of an individual flower by puncture.

Newbigin ascribes color in flowers to the result of diminished vegetative power; another has given an opinion that change of color is due to "the struggle for life."

It is well known to botanists that flowers change color by the mere process of drying, while in press.

A white *Monotropa* turns coal black, also yellow Baptisia; some purple asters fade to white, and the white pappus of others turns red.

A rain drop or a spider, remaining for a few moments on a petal of a purple morning-glory, will leave a red spot.

The sap in Borraginaceæ, as forget-me-not, etc., is said to be first strongly acid, but that with age the acid disappears. These flowers change from pink to blue.

According to Louis Prang, yellow can be obtained by a mixture of red and green.

There are some indications that insects by their stimulating influences may really evoke in a limited degree a new or modified tint by drawing some new element to the surface, as suggested in Liriodendron.

Many flowers as a whole, or their honey guides, change color at the time of fertilization, probably by the plant diverting its energy at that time to the setting of the seeds. Different reliable gardeners have stated that cuttings from a blue Hydrangea hortensis frequently produce at first pink flowers. This may be accounted for by the new, rich soil and better nourishing, for according to the same authority, when the plant gets pot-bound and starved, its flowers are apt to come blue!

ADDITIONAL REASONS WHY INSECTS DO NOT SELECT COLORS.

1. There are numerous species of flowers which have never been known to change color, for example, dandelion and buttercup.

2. A considerable number of different hues are devoid of odor and nectar.

3. Flowers of the same species growing naturally in different regions, are visited by quite different insects. According to Müller himself there is a vast difference in the number and kinds of insects visiting *Thymus serpyllum*, whether in lowlands or on the Alps. "In lowlands there are more flies: in the Alps more butterflies."

4. Short-lipped insects would naturally seek open or diminutive flowers, but ordinarily there would be nothing to prevent their entrance to tubular or bell-shaped flowers, nor anything to prevent bees and butterflies from visiting the former. Comparatively few flowers are specialized for a single species of insects.

5. If insects have preferences and can change the color of flowers by their partiality for their favorites and the neglect of others, one would expect that the resultant of the visits of a score or two of insects belonging to different species would be a dull or neutral hue, while as a matter of fact our flowers as a rule have remarkably pure and rich colors, as seen in the daisy, buttercup, rose, etc., notwithstanding that they may be visited by as many as fifty different species of insects, or even more, including coleoptera, hemiptera, lepidoptera, and humming-birds.

Müller states that eighty-eight different species of insects visit *Cnicus arvensis*, rose-purple, and ninety-three species *Taraxacum officinale*, yellow. If these insects, each with its special taste for color, can by their combined efforts produce a pure yellow in one case, and a rich purple in another, it must be because they were guided by Omnipotence, and the result is no less than a miracle!

6. The same species of insects are the principal fertilizers of flowers of totally different colors: as bees in *Melilotus alba*, and *Ligustrum*, privet, both white: *Baptisia tinctoria* and *Impatiens fulva*, both yellow: *Trifolium* and *Veronica*, both purple but of different grades: *Salix* and *Ptelia*, both green.

In the Spring, the same bees being almost the only insects in motion, visit one color of Crocus just as readily as another, and honey bees visit the wholly green, pistillate willow as promptly as the bright-flowered Crocus.

If it were urged that these divers colors have not changed because they have never shown any tendency to change, then it should be allowed that the larger portion of our Flora is not at all affected as to color by insects!

7. Flowers change color in spite of their visiting insects. The same bees visit the same flowers, continuing in the same pathways to the nectaries, tracing thereby permanent guiding lines made of the original color, which said bees were supposed to especially fancy, but, while the guides remain, and the bees continue as before, the remaining portion of the corolla changes to a strongly contrasting hue. The bee selected nothing, his remonstrances, if any, were in vain, the flower for good and sufficient reasons just simply changed color, and if he did not like it he could leave it!

8. There is collateral evidence that color does not result from insect or animal selection in the color of spathes, involucres, sepals, and many pretty winter buds which have no nectar nor odor and yet are found of every hue, in numerous instances totally unlike that of the petals. In such cases two different kinds of insects would be necessary to accomplish the variegation: are they each competing for the ascendancy, or one trying to confuse the other? True foliage likewise changes color, as from red or purple to green, or from green to yellow, red or purple. Insects obviously are not concerned in these color changes, nor are

animals either. The same may be said of the stems. Green brier and sassafras are green, cornus and viburnum red, grape vine brown, blackberry claret color, some birches snow white, certain willows yellow, a host of shrubs gray, a few goldenrod and adiantum stems black.

We are not aware of such a diversity of grazing animals of individual tastes as would be sufficient to meet the requirements of the infinite variety of hues displayed in stems and foliage. Donkeys and goats do not run wild in New England, and rabbits, deer, bears and bison are not æsthetic in their tastes. Nor do we believe that there exists a sufficient number of burrowing and rooting animals (earth worms are said to be eyeless) to account for the numberless varieties of tint in roots, bulbs, etc.

The common garden radish is of a pure red, carrots orange color, parsnips pale yellow, beets dark red-purple, turnips, some white with purple tops, others yellow with purple bases, onions run from a porcelain white through every color to purple or blue, and the whole range of color is also found in the roots of our native wild plants.

9. If blue flowers are especially attractive to "azure-loving bees," one might naturally expect in view of the numerous species of *Apidæ*, that blue would be the pervading color, or at least a very prominent one, but it is a well known fact that blue flowers are comparatively rare. I do not recall any tree or shrub in New England bearing a blue flower. Moreover, it is obvious that many blue flowers are wholly independent of bees. We have already alluded to Larkspur as not being adapted to bees on account of its long spur. The widespread blue flower of Clematis, Jackmanni, is not nectariferous, and is only occasionally visited for its pollen, while several other species of Clematis of a blue color, have tubes so long and narrow that both bumble and honey bees are excluded from the honey, unless they bite holes from the outside, as *C. tubulosa*, *C. Davidiana*, etc. These flowers of our gardens are exotics, but it is

clear that they were never developed by nor intended for bees; the same is true of garden phlox and verbena.

Even among blue flowers there is a marked difference in the visits of bumble and honey bees: honey bees enjoy heliotrope, bumble bees do not visit it: bumble bees delight in pickerel-weed, honey bees are not attracted: bumble bees only, visit pansy: I have not seen honey bees on Anchusa, etc.

Of two rows of Snapdragon, one yellow and one purple, each bee followed down his own row to the end without crossing to the other which was equally near, also in a bed of Crocus each bee generally takes a single color, and when pursuing yellow colors will fly directly over and across blue flowers to find the object of their search, which outside of flower gardens means a particular species of flower, to which they are guided by the color. When certain species are scarce they are not so methodical. This clearly indicates that if a particular flower satisfies their gustatory tastes they do not abandon it simply for one which pleases the eye.

Bees take their repasts mostly in courses. It will probably be found that they know the hours at which the different species blow, and are then promptly on hand; they will take the roses in the morning, and the honeysuckles approaching sundown; crepuscular moths appear with wonderful promptness as soon as *Oenothera* expands.

In changeable flowers they take the freshest, whatever the color then may be; and they often are obliged to discriminate against purple and blue!

Bees are able to distinguish between different sorts of blossoms of the same color, but a difference in hue is of great assistance in finding the kind of flower they want.

We see changes going on in the individual flower under our very eyes, without the aid of insect selection: yellow Pansy to blue, white Lonicera to yellow, etc. What takes place in an individual flower in a few hours, we can well conceive might require under other circumstances many generations to effect, and the change would just as surely be made without insect selection in the latter case as in the former.

When the more recent leaves of a Croton change from yellow to scarlet and the older green leaves at the same time change to a red-chocolate color, no insects whatever are concerned in these color changes, and yet the new colors are as distinct and well defined as those of a flower. No insects are concerned in the colors of bracts, leaves, stems, petioles and roots; why in the parts of a flower?

10. There are a plenty of existing flowers of a dull hue owing to crude combinations of pigments, as perhaps green and purple. Why have the bees not selected the purple thousands of years ago? Simply because they have no control over the acids, alkalies or other chemical agents in the sap. Their utmost ability is to perpetuate what the constitution of the plant creates.

The white water-lily (*Nymphæa*) in south-eastern Massachusetts is slightly inclined to a pink color, discoverable on the borders of the sepals. On Cape Cod there is a variety wholly of a beautiful pink tint. Does anyone believe that this tint was produced by the selective agency of some insect peculiar to Cape Cod? The idea would probably strike the average mind as absurd.

In brief, Müller's idea is that insects have changed the form and the color of flowers, which is equivalent to saying that insects have created the different species of plants. The result of this doctrine logically carried out to its final analysis would be that, as species affect the fruits, all the various kinds of fruits, as plums and cherries, apples and pears, oranges and pineapples, etc., were originated practically by bees and butterflies! I do not think that with our present knowledge we are quite ready to accord to them so much power and influence over the floral world.

With all deference, therefore, to Müller's opinion regarding *Gentiana*, we are forced to believe that he was mistaken regarding the cause of a different color in a different species.

CONTENTS.

OBSERVATIONS

ON THE

COLORS OF LEAVES.

PRECEDED BY A

SUPPLEMENT TO

Observations on the Colors of Flowers.

BY

E. WILLIAMS HERVEY.

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SUPPLEMENT

TO

OBSERVATIONS

ON

THE COLORS OF FLOWERS.

Among various notices of my *Observations on the Colors of Flowers*, certain criticisms which appeared in *The American Naturalist* and *The Gardeners' Chronicle*, may conveniently, and, as it seems to the writer, very properly be referred to in this supplement to the same.

The Gardeners' Chronicle of Feb. 10, 1900, while giving on the whole an appreciative notice of my pamphlet, suggests, very courteously, that on the subject of honey guides I might have "unconsciously absorbed and appropriated" Mr. Henslow's theory.

But as a matter of fact I had not read or heard of Prof. Henslow's *Origin of Floral Structures* until I had formed my opinions from my own observations upon the genesis of honey guides, and the "copy" was ready for the printer. Moreover it would seem that *The Gardeners' Chronicle* wholly misapprehended my views upon the subject, although special pains were taken to present them clearly. As my ideas were totally different from those of Prof. Henslow, both his and mine will now be re-stated, but in different phraseology from the originals.

Prof. Henslow's method may be understood by supposing bees or other insects, in pursuit of nectar, to alight habitually, season after season, upon a particular petal of, for instance, a white flower until finally a yellow spot be produced upon the white foundation, as a result of the continued insect irritation. The yellow spot would be called a honey guide.

Prof. Henslow's own words are: "The spots have been determined by insects": "*they are simply the direct results of the insects*": "one result of a more localized flow of nutriment"; "the insect visitors induced the flower to paint the petal with a golden streak."

The writer's method supposes, for instance, a yellow flower to be visited in like manner, but the irritating effects of the insects result simply in *deepening the existing color* in the one irritated spot but not otherwise changing it, as in the preceding case. Thus far we have a flower still of a single color but with a part of one petal usually, of a somewhat deeper shade. Numerous cultivated flowers are to be met with, in practically this condition, without any more striking feature. To produce a strongly contrasting spot, marking, or entire petal, as is more commonly seen in honey guides, something more is required, which is not within the power of insects to effect, namely, a general change of the basal color, except in the circumscribed and irritated spot before mentioned *which does not change.* This general and often profound transformation is not limited to any one color, but a very common change is from yellow to white. Our entire flower would therefore have changed from yellow to white except in one spot, and that spot is yellow because it is part of the original color. The honey guide thus formed has the *old* color; Prof. Henslow's honey guide has a *new* color. Our flower has a *new foundation color*, while that of Prof. Henslow has the *old*, *original one.* The methods it will be observed are as unlike as could well be imagined; there is absolutely nothing in common and yet we are told that our method is appropriated from Prof. Henslow!

Prof. Henslow remarks farther regarding honey guides:

"Those peculiar and special displays of bright tints distributed in spots and streaks in certain and definite places only, have been called 'guides' and 'path-finders,' as they *invariably* lead to the nectaries."

In this statement, Prof. Henslow falls into the same error as several other writers, the fallacy of which is pointed out on pp. 67, 70, and 74 of my *Observations*.

Joseph Y. Bergen in *The American Naturalist* for November, 1899, referring to the comparison of the effects of mechanical irritation on animal and vegetable tissues on p. 58 of my *Observations on the Colors of Flowers*, viz.: that the bees stimulated the flower to send more pigment to the honey guide, as friction or a pinch would bring more blood to the cheek, observes as follows:

"Even the lay reader will find little difficulty in judging of the value of the analogy between the development of pigment in cells of petals and the response of human arteries to stimulation transmitted from the central nervous system."

My statement is perfectly plain, viz., that the additional pigment which made more depth of color in the flower mentioned was *sent* to that point the same as the blood was brought. But the critic has the faculty of wresting the language of the text to suit his own ideas, as is seen in his accompanying comment. It seems inexcusable that he should represent me as saying that the pigment *was developed in the cells* when I distinctly say that the pigment was *sent* to the cells. Furthermore the introduction of the subject of the Central Nervous System was purely gratuitous, as was the absurd analogy which he himself invents, and upon which he asks judgment.

The cause of the redness of the skin from friction is solely the relaxation of the coats of the blood-vessels, allowing the ordinary flow of blood to dilate them.

We apprehend that the cause of more color in the honey guide, to which reference was made, was that the irritation and pressure of bees and of other insects upon the spot caused a relaxation of the cell-walls, which became thereby more permeable, and that more colored sap was attracted to the stimulated spot. There was in the process no extra heart pressure on the one hand, nor more root pressure on the other. The flower being of one uniform color as stated, the stimulus at one point would naturally draw some of the colored sap from the neighboring cells to that point, precisely as more red blood is drawn to an irritated spot simply because the caliber of the vessels is enlarged.

The analogy therefore is, that local friction brings color from the immediately surrounding parts, and that this additional color in both plant and animal is confined exactly to the limited space which is irritated. Whether my analogy (not his) is to be regarded as valuable or worthless will not make the slightest difference to the main facts given regarding the origin of the honey guide, which the critic completely ignores.

I may be excused in extending these remarks somewhat upon the subjects introduced by the reviewer. Undoubtedly the same irritation of the insects might, under some circumstances, attract colorless sap, laden nevertheless with pigmental elements, from which the chemical character of the cell contents would develop color. If for instance the cell contents of the petals should happen to be of a slightly acid character, a certain color might develop, while at the same time if some of the same general sap should enter the cells of another part or organ, as the stamens, whose cells might chance to be slightly alkaline on account of their special functions, these would be more than likely to develop a different color. Whether a flower is to be red or blue may depend upon which of these elements prevail, and how long it prevails, for cell contents vary, and color varies with them. The sap in *Borraginaceæ* is first strongly acid, but as the flower develops, the acid disappears. The flowers commonly change from red to blue.

But whether the pigment was actually brought to or developed in the petals' cells, would really make but little difference to the analogy, inasmuch as there would be an actual movement of sap in either case. In our example however not even this possibility was suggested.

Mr. Bergen alludes to "the development of color in cells of plants," a subject not mentioned in my text, but in passing I will point out some resemblances in plant and animal as to color. Cells, of course, and the development of color in them, are not peculiarities of plants: the bodies of animals as well, are composed of cells, and even the blood vessels are only lengthened cells. As pure and brilliant colors are derived from red blood as from colorless sap. These colors are more common among those lower animals which in simplicity of organization are nearer to the vegetable. Many species of worms have colors of much beauty; the *crustaceæ* are remarkable for the brilliancy of their coloring; reptiles are highly colored; there are green frogs, black and yellow salamanders, snakes and lizards of innumerable tints: "in insects the colors of the two stages larval and adult are often strongly contrasted, and such beauty of pattern and design cannot be found in the floral kingdom": birds and fishes have both structural and pigmental colors, while mammals are rarely remarkable for brilliant pigments; the different races of man have quite a range of color, white (?), red, brown, and black, and disease of the liver may produce a yellow color, but the principal display of color is confined to the hair and the visual organs, which contain real pigments liable to change of tints as in flowers, and the internal organs have various tints. These colors are separated in the animals from the nourishing constituents of the blood, by dialysis, chemical action, and to some extent by the effect of solar light closely similar to the development of color in vegetable cells from the colorless sap. Moreover some lipochromes identical in character are produced in the animal and the vegetable!

When the color of the flower and that of the sap are similar the resemblances are apparently nearer. Many plants have laticiferous vessels in which the latex circulates as freely as the blood in the veins. The latex varies in color in different plants, being white, red, purple, or yellow, etc., and is frequently of the same tint as the flower, as seen in Celandine, Tradescantia Virginica, Sanguinaria Canadensis, Apocynum, etc.; in Sanguinaria the flower is usually white, but sometimes rose color, and in Apocynum the white latex is often tinged like the flower, being white and rose. The latex and colored sap is apt to vary in color in its course, likewise blood varies from scarlet or crimson to dark purple.

In a cyclamen with purplish petioles and scapes, the purple vascular bundles surrounding the central part or pith were traced uninterruptedly from root or bulb to the red purple flower, a cross section of the scape displaying a purple ring, and numerous purple dots which were the ends of scattered bundles. Similar colored bundles are to be seen in Primula sinensis, and P. stellata, a cross section showing a crescent: the bundles run to the ribs of the leaves, also colored, and up to the flower which may be of a different color, or they may be broken, by an uncolored gap, from the flower. All the sap of a beet root is red, and it supplies the red petioles and the ribs of the leaves. But of course sap is usually colorless.

The gratuitous introduction by Mr. Bergen of the subject of nerves, was obviously for the purpose of showing an immense difference between animal and vegetable tissue, and the impossibility of any analogy on that account. He is very positive that the redness produced by friction is due to "stimulation transmitted from the central nervous system": but there are serious doubts as to that on the part of the writer. Whither the stimulation is transmitted he does not say, and one is obliged to enquire whether he means that it is sent to the heart, or directly to the reddened skin.

That the heart is not stimulated is clear from the fact that the pulse is not appreciably quickened, and that the effect is not general, but local. Some facts may be of interest concerning the effect of stimulus upon the blood vessels, and the effect of a suspension of all stimulus.

"When a person blushes the action of the nerves upon the vessels of the cheek is *temporarily suspended*, causing them to dilate." (Huxley and Youmans).

"When pure alcohol is applied to the skin, after the first effect of cold caused by its evaporation has passed off, the part becomes red from temporary *paralysis of the blood vessels*, causing them to dilate." (Prof. H. N. Martin).

"If the sympathetic nerve in the neck of a rabbit be divided, a vascular congestion of all parts of the head on the corresponding side immediately follows. The vessels of the ear become turgid with blood." (Prof. J. C. Dalton).

"Terror causes the skin to grow cold, and the face to appear *pale* and pinched, the supply of blood to the skin is greatly diminished in consequence of an excessive *stimulation* of the nerves of the small arteries which causes them to *contract*." (Huxley and Youmans).

It will be observed that in each of the first three examples preceding the skin becomes reddened when there is *no stimulation whatever* from the central nervous system, and in the case of the rabbit *all communication was entirely cut off from it* by section of the nerve. The effect therefore of a *suspension* of stimulation, is relaxation of the vessels, dilatation, and redness! If the blood vessels are really stimulated by an influence transmitted from the central nervous system as Mr. Bergen implies, then it appears that the same effect is produced when they are stimulated, as when they are not!

The subject of nerves is a very difficult one, and notwithstanding the increase of knowledge on the subject in recent years, it is still far from being well understood. It is known however that there are vaso-constrictor nerves which contract the vessels, when stimulated, and vaso-dilator nerves in certain parts of the body which are said to dilate the same when stimulated, and in certain nerves both kinds of fibers have been discovered. Several authors state however, that the action of the dilator nerves is of an *inhibitory* character.

One writes that "inhibition is connected with the effect of two sets of impulses upon the responding cell, and the two stimuli must tend to excite different reactions." There is little doubt from a consideration of the subject but that the cause of the relaxation is a removal of the normal tonic action by *inhibition of the activity of the constrictor nerve centers*. The blood vessels themselves would in that case be temporarily without stimulation, and practically in the same condition as when a nerve is paralyzed or when it is severed, as in the examples above stated. Inhibition, which checks or restrains the constrictor nerve centers from sending out their ordinary impulses, is a totally different thing from stimulating them to action. From the foregoing facts it would seem therefore, that while the relaxation is due to the action of the nerves, the action is a negative one, and that *no stimulation is transmitted* from the central nervous system to the coat of the blood vessels!

But, when the nerves resume their activity and *stimulate* the muscular fibers, those fibers again contract, and the result is, smaller tubes, and lessened color!

It should not be overlooked, while referring to the action of nerves, that muscle has in itself, wholly independent of the nerves, the properties of contractility, irritability, and conductivity, and that therefore muscular fiber can be excited to action not only indirectly by the nerves, but by application of the stimulus directly to the muscle. Inasmuch as vegetable tissue has precisely these same properties it can well be imagined that plants and animals have many functions of a similar nature: indeed many of the lower animals have no nerves at all, and so nearly resemble vegetable tissue that the two classes are with difficulty distinguished, and yet the former have the power of locomotion and other movements.

The human flesh is competent to heal slight injuries by its vital action: the same is equally true of vegetable tissue which has no nerves and yet can heal greater injuries. Irritation of the skin has been known to produce various kinds of tumors in man and beast, especially in horses and dogs; various outgrowths on flowers, roots and stems result from the same cause.

The hair of a horse where the skin is galled by the harness frequently changes from brown or black to white; the color of a leaf may be altered by an injury of the stem or petiole.

To show more fully the analogy existing between nerve in animal and irritability in plant, we submit the following quotations:

"The property of conductivity (of transmitting a condition of activity aroused in one part by a stimulus to any other portion) is exhibited by a vast variety of forms of cell-protoplasm, and *by plants as well as animals.*

"In the case of plant-cells and in certain forms of muscle-cells about which there is a more or less definite wall or sheath, there are little bridges of protoplasm binding the cells together." (Am. Text-Book Physiology).

There is an irritability of muscular fiber distinct from irritability of nerve. This independence of irritability is proved in many ways:

"By the use of the drug *curare* we are enabled to prevent the nerve impulse from reaching the muscle, and when we have done this we find that the muscle is still able to respond to direct excitation, with all forms of irritants, viz., electrical, *mechanical*, thermal, and chemical." (Am. Text Book Physiology).

"Some parts of muscles, such as the lower end of the sartorius, and many muscular structures which have no nerve terminals in them respond energetically to all kinds of muscle stimuli." (Prof. J. C. Dalton).

"There are some substances which act as stimuli when applied *directly to the muscle*, but have no such effect upon the nerves, viz., ammonia." (Prof. J. C. Dalton).

"In some of the lower animals there are simple forms of contractile tissue in which nerves cannot be discovered and which are irritable." (Am. Text-Book Physiology).

"The scientific biologist recognizes the *fundamental likeness* in the structure and functions of plants and animals. Plants feed, breathe, and reproduce exactly as do animals; respiration takes place in all plants precisely as in animals.

"Protoplasm, the physical basis of life, is in each and is much alike in each. The cause of the movements of plants is largely due to the direct effect of light upon the *sensitive protoplasm* of the cells of the motile parts." (D. H. Campbell, Ph. D.)

"Plants are exhausted by over exercise and require rest, and like animals they are lulled and put to sleep by chloroform and narcotics! The faculty of responding to external irritation by internal movements and change of form *belongs to cells* and holds good in the vegetable as in the animal kingdom. All M. Cohn's experiments prove that in *Mimosa pudica*, which is highly sensible to the action of light, heat, electricity and touch, the propagation of the external excitement proceeds in the same mode as in animals." (Somerville Molecular and Microscopic Science).

"Mechanical irritation of the glands of *Drosera rotundifolia* by insects causes secretions." (Prof. Goodale).

"The three delicate hairs on each face of the trap and the median line of *Dionæa muscipula* are exceedingly *sensitive*, the lightest touch upon one of the hairs will cause the valves to close instantly." (Prof. Goodale).

"In *Drosera* the secretions of the hitherto neutral glands become acid in consequence of the *stimulus* of insects. On stimulation of *Dionæa*, electric currents arise in the leaves," etc. Tendrils are distinguished (from twining plants) by being in a high degree *irritable* especially to *contact with a solid body.*

"If a leaf of Mimosa be stimulated by means of the hot focus of a burning glass, not only that leaf folds together, but the stimulation extends, till all the leaves of that branch have the movement"!

"The millions of stomata in an average size leaf simultaneously open when the sun shines on the leaf, and simultaneously close when it becomes shaded."

The leaves of many plants are so sensitive as to close in slightly cloudy weather, as oxalis and anagallis. Numerous flowers close at night and open in the morning, etc.

"We have no necessity to refer to the physiology of nerves in order to obtain greater clearness as to the phenomenon of irritability in plants; it will perhaps on the contrary, eventually result that we shall obtain from the *processes of irritability in plants data for the explanation of the physiology of nerves.*" (J. von Sachs).

"The *irritation* set up by insects themselves is one of the most potent causes of a flow of sap to certain definite places which encourages local growths. The effects under mechanical irritations and strains, of nutritive matters of the same kind, of poisonous substances, of electricity, etc., all show that the bond which unites the animal and vegetable kingdoms is of one and the same nature." (Prof. Geo. Henslow).

"When muscular fibers are touched by a pointed instrument they exhibit contraction even after they have been detached from the body, provided that too long a period of time has not elapsed. At one time it was supposed that the contraction of a muscular fiber depends so completely upon the agency of the nervous system that it might be considered as the direct function thereof; but a more critical examination of the circumstances of the shortening of the fiber cells, shows that it possesses many features in common with the same contraction of the cells of plants which have no nervous system." (Prof. J. W. Draper).

"It is impossible not to be struck with the resemblance between the foregoing movements of plants (sensitive plants) and many of the actions performed unconsciously by the lower animals, etc. Yet plants do not of course possess nerves, or a central nervous system; and we may infer that, with animals, *such structures serve only for the more perfect transmission* and for the more complete intercommunication of the several parts." (Darwin).

"In the last instance (final analysis) indeed, I might say, animal and vegetable life must of necessity agree in all essential points, *including the phenomena of irritability*"! (J. von Sachs).

In addition to Mr. Bergen's analogy before mentioned, which he would have the reader believe to be mine, he gives a mangled and distorted account of my explanation of the origin of the honey guide by quoting one half of the same only, omitting a very important part, which cannot fail to convey a false impression. While seeking for Mr. Bergen's views upon the color of autumn leaves (to be referred to later) in his small volume of *Elements of Botany*, the writer's attention was arrested by two remarkable statements: —

"Old leaves are found to be loaded with mineral matter left behind as the *sap* drawn up from the roots is *evaporated* through the stomata." p. 117.

Mr. Bergen appears to be oblivious of the fact that sap may contain many ingredients other than mineral matters which are not evaporated, and that these substances may occur even in the roots of plants, as sugar in beets, sweet potatoes, etc., albumen in the juices of carrots, turnips, etc., gluten in the juices of turnips, starch in sago, tapioca and arrowroot, etc., all of which go to build up the stems, leaves, flowers and seeds and do not go off into the air!

Mr. Bergen evidently confounds sap with water.

Referring to *stomata*, Mr. Bergen writes: "To some extent they regulate the rapidity of transpiration, opening *more widely in damp weather*, and closing in dry weather."

Vines' *Physiology of Plants* however states, that Moldenhauer supported by Amici, von Mohl, and Unger, find that the *stomata are closed on rainy days and dewy nights*, and are open when the sun is shining upon the leaves!

Such statements as the foregoing indicate that an hypercritical reviewer may himself be open to criticism.

TRANSFERABILITY OF COLOR.

Most of the coloring matters in cells can be dissolved out by pure alcohol. The veins of petals and leaves are speedily tinged with colored solutions absorbed through the stems: the cellular tissue may also be tinged somewhat, but much more tardily. A white petaled Cyclamen with a crimson projecting central part or eye, placed in alcohol changed to white at the center, and after the alcohol had evaporated, it changed back to crimson, but a portion of the red pigment, evidently dissolved out of the cells, penetrated and tinged the veins of the reflected white petals nearly to the tips.

The dark purple eye of an Ixia, after remaining in a tumbler of water for a couple of days entirely disappeared, but the coloring matter reappeared in the veins and cellular tissue of the white outer portion of the petals. The yellow pigment in flowers, not being dissolved in the cell sap, but associated with granular substances in the cells, is not easily transferred through the cell walls.

In order to test the transferability of coloring matter by some mechanical device roughly approaching the irritations of insects, experiments were made by brushing the colored surface of the petal with a small camel's-hair brush such as is used in water colors.

Several blue violets taken from conservatories in winter were selected, which, owing to cloudy weather perhaps, were imperfectly colored, and had many small green specks on the petals. When these specks, or diminutive spots, were brushed across for a few moments they disappeared, being lost in the general blue color, and blue veins appeared in the whitish area at the base.

Similar effects were produced on the white specks in sweet william, and on the white halos surrounding the purple dots of foxglove.

One of the maroon spots on a yellow pansy was brushed lightly for 10 or 15 minutes, when numerous fine purple veins appeared at the outer border, while in the intermediate space few were seen, they being more deeply imbedded in the cellular tissue. A white pansy with blue honey guides gave better results. A white variety of Martha Washington geranium, with dark maroon honey guides on the two upper petals, when treated in the same manner, became covered with a network of dark red lines, while the parenchyma itself was largely tinged with the same color. The dilute coloring matter must have been conveyed by capillarity through the vascular bundles, and diffused through the cellular tissue by osmosis, as no pressure was brought to bear beyond the area of the honey guide. When two different colors meet, as the basal color of a petal with the honey guide, an intermediate color is sometimes produced naturally, by the blending of the two as in water colors, which would also seem to imply that there was a diffusion and commingling of the contents of the contiguous cells.

An experiment was made to ascertain if the color of a flower could be changed or in any way modified by mechanical irritation on the surface of its petals. The writer noticing that *Primula Sinensis* was apt to change color with age, selected several varieties of the flower and proceeded to manipulate them with a camel's-hair brush. A deep crimson variety with a green eye was chosen for the experiment. Holding a flower while still attached to the plant by the left hand, it was brushed with the right lightly and rapidly with the soft haired brush, with a circular movement around, but outside the green eye. After a few minutes' brushing a slight alteration in the hue was detected; continuing the process, soon a new and totally different color began to declare itself. The brushing was continued for fifteen minutes in all, when there was displayed a permanent circular band of a violet color around the green center, the untouched outer portion retaining its original crimson hue.

Another blossom freshly expanded was tested. It was brushed for a few minutes only, when it became of a pale violet color, and then, it being a late hour in the evening, the plant was set aside till morning. In the morning it was found that this pale violet color had faded to a clear white!

This Chinese primrose plant therefore had beside the regular crimson flowers, one with a deep violet circular band, and another with a white band!

The results were not only interesting, but decidedly surprising! Some time later a variety was procured with a rich purple eye, otherwise of a similar crimson color. The purple eye in this was experimented upon; with a few strokes of the brush, lasting but a moment or two, every particle of the purple color disappeared as if by magic and was replaced by green. Similar results were obtained from other varieties, some more successful than others, and depending somewhat upon the age and condition of the flower.

Referring to these colors produced by friction upon the Chinese primrose, it would seem that some natural examples of red colored flowers with blue or white spots might be found in which insects induced the spots. In fact such are occasionally to be found. Among the primroses themselves, whitish areas are often seen near the base of the corolla, and also in other blue flowers.

Viola cucullata, which at first is usually of a reddish-purple hue, when growing in wet woods has generally a bluish or violet spot more or less distinct at the base of each petal; on uplands the spots are less common, and the flower is variable in this respect. A colony of V. cucullata was found by the writer in a moist field, all the flowers of which had white spots instead of blue! These two colors, the same as were produced artificially, were doubtless caused by insects.

Those artificially produced were not induced evidently by any additional nutriment, or localization of new color material, but rather by some chemical change in the sap already present in the cells, caused by the stimulating effects of the friction.

A red variety of poppy with large, round, white spots instead of black, suggests a similar origin.

Insects often indirectly change a color by changing the character of the vegetable tissue. This is apparent in galls and other excrescences produced by bites, punctures, or stings. A small worm hatched from a minute egg in the stem of *Solidago rugosa*, will cause by its irritation an enlargement of the stem. This swollen part, if exposed to the sun, generally becomes of a purple color, whereas the rest of the stem and leaves is perfectly green; in like manner red nodules are caused on the ribs of the green leaves, and tendrils of the wild grape vine, and red excrescences on the oak and wild cherry, and white balls on oak leaves, etc. The puncture of an insect may change the green calyx of *Oenothera biennis* also to red. The change of color in these examples follows some change in the character of the tissue and a change in form. Changes in the forms of flowers and many peculiar outgrowths from the petals are also caused by insect agency.

If one sees the lip of an orchid, two, four or six times as broad as the other segments and knows that that lip is habitually used as an alighting place for the insects visiting it, he hardly needs a demonstration to prove that its enlarged size was due to their presence.

A new outgrowth, caused by insects, and but slightly modified in tissue, appears therefore to favor a change of color in stems and leaves, and the same tendency is seen in the petals of flowers. The two upper lobes of Rhododendron (Azalea) under a lens will be found to be obscurely wrinkled with slight elevations and depressions. The dots or hyphen-like marks occur on the elevations. A slight change of tissue, and their prominence cause a concentration of coloring matter in the dots, which are always of a deeper shade than the basal color. The beard on the petals of certain species of Iris is doubtless caused in a similar manner by the fretting effects of insects such as bees with sharp clinging claws on a very sensitive surface. It is not improbable that the yellow color of the beard on an otherwise blue flower, is due to the fact that the beard is a comparatively recent outgrowth of tissue of a different character as regards the cells, and probably ot somewhat different functions *Calopogon pulchellus* has a crest-like outgrowth on the lip, and the teeth-like processes have different colors, white, lemon-yellow, orange and purple, according to their varying lengths and forms.

The central, yellow eye in Pansies has papillæ several times as long as in other parts of the flower.

A white variety of *Weigelia rosea* with age changes to pink or rose color, also the two yellow, narrow streaks in the throat, but the area within and about these streaks, being the part stimulated the most by the bees, becomes a deeper shade than the rest. *Catalpa speciosa* has two yellow lines and numerous purple dots as honey guides. With age the white ground upon which these markings occur changes to purple, but no other part of the white corolla changes. The influence of the bees is thus plainly indicated in deepening color, or producing color where there was none previously. In the morning glory, a rain drop or an insect resting upon a petal, while the sun is shining, is apt to change the color beneath it.

The colors which are quickly changed, either naturally or artificially, are not likely to be lasting, and the latter generally merely anticipate what would naturally take place in due time later.

The colors of new outgrowths appear to be developed with, and as a part of the new tissue, as in the beards on petals, etc., but such outgrowths are rather of an exceptional character, whereas spots, streaks, and dots on the plain surface of a petal are of very common occurrence, and are ordinarily remnants of the original color, and have become hereditary. The scarlet zone in the Kaiser Crown tulip, referred to on p. 64 of my *Observations*, was thought to have been developed directly from a different base-color, but from an examination of additional specimens, it is found that this scarlet zone, like the ordinary honey guide, is also a remnant of a color which once extended upward to the tip of the petals; it therefore affords an additional proof of the correctness of the method above described.

We have seen by the foregoing statements that insects indirectly change the color of stems and leaves as in galls, etc., and that of flowers by causing new outgrowths as hairs, beards, ridges, crowns, nectaries, etc., and also directly by stimulating a plain surface as in the Chinese primrose; that their irritations on the petals tend to transfer and diffuse the coloring matter dissolved in the cell-sap, or to concentrate it into spots and streaks according to circumstances — directly, or indirectly by bringing more colorless sap to be colored within the cells, or by so affecting the tissue that when a flower changes color by age, the stimulated part only may change, or if the change is general, then the stimulated part acquires a deeper color.

OBSERVATIONS

ON

THE COLORS OF LEAVES.

Every one is familiar with the colors of autumn leaves, but comparatively few have paid attention to the more quiet, yet beautiful, hues of the young and tender leaves of many trees and shrubs in springtime.

Perhaps one-half of the different species display, in the unfolding leaf, colors other than green, such as silver-gray, pink, red, purple brown, or bronze green, with a very few of a yellow or white color. These colors are for the most part of a transitory character, lasting for a few weeks only, when they are gradually replaced by the more permanent and all prevailing chlorophyll green. They are not peculiar to spring, but appear on all recent leaves of the same plants throughout the growing season until fall.

It has been thought that these temporary colors may serve as a screen to protect the young chlorophyll granules from the too warm rays of the sun. In certain plants as the purple beech, purple barberry, etc., the color persists until the cool fall weather and then disappears. While these temporary hues of spring foliage resemble in some respects the autumnal hues, they are evidently of a different chemical composition, for the latter result from the disintegration of the chlorophyll, while the former appear to be due to additions to the cell contents: yet many of the same trees and shrubs conspicuous for color in the spring, after their foliage has completed its summer work of assimilation, array themselves again in very similar but much brighter hues than before, such as the Oaks, Maples, Poplars, Sassafras, Vaccinium, Prunus, Viburnum, Rubus, Ampelopsis, Amelanchier, Leucothoë, Clethra, Vitis, Salix, etc. A few of the preceding are purplish in spring and yellow in fall.

As tending to strengthen the view that spring colors are screen colors, is the fact that many plants display these colors only in the sun, but in the shade they are entirely green, as Vaccinium vacillans and V. Pennsylvanicum (blueberry).

In addition to these spring colors, the leaves of numerous species of a semi-evergreen character which have weathered the winter months, but changed to brighter hues where exposed to the sun, still linger on their stems, as Blackberry, Rumex, Strawberry, Cranberry, Boxberry (Gaultheria), Smilax, Chimaphila, Pyrola, Mahonia, Lonicera, Kalmia augustifolia, etc. Among them all it is possible, if one will take the pains, to obtain a bouquet of different colored leaves vying in beauty with those of autumn.

The change of color, especially to yellow, usually begins at the periphery of the leaf and then follows the chlorophyll as it recedes, and its nitrogenous elements are absorbed into other parts of the plant. But this manner is not uniform: maples often show the red color first in the veins, and some while green, and others when changed to yellow, are not infrequently blotched and variously splashed with blood-red.

Circidiphyllum frequently begins to develop its pure yellow at the base of the leaf. Leaves suffering from insects are apt to change color first at the affected part: those developing scarlet, crimson, purple brown, etc., often have those hues confined to the parts only which are reached by the direct rays of the sun, while the shaded portion of the leaf remains green or yellow, and the outline of the upper or shading leaf is depicted as a sun picture upon the lower one. Examples of the latter are common in Maples, Ampelopsis Veitchei, Gaultheria (boxberry), Vaccinium corymbosum (blueberry), Lonicera, etc., and are especially noticeable in the fall. No sooner has the new foliage of the year assumed its emerald hue than it begins to show signs of decay in individual cases, the leaves here and there turning yellow, orange, russet, red, dull purple or purple brown, and falling off. Yellow leaves have been seen on maples even in May.

Various causes operate to produce the change of color: the following may be designated: lack of sun and air (ventilation), bad drainage, drought, frost, excessive heat, injury to roots, branch or leaf, fungus, blight or other disease, transplanting, rapid evaporation by drying winds or hot sun, embrace of twining plants, injuries from insects, ripening of the leaf, sudden changes of temperature, forest fires, injuries by storms and other accidents, etc. We shall illustrate some of the foregoing causes of color change from actual observations:

A potted India Rubber plant was placed into a larger, but closely fitting, decorated pot having no outlet for drainage. In a short time the leaves began to turn a rich yellow and fall. It was found that there was an accumulation of water in the outer pot from excessive watering, which drained from the inner one, and this had driven out the air necessary for the roots, for the plant speedily recovered with proper drainage.

Trees, shrubs and herbs with dense foliage are apt to have some of their interior leaves "damp off" and turn yellow from lack of sufficient sun and air. This is frequently seen in sugar maples, apple trees, currant and gooseberry bushes, and among low plants in shady woods even in early summer.

Plants in greenhouses also decay from too much watering during the resting period. The leaves of many gray birches (*Betula populifolia*, *Ait.*) growing in dry, sandy ground were largely yellow early in July: the trees were evidently suffering from drought as the month was very hot and dry. A number of herbaceous plants growing in wet places change color, or at least the lower leaves, when the water dries up in early summer, as Polygonum, Ludwigia, and Statice, which change to red or purple.

Also in July a considerable number of leaves of *Pyrus arbutifolia*, *L.* in similar dry soil were seen of a bright red color: it was found that nine-tenths of these had been punctured or otherwise injured by small insects which had sucked their juices. The latter part of July, *Ampelopsis quinquefolia*, *Michx.* often displays more or less red leaves. They are most commonly seen in sunny places, especially on stone walls and ledges. Their color is also induced partly by insects which prefer sunshine to shade, and in part to excessive heat, direct and reflected, increasing transpiration in excess of absorption. The temperature in such situations is frequently 15 to 20 degrees higher than in the shade and often above 100 degrees Fahrenheit. A portion of the same vine if shaded from the sun's rays is likely to be green and not attacked by insects.

July 20, many yellow leaves were seen on black walnut (*Juglans nigra*), and butternut (*J. cinerea*). They were caused by a caterpillar $\frac{3}{4}$ in. long covered with a fluffy, white, woolly substance which stood erect on their backs. This was doubtless for protection from enemies, as it finally disappeared. They bit a small crescent shaped hole about an inch from the base of the leaf, severing the midrib at that point and apparently sucked the juices Of the numerous fallen leaves every one had the midrib punctured at the same spot.

About the middle of August, bright crimson leaves were seen on a scarlet oak; this was two months before the leaves of this oak change color usually. It was found that every colored leaf had been punctured on the midrib precisely as those of Juglans!

Some leaves of potted Pelargoniums in February were noticed to be red at the tips. The broad, heart shaped leaves, of a succulent character, were found to have been accidentally broken across the brittle leaf ribs in handling, or by brushing past them as they stood near the sides of the benches; only the outer portion of the leaf beyond the break was changed in color. It was perfectly evident that the cutting off of the supply of water by the fracture of the ribs, while at the same time evaporation continued, had induced chemical changes in the tips similar to those of a dying leaf.

A fine specimen of *Cladrastis tinctoria, Raf.* July 1, bore yellow leaves on one side of the tree and green on the other. Tussock moths were abundant, but they did not seem to account for the division of color: the real cause was that borers had attacked the trunk close to the ground and girdled three-fourths of the circumference. By the middle of August half the limbs, viz., those which bore the yellow leaves, were bare and the leaves of the other half had become yellow.

Sept. 1, a Fringe tree (Chionanthus) and a flowering dogwood (Cornus) were changing color: the former to yellow, and the latter to red. Their trunks were riddled by borers; near the same time a fine Tupelo (Nyssa) was aglow with crimson and purple brown; in this instance borers had attacked the branches and eaten off much of the bark on the principal limbs.

A red maple when seen, had changed to a yellow hue, excepting one branch which was crimson and in strong contrast with the bright yellow. It was found that at the bottom where it formed a fork with another limb it was deformed by a knot much larger than the stem. This deformity, probably originally caused by an insect, impeded the circulation of sap with the result of a change in color. The singular appearance may have occurred in a previous season, and would be likely to be repeated in the future. A Circidiphyllum of a prevailing yellow color, though reddish at the top, had a single lower branch of a crimson purple! Two months before, the gardener at the suggestion of the writer made some incisions on the bark, cutting and partly stripping it down an inch or two; the result as seen, was a branch of a red purple instead of yellow. It would seem that a lack of nourishment or water may produce a darker color; if so this may explain why some red maples of the same age, and growing in the same vicinity, change to yellow, while others change to scarlet or crimson.

In the middle of August several red maples seen in different localities were ablaze with crimson color. Each tree was visited and the cause of the color investigated. One was found to be deeply girdled by the woodman's axe: one had the bark entirely peeled off to the height of six feet, probably by hoodlums; another, a beautiful shade tree in the city, had one magnificent branch of crimson-scarlet, while the others retained their ordinary verdure. The owner of the residence before which the tree stood admired its beauty, but was unable to account for it. The explanation was simple: a horse which had daily stopped at the tree, had gnawed the bark badly on the color side! The leaves of elm and ash in city streets, frequently mutilated in a similar manner, turn prematurely yellow, and fall. Such, besides the unsightly appearance of the trunks, are the effects of utilizing trees in cities for hitching posts.

Several maple trees with bright crimson leaves were noticed in a wooded swamp. When the brakes and small bushes were brushed aside, the trunks close to the ground were noticed to be somewhat darker than usual, but it did not seem probable that it could be the result of a fire, as the soil was still wet, but such proved to be the fact, as a farmer residing near by stated that one had been set by bicyclists in February. Two other instances of premature coloring by forest fires were observed later in dry woods.

Of the numerous kinds of insects directly attacking the leaves, those most effective as a rule in modifying the color, appear to be the diminutive ones which pierce minute holes and very leisurely suck the juices, such as the aphides, rather than those more ravenous like the Elm Beetle and Tussock Moths, which devour much of the substance of the leaf, and leave the remainder to dry up and turn a dead brown.

The early change of Pyrus arbutifolia, Sassafras, Maple, Birch, Elm, Rhus, Tupelo and Ampelopsis, is largely due to their agency, and in dry seasons, in dry or sandy soil, these trees and shrubs are conspicuous for their bright colors before the light frosts appear in the latter part of September, but the change is not general, as the gray birch and elm are really among the last to lose all their leaves, and even many individuals of maple and tupelo retain their foliage until the October frosts.

Oak tree borers, after channeling the stem of a small terminal branch for several inches, make a neat transverse cut entirely across the ligneous portion, sparing only the bark, by which sprays two or three feet in length hang suspended with their unsightly, dried up, brown leaves until dislodged by wind or rain. These dead branches are most commonly seen on the scarlet or black oak, but are also to be met with on other species, and on the elm.

Trees transplanted in summer are pretty sure to have some of their leaves change color. As an experiment some young growths of birches, pyrus arbutifolia and rhus copalina were transplanted. The lower leaves of the birch turned yellow, half of those of rhus and nearly every one of pyrus became crimson. Disturbance and injury to the roots was the cause. Colored leaves can easily be produced artificially by girdling and other methods. Many leaves when changing color become red or yellow according to exposure, as the tupelo, which is scarlet in the sun, yellow in the shade, and orange in medium illumination.

Several red tips of branches of *Leucothoë racemosa*, *Gray*, Aug. 10, were due to injury: one branch was broken, another split down the stem, one eaten by a worm under the bark, and one was closely entwined by the tendrils of

Smilax glauca! *Gaylussacia resinosa* is frequently seen having a stunted branchlet of a rose color from the effect of a fungus.

Ampelopsis Veitchii, which is generally green in August, was seen in many instances to have long, running terminal branches of its closely clinging vine with leaves of a brilliant red color. These were traced back to a point where the stem was much constricted for a quarter of an inch or so and swollen on either side; as the constrictions observed in different vines were always similar, they were probably due to insects. Instances were observed where there was a succession of red leaves from a single root streaming and intertwining to the highest point among perfectly green leaves, borne on stems from other roots. The red-leaved stems were constricted close at the ground. The connecting link of the constriction was often reduced to a slender thread which sometimes becomes desiccated, when the leaves beyond the point fall off; on the other hand, the injury in some cases is healed by enlargement and union of the parts before the link is broken. A vine may become red-leaved from other causes. A brick building on its extensive northern wall was mantled with green Ampelopsis variegated with much red color. The red leaves originated from a stem whose roots probably penetrated into gravelly or stony ground where there was a deficiency of moisture.

The southern side of a church clad with Ampelopsis which was exposed to the full glare of the sun, became a solid red color, also late in August. Undoubtedly this early change was also caused by drought. Another example of Ampelopsis coloring was peculiar in having an *intermediate* portion of a running branch with small, red leaves, while both below and above on the same stem the leaves were green and of a larger size! A probable cause of this phenomenon was, that when the now red leaves were green and terminal, they lacked water and became dwarfed and burned by the sun, but with more favorable conditions, the later leaves attained their normal proportions. A similar irregular and interrupted growth is not infrequently seen in ferns when several of the central pinnæ of the frond are much reduced in size, and for similar reasons.

In spring a vine of Ampelopsis on the north wall of a building was wholly green, but where it turned a corner to the east side it was a purplish brown. A similar change of color was witnessed in the fall on a vine on a brick church. It was scarlet on the south side which had direct sunlight, but green on the west. Even a change in the declination of the sun under certain conditions may produce a change of color. A vine on a north wall of a building had become scarlet from drought and three or four hours of afternoon sunlight. When the sun no longer shone upon that side, the later growth of runners bore only green leaves! Moreover on a building wall composed of boulders, or cobble stones, the leaves on each rounded surface were colored, but those in the depressions between, which were of mortar and partly shaded were green. The effects of frost on Ampelopsis will be referred to farther on.

Ampelopsis Veitchii is a very interesting plant for the study of the effect of insects, drought, frost, etc., on the color of leaves.

Allusion has been made to the fact that there is a natural coloration of foliage common to certain species in early spring, but dependent upon the amount of direct sunlight which they receive.

The foliage of the cultivated, red variety of *Begonia vernon* growing in the shade is green, but in the sun is a dark mahogany color on the parts of the leaf reached by the direct rays, as a side, the tip, along the midrib, or on the lower surface, according to the position of the leaf, which has its sides naturally more or less incurved, thus preventing the impact of the sun's rays upon the entire surface. Varieties of purple-leaved beets and lettuce, of Ampelopsis Veitchii, Canna, etc., are similarly dependent for color: and the purple-leaved beeches, birches, and barberry, etc., have a deeper color in the sun. The stems, peduncles, pedicels and calyx of *Phytolacca decandra*, *L.* turn from green to a deep crimson. The coloration of many other stems and petioles on their sunny side, and the rosy cheek of the apple, pear, and peach is of a similar nature. These, as also the spring examples already mentioned, are the colors of health and vigor, and should be distinguished from the tints of the dying leaf; they are at times however so similar that it is difficult to determine to which class they belong. The development of color in flowers themselves is not unlike that of the parts of the plant mentioned. In *Begonia vernon* the red color of the flower was seen in the foliage, only that it was modified by the chlorophyll. The white and pink varieties of this plant have their foliage unchanged by sunlight.

Florists are often able to determine the color of the future flower by the tint or shade of the leaf.

Coleus, Acharanthus and similar foliage plants are so surcharged with their coloring ingredients as not to be dependent upon strong sunlight, but the greater part of evergreens, which become more or less changed, and the brightest hues of autumn require direct sunlight as a factor in connection with other inducing agents.

The golden leaved Elderberry changes its youngest leaves from green to yellow. Yellow with few exceptions does not require the sunlight to develop, but it is of a richer color with it.

The season for autumnal tints may, for convenienee, be divided into three periods: from the middle of August to the middle of September, from the middle of September or the first light frosts, until the middle of October, and the last period extending to middle of November, or for evergreens, into December. In the first, it is virtually summer protracted into September; usually a very dry season with little or no rain, when vegetation often suffers from drought.

One may then expect the red maples and elms to begin to show color on dry uplands, also in similar places the choke-berry (Pyrus arbutifolia), tupelo (Nyssa sylvatica), Virginian creeper (Ampelopsis), and white birch (Betula populifolia, Ait.), etc.

Early in September, before there had been any frost, a southern hillside was brilliant with the crimson foliage of the swamp or red maple. The thermometer rarely registers so low as 32° Fahrenheit in Massachusetts in the first part of this month, but it does occasionally in the latter part. The cause of this premature coloration was obviously the prevailing drought, affecting especially uplands, for it was remarked that an extensive row of the same species in a well watered meadow at the base was perfectly green.

It was the hot weather and drought, together with the injury sustained from insects, which had also induced the colors in the other species above mentioned, for the same kinds under more favorable conditions as to moisture continued green. That this was a correct view of the matter was proved by numerous observations in different localities; the trees and shrubs with colored leaves being always in dry situations.

In the second period the weather conditions are considerably different: the fall rains set in, the nights become cool or even chilly, and a hoar frost is likely to occur in the latter part of September. There was a light frost Sept. 20 of the present year 1900, the thermometer registering in different localities from 36 to 39° Fahrenheit. The effects of this frost would hardly have been noticed except by a close observer, for the reason above stated, that several kinds of trees and many shrubs had already assumed autumnal hues; some instances however were noted which served to show that the foliage had been subjected to some other influence than drought: *Hydrangea Japonica*, var. Hortensia which till then was green, became much bronzed and later changed to red; the yellow leaves on elms, ashes and birches became more numerous, also the foliage of many wild shrubs became conspicuous for brighter hues; an ampelopsis vine on a lofty building became crimson in the course of a few days: a broad belt on the lower side of a field of millet changed to a pale, grayish green, while the upper portion, separated almost by a straight line, retained its normal deep green color; but a matter of more consequence from an agricultural point of view was, that a farmer not many miles away lost one half of the cranberries in his bog! It is during this second period that the red maples in valleys and lowlands assume their most brilliant hues, culminating in splendor from the 10th to the 15th of October. Other plants conspicuous for color at this time are cornus florida, witch hazel, yellow birch, several species of rhus (poison dogwood and poison ivy), sassafras, clethra, grape vine, smilax, hickory, tupelo, blackberry, blueberry, chokeberry, hazelnut, Virginian creeper, etc. The landscape in south-eastern Massachusetts during this period for the year 1900 was especially gorgeous with a profusion of the most lovely tints. Upon the appearance of frost in October we enter upon the final period for deciduous foliage. In the present year on the night of

Oct. 16, the thermometer registered 34°: ice was seen in one locality.
" 17, " " " 34°; there was a hoar frost.
" 19, " " " 28°; ice and frost were formed.
" 20, " " " 34°: frost was noticed.

These were the minima temperatures shown by a self-registering thermometer. The temperature varies greatly in different localities. The above were registered in the city proper: in the country, away from the seashore, it is often lower.

While the landscape just before these frosts was resplendent with gay colors induced by the double agencies of drought and frost, a little attention to the subject disclosed the fact that perhaps not much more than fifty per cent. of our trees, shrubs, etc., had changed color up to that time, especially so if one includes the numerous cultivated species.

The following is a partial list of plants continuing green until the frosts of Oct. 16–20: Oaks, nine species, poplars, three native and three cultivated, willows, many species, black walnut, butternut, buttonwood (Platanus occidentalis and P. orientalis), beech, chestnut, locust (Robinia Pseud-acacia), honey locust (Gleditschia), wild cherry (P. serotina), English elm, slippery elm, Dutch elm, English oak, linden, horse chestnut, white birch mostly green, mulberry, beach plum, elderberry, privet, osage orange, buckthorn, white thorn, Norway maple, Sycamore maple, white maple, black alder (Alnus), winterberry (Ilex), magnolia, catalpa, sophora, etc.: many garden shrubs: althæa, Cornelian cherry, laburnum, wistaria, Forsythia, pyrus Japonica, lonicera, hydrangea paniculata, clematis, deutzia, spiræa, ampelopsis Veitchii (the most of these vines green), philadelphus, bittersweet (Celastrus), weigelia, bignonia: fruit trees: apple, pear, cherry, etc.

Some of this list scarcely change color, as mulberry and catalpa, others being semi-evergreens, change only to dull or sober hues.

Immediately after the frosts of October the foliage of the trees which had previously changed color became less brilliant, the yellows being somewhat browned, the reds dulled and many trees defoliated. The remaining foliage was nevertheless still beautiful, though more quiet and subdued.

The succeeding frosty nights, which were followed by warm days, were, however, rapidly bringing new beauties into evidence. Special observations were made just before and after the frosts on certain prominent, vigorous trees and vines which had retained their verdure until then:

The green leaves of the terminal runners of Ampelopsis Veitchii on the north side of the church before mentioned, were found two days later to have changed to red; at the same time the green clad western side of another church became completely crimson; certain red maples which being favorably situated had retained their emerald hue, glowed with crimson and gold: a cluster of shrubs of *Rhus typhina, L.*, which previously had only a few red, lower leaves, became entirely crimson; a scarlet oak, being near the writer's residence, had been carefully watched from day to day. It had no red leaves at all before the frosts, but, two or three days after, all of the foliage of the outer branchlets were tinged with crimson, and in less than a week every leaf had changed color. The leaves of a white oak in the vicinity changed to a yellow russet above and purple beneath. Four handsome Tupelos of large dimensions, spared when the woods were felled and which the writer passed daily, changed almost in a night to deep crimson. Sugar maples, not native here but planted extensively for shade trees, assumed a mellow yellow, also elms, which had been slowly shedding their leaves since August, now changed entirely to yellow; Liriodendron, Honey Locust, Kentucky Coffee Tree and Horse Chestnut joined the gay assemblage. Thus "millions of leaves were painted by the magic fingers of Frost with innumerable and indescribably beautiful tints and shades of color" in the course of three or four days!

Extensive forests principally of oak, and almost entirely green before, also when viewed a few days later from a commanding eminence, except for a few pines, were completely changed to a reddish brown or brick red color! No one who had viewed these trees before and after the frosts could have had any doubts as to the cause of the wonderful transformation. And yet it is asserted with much positiveness by some writers that frost has no effect upon the color of foliage!

J. Y. Bergen, in *Elements of Botany*, states that "The brilliant coloration, yellow, scarlet, deep red and purple of autumn leaves is popularly but *wrongly* supposed to be due to the action of frost." This positive statement is in a few lines farther on qualified by the remark that "*Frost perhaps* *hastens the breaking up of the chlorophyll*, but individual trees often show bright colors *long before the first frost*," etc.

He, it appears, is not certain that frost has any effect upon color, and seemingly can assign no reason for the change of color before frost. Mr. Bergen's ideas and language are very similar to those of Doct. George L. Goodale, a much earlier writer, in his *Physiological Botany*, who says: "That frost is not essential to the production of the leaf-colors of autumn is plain from the widely known fact, that many leaves undergo precisely these changes of color *long before any frosts appear*. It is generally believed however that *freezing may somewhat hasten the process of chlorophyll disintegration* which underlies all the changes."

Geo. B. Emerson in *Report on the Trees and Shrubs of Massachusetts*, writes as follows regarding the Scarlet Oak, p. 166, vol. 1: "The leaves after they have undergone this change of color *which has no dependence on the action of frost*, remain long upon the tree," etc.

The Scarlet Oak here, in the vicinity of New Bedford, was scarcely changed at all before the frosts of Oct. 16–20. A letter from the Arnold Arboretum, dated Oct. 23, 1900, states that: "The foliage of the Scarlet Oaks is just beginning to turn here." Advices from other points in New England were of a similar tenor.

Again quoting Emerson, p. 552, vol. 2: "The observations for a single year of the varying colors of the red maple would be sufficient to disprove the common theory that the colors of the leaves in autumn are dependent on the frosts. It is not an uncommon thing to see a single tree in a forest of maples turning to a crimson or scarlet in July or August while all the other trees remain green. A single brilliantly colored branch shows itself on a verdant tree, or a few scattered leaves exhibit the tints of October while all the rest of the tree and wood have the soft greens of June," etc. "The frost has very little to do with the autumn colors." But, the "single tree," "single brilliantly colored branch," "or a few scattered leaves" in August mentioned by Emerson have been fully accounted for in the preceding pages, and it is unnecessary to remark further that such cases have nothing whatever to do with the agent that transforms the color of a whole forest almost in a night!

Of course it is to be understood that it is not frost alone, but the alternate action of frost and sun, the sudden changes of temperature, which derange the normal functions of the leaf, and induce the chemical changes which accompany the change of tint.

Gray's Manual states that *Quercus rubra, L.* Red Oak, turns dark red *after* frost!

A hoar frost, as is well known, "is the moisture of the air condensed at freezing temperature upon plants and other objects near the surface of the earth." It is not limited to a general temperature of 32° Fahrenheit or below, but "may as a rule be expected when the thermometer indicates 8° to 10° above the freezing point"! A. G. McAdie states it is liable to occur at an air temperature of from 40° to 45° Fahrenheit when the other conditions are favorable, as a clear and still night and much moisture in the air.

The cause of the frost is the radiation of heat which reduces the temperature of the surface of the earth and vegetation below that of the free air. Rapid evaporation also reduces the temperature, as is shown by the difference often seen between the wet and dry bulb of thermometers, which, at times, may be as much as 12°, or more, lower in the wet one, which more nearly represents the actual temperature of foliage wet with night dews.

The minimum temperature at New Bedford, Mass., on three different nights for *September, 1900*, was 36°, 39°, 43°. Upon an examination of the records of the City Engineer's Department for the preceding nine years, it was found that in each year there were at least three days when the minimum temperature was not above 42°, and ranging from 35° to 42°, except in 1891, when the minima were 44°, 46°, 49°. The reports from various stations in the State to the Weather Bureau at Boston for Septembers average considerably lower than this, thus: in 1896 from reports of 27 stations there were 10 under 32°, 25 under 40°, the lowest being 30°. In 1897 of 24 stations, there were 2 under 32°, 21 under 40°, the lowest being 31°. With the same ratio for the entire State, it appears therefore that there would be freezing weather in a considerable number of towns every September, and that light frosts would be liable to occur in almost every place!

The difference in the mean temperature of the summer months is generally insignificant. In 1895 there was an increase of 2° between that of June and of July, and 2° more between July and August. In 1898 the increase between the mean of June and of July was 6° plus, and between July and August but eight-tenths of a degree. Between August and September, however, there is usually a decrease of 8°, and between September and October 12°, the mean temperature of October being on an average 20° below that of August!

Growers of roses find a temperature of not lower than 55° at night and 70° to 75° by day the best for certain varieties, as Brides and Bridesmaids. If the temperature should fall 10° lower at night, the growth would be checked, few or no roses produced, and the plants be liable to mildew and black spot and to change color. That is to say, the sudden change from an unusually low temperature at night to a high one would be prejudicial to the health of the plant.

If a plant under glass is injuriously affected by a fall of 10° below the usual temperature, it is quite likely that an average fall of 20° in the open air would diminish the vitality of many kinds of leaves, and that the sudden change from very cool nights to very warm days would be likely to slowly disintegrate the chlorophyll and induce the autumnal tints even when there were no frosts! *Notes on Frost*, by Prof. E. B. Garriott, Weather Bureau, Washington, says: "Cotton will be seriously injured by *a low temperature* early in the spring whether frost occurs or not." "No adequate means of protection against *cold* and frost, suitable for general use, has been discovered." Another writer (John Tyndall) says: "Sudden changes of temperature are prejudicial to animal and vegetable health." This point may be farther illustrated by the following instance: A florist early in May discontinued the fire in his hot house devoted to Pelargoniums, as he had but a small supply of fuel on hand. His method was to close the ventilators early in the afternoon and thus store up heat for the night. Up to the time that the fire went out the plants were healthy and green, with only an occasional yellow or reddish leaf. In about a week after he ceased firing, all the lower leaves, being fully one-third of the total foliage of the central bed and a part of the south side, changed to red! Those on the north side, and those close to the south side which were partially shaded by the framework of the roof and side, retained their original verdure. The central beds had the full benefit of the direct rays of the sun. The day temperature was probably a little higher in the afternoon, and a little lower in the morning, but averaging about the same as before for the daytime, while the night temperature was probably 10 or 15° lower, as there were some frosty nights. The plants were ventilated and watered according to requirements, and it is believed that there could not have been any frost within. That the red color was induced by the changes in temperature there could be little doubt. They had previously experienced as much heat by day, and the only special difference was the lower temperature at night. It has been mentioned that the plants partially shaded were unaffected; it was only those subjected to *both extremes of heat and cold* that became red. As a further test of the real cause of the red leaves, several of the potted Pelargoniums and also of Ampelopsis Veitchii were plunged into the ground in the open air. There was a hoar frost soon after and in less than a week the Ampelopsis became purple and the Pelargonium red! No red leaves appear on these plants during the summer months, but an occasional leaf dying from any cause simply turns yellow. The rationale of the phenomenon would seem to be, that all the plants being somewhat chilled by the low temperature and dampness, the older leaves of the central plants receiving the full power of the morning sun, on account of their diminished vigor and the check to the flow of sap, were unable to respond to the demands of an active evaporation caused by a hot sun. "The drying of the tissues is fatal to the component cells and the organic contents speedily undergo decomposition," and I may be permitted to add to the quotation: that new colors result from the chemical changes set up. This I apprehend to be the explanation of the color change in the Ampelopsis and Pelargonium, and also of the effect of frost as well as that of drought, and it will apply with equal correctness to some at least of the winter colors of evergreens which will now be considered. One of our cultivated vines which retains its leaves among the latest is the semi-evergreen Lonicera Halleana or Japanese Honeysuckle. It may be seen at times as late as Christmas, more or less variegated with dull reds, reddish brown or yellowish colors, together with much of the unchanged green foliage, presenting a cheerful sight while most trees and shrubs are leafless. But not every Lonicera is thus changed in color, for many a trellis covered with this vine bears only green leaves. It depends upon the exposure. A trellis serving the purpose of a fence or screen covered on both sides with vines was colored only on the sunny side, the other, more exposed to the cold north winds, remained entirely green; also similar vines when on the north side of dwellings were found to be green and when on the south they were colored!

Many of our native shrubs of an evergreen character are similarly affected in the winter months: *Gaultheria procumbens*, *Smilax glauca*, *Kalmia augustifolia* and *Ilex glabra* on the sunny side of wooded roads are apt to be colored various hues as red, purple brown, or jet black, while similar plants on the opposite and shaded side retain the normal green color.

If a leaf of Lonicera chances to be turned so that the inner side is outermost and faces the sun, it will assume a deep blue color, much different from the usual purple-brown of the other side, this being on account of the different character of that surface. If it happens that one leaf partially shades the one below or even at some distance in the rear, the shaded portion will simply change in the usual manner, commonly to yellow, while the projecting part, whether tip, side, or entire border, receiving a more intense heat will, in the case of a maple, be likely to become scarlet, or in Lonicera a purple brown, and in Ilex an inky black: the contour of the upper leaf, whether rounded or angular, will be photographed as before stated upon the lower one, and when from intense cold the sides of Lonicera become so strongly reflexed as to become tubular, the sun paints only a longitudinal streak along the prominent rounded part. All of these evergreens are subjected to substantially the same degree of cold, but cold alone, at least as a rule, is incompetent to change the green color: it is the freezing and rapid thawing in the sun of the leaves, causing evaporation faster than absorption, which causes disruption of the chlorophyll.

Other evergreens which partially change color from these causes are Mahonia, Forsythia, Rumex, Sphagnum, Blackberry, Cranberry, Pyxadanthera, Pipsissewa, Sheep Laurel, Privet, Strawberry, Pyrola.

According to Kraus, the chlorophyll of certain evergreens is not disintegrated by sun and frost, but a reddish or yellowish substance develops, supposed to be tannin, which conceals the unchanged green granules during the cold season. This may refer to the class of evergreens including Arbor Vitæ, Retinispora, Red Cedar, and others assuming a yellowish or brownish color.

Hemlocks and spruces generally retain their verdure in a remarkable degree. The variegated Japanese Honeysuckle has its recent leaves of a yellow color, or green reticulated with yellow. It is only *after successive frosts* in November that the yellow is replaced by crimson!

Euphorbia Cyparissias, a garden escape, often common by roadsides, also changes only after freezing weather in November, from green, through purple, to a bright orange red!

"Chlorophyll during the absorption of light is slowly broken down. If it is decomposed faster than it can be rebuilt by the protoplasm the entire leaf dies." (Prof. D. T. Macdougal).

"Another cause which may disturb the relation between absorption and transpiration, is the diminished conductivity of woody tissue at low temperature." (Doct. G. L. Goodale).

The autumn change of color in foliage, resulting in part from the decomposition of the chlorophyll, in distinction from the screening colors which disappear after a time, indicates a loss of vitality and a gradual dying of the leaf. This state can evidently be effected by either drought or frost, as well as by many other causes. In the case of drought, the lack of moisture at the roots prevents the necessary supply of water to the leaves, on account of which the tissues become dried, and the character of the cell contents greatly changed. In the case of a frost, the frozen ground, or chilled trunks and twigs, with lessened conductivity, fail to deliver to the leaves an adequate amount of water for transpiration, and the result to the leaf is virtually the same as from drought.

If the various causes of color-change enumerated in the preceding pages were analyzed, it would be found that the proximate cause in all cases was an insufficient supply of water to the leaf. Frost alone, as previously remarked, may not be competent in all cases to effect this change, as in the semi-evergreens, Lonicera Halleana, etc., the reason being probably that when frozen roots, stems and leaves are in the shade and the atmosphere be not too dry, there would be little or no transpiration, and with return of milder weather the leaves might wholly regain their lost functions without any change of color or serious damage to their tissues.

It is undoubtedly the frosty nights followed by warm suns that changes the foliage of the oaks and all other remaining foliage capable of change, represented by a large number of different species. Before the frosts arrive, individual oaks may change from drought the same as other trees, but whole forests do not often so suffer, and yet they regularly change color rapidly and within a few days after the severe and late frosts of October. About November 5 they are in their brightest and best tints of reddish brown, yellowish brown, purplish tan, dull purple gray, and similar tones.

December 1, 1900.

CONTENTS.

TO "OBSERVATIONS ON THE COLORS OF LEAVES."