CONTRIBUTIONS TO THE LIFE-HISTORY OF PLANTS. No. XIV.

BY THOMAS MEEHAN.

I. Fungi as Agents in Cross-fertilization.

My studies have convinced me that in the main all plants that do not depend on insects for fertilization never fail to produce seeds abundantly. The fact that any individual plant is prolific indicates self-fertilization. Compositæ, as a rule, seed abundantly. Hermaphrodite disk flowers rarely miss perfecting seed; and covering them by gauze to protect from insect visitors shows the full potency of own-pollen. Even when the ray florets are pistillate, the chances of receiving pollen from their own disk flowers are great, and this is not cross-fertilization. In short, the rule in Compositæ is that they are arranged for self-fertilization.

In Gray's *Synoptical Flora* we read, under *Vernonia*: "There are spontaneous hybrids between such very different species as *V. Arkansana* and *V. Baldwinii, V. fasciculata* and *V. Baldwinii,* and even between *V. Baldwinii* and *V. Lindheimeri!*" Knowing how apt botanists are to attribute any striking variation to hybridism, ignoring for the time being the well-known fact that the innate power of the plant is fully equal to such phenomena, Dr. Gray's statement seems liable to a different interpretation.

In the Meehan nurseries are large quantities of *V. Baldwinii* and *V. Arkansana* growing side by side. Adjoining were a few plants of *V. Jamesii.* Desiring to increase the quantity, the seeds were saved and sown by the foreman in charge of the herbaceous department. Hundreds of these flowered in the summer of 1889. To our surprise there were not a dozen specimens of the genuine *V. Jamesii;* the rest were either intermediate between the two species named, or, where exactly the species, without any evidence that they had ever sprung from the *Jamesii* plants. I could not understand it. It seemed a blow to my deduction about close fertilization in Compositæ.

It so happened that I had been watching for several years past the influence of root-fungus on species of *Liatris*, as well as on *Vernonia Jamesii*, when the original plants were brought from the West. They would grow well the first year, but there would scarcely be one left after three years. The effect on the plants was to induce a more branching habit. Even the spicate species would become paniculate. This was especially so with *Vernonia Jamesii*, though these plants were never wholly destroyed, as the *Liatris* would be. A plant selected for special observation in 1889 showed brownish-red blotches on the stems as they pushed up in spring, which the practiced eye of the gardener would attribute to fungus agency. Later in the season some of these were sent to the eminent mycologist, Mr. J. B. Ellis, of Newfield, N. J. He could detect nothing satisfactory, and advised that specimens should be secured just before frost, when the spore-bearing organs might be formed. There was a gradual enlargement of the stem upward, and indeed the upper portion became almost fasciate, and the branching particularly abundant, just as we often see in some species of *Solidago* or in *Erigeron Canadensis* in the autumn. This was sent to Prof. Byron D. Halsted, of the New Jersey Agricultural Experiment Station at New Brunswick, who also could find no indications of fungus, but simply enlarged tissue such as is usually represented in an insect gall. That it is a development in some unknown way from the operation of the root fungus is clear from the watching of the plant-growth through its whole term.

It was after the discovery of the certain hybridity of the seedlings above described that a careful examination of the flowers of *V. Jamesii* was made. It was found that the normally white anthers had turned brown, and had perfected no pollen. The pistils only were perfect. A small bee, identified for me by Mr. William J. Fox, the well-known entomologist, as *Halictus parallelus*, was an active visitor, its thighs loaded with the clear white pollen from the other species. All this confirms Dr. Gray's suggestion of the hybrid origin of the forms he finds spontaneous; but the probability is that this is not due to any specific arrangement for cross-fertilization, but the consequence of some accidental derangement of the anthers in some one of the species, which gives the opportunity for the reception of pollen by any given plant from some of its neighbors.

II. Morphology of Twin and Triune Peaches.

There are under cultivation double-flowered peaches of several varieties. The stamens have mostly been transmuted to petals, but a few continue polleniferous around the pistil, which remains in its normal perfect form. There is nothing, therefore, to interfere with fruit bearing, and peaches are often found on these double-blossomed trees.

The singular feature of these cases is that the fruits are usually borne in sets of two or three. What we might term the carpellary suture in the peach fruit is on the interior line, with a slightly recurved apex. Any cursory observer might be pardoned for supposing that the peach had returned to the pluricarpellary condition, which we are taught is the original plan. Four out of five of the primary carpels are supposed to be atrophied in the formation of the single-stoned peach.

This note has been prepared because this supposed pluricarpellary condition is so commonly used as an illustration of the development under special conditions of organs usually arrested. The author had conceived this position to be sound; and yet was unable to satisfy himself in regard to any physiological law by which the condition could be brought about. The conversion of stamens to petals is a retrograde movement—a movement that could scarcely aid in the acceleration of development in parts usually dormant.

A new opportunity for observation shows that the condition arises from the union in an early stage of two or three distinct gynœciums, and not from the unusual development of carpels in the one gynœcium. The illustration shows the bases of distinct gynophores

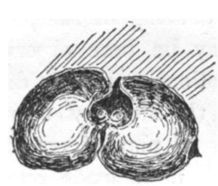

Fig. 1.

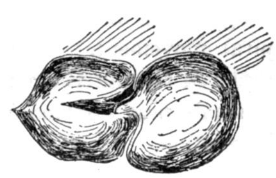

Fig. 2.

(fig. 1), while the full-face view (fig. 2) shows how the suture of one carpel had grown into the carpel of the other by the simple coiling of the spiral faintly outlined at the base in the other drawing.

The double flower in these peaches is the result of the arrestation of normal parts, and this arrestation has extended to the axis on which the flower-buds are borne. These buds have thus been drawn so closely together that they have met in a very early stage of their development, and the carpels of the distinct blossoms become united. It is not the result of a multiplication of normal parts, but a union of distinct individuals.

III. Galtonia candicans—Self-fertilization and Growth-energy.

Noting from the abundance of seed vessels on this plant that it was a self-fertilizer, I set myself to observe it closely with some specially interesting results.

In all plants growth is rhythmic, not continuous. In this case the pauses are of unusual length, while the advances, between the rests, are proportionately rapid. The flower-stalk is strong and very leafy. Some of the leaves are in verticils of three. Then follow two, alternately disposed and widely separated, followed by three arranged in a verticil. This is the rule throughout the whole growth. The time occupied in forming the verticil seemed as long as in constructing the interval, but the foundation for this arrangement occurs in an early stage of development, and could not be positively determined.

In a later stage of approaching anthesis, the rhythmic intervals are still more infrequent. The pedicel curves near the apex, and the flower-bud is drooping. At the curve there is a rest of two weeks, when the flower, which by this time has gone through all its functional purposes, starts on to an ultimate erect position. This renewal of motion in the curve seems to be rapid, but unfortunately a record of the time occupied was omitted. It was, however, discovered that the motion was in the form of a straightening and upward curving of the pedicel, and not by any spiral movement. It may be here observed that the method employed to note these motions and their directions, is by the use of small pins inserted in the stems at or near the points under observation. Most species of plants have their special hours and methods of opening, and it depends on the growth-rhythms whether the various functions operate simultaneously or each set of organs are functional at different times. The corolla occasionally expands before the stamens finish their growth, and not infrequently the pollen is not ejected till some time afterwards. In some, as in *Antirrhinum* and other Scrophulariaceæ, the pollen is ejected in advance of opening. In many kinds of flowers the stigma is not receptive till long after opening, while in other cases this period is reached simultaneously with other functional activity. In the case of *Galtonia* my observations have usually commenced at sunrise, but by that time the perianth has expanded, the two series of stamens have perfected their growth and discharged the pollen on the stigma that the anthers closely cover, the pollen evidently actively at work. Only once was I able to see the pollen in process of ejectment from the anther-cells. These are horny, resembling miniature mussel shells. The pollen was being forced out from the lower portion of the anther-septum, before dehiscence, in the form of small sections of silken thread. Though seeing this remarkable phenomenon but on one occasion, it is probably the normal manner, judging from the fact that the pollen collected on the thighs of the honey bees, that had been at work before the rising of the sun and the beginning of my task, was of a rough and stringy character.

The observations sustain my points : that fertility is mainly dependent on self-fertilization, and that form is governed by varying rhythmic movements of growth-energy.

IV. Evolution in Walnuts and Hickories.

From time to time during past years reports have been received of curious hybrids between the black walnut, *Juglans nigra*, and the butternut, or between the black walnut and the English walnut, *Juglans regia*. Specimens have now come to hand through the courtesy of Mr. H. G. Shelby, of Burlington, Iowa. The popular impression that a hickory (*Carya*) was growing out of the husk (involucre) of the black walnut might well be pardoned, as indeed might those botanists who see hybridization in any serious departure from the normal form.

The departure can, however, be readily explained under well known morphological laws, and it furnishes us at the same time with some direct evidence in regard to the morphological conception of the structure of the fruit and its envelopes that has hitherto been but theoretical. Though seemingly of a single piece, so uniform in structure that the husk of the walnuts—the black walnut and butternut especially—has to be separated from the nut by heavy blows, morphology teaches us that it is primarily composed of several bracts that have become wholly consolidated, and that it is really the analogue

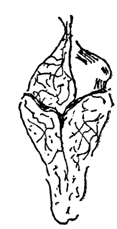

Fig. 1.—Fruit of *Juglans nigra* — outer husk but half developed, developing an interior series of bracts.

of the involucre of the hazel-nut, or the cup of the acorn. In the specimen before us the husk has been but partially developed, and is seen to be composed of two leaflets. It has the ordinary rough exterior of the walnut husk. From the interior proceeds what appears to be a hickory nut with something of the flattened sharp-ribbed form that characterizes the shell-bark series, *Carya alba.* It is, however, still green and papery, divided into four parts at the apex, reminding one somewhat of the involucre of the bitternut, *Carya amara.* After soaking well the parts in water, we find that these two layers, though apparently united, are easily separable, and the inner layer, of which the four-cleft apex of the abnormal walnut is the continuation, remains as a covering to the true nut-shell. If the husk be removed hastily, we have the ordinary rugose character of the nut, but when it is carefully separated the lower layer remains as a shining brown pellicle, obliterating the usual roughness, and presenting the nut to us as smooth as a nut of an ordinary hickory. The conclusion derived from the study is that the fruit of the walnut is made up from an indefinite number of floral bracts, and that the different species, or even genera of the walnut family, differ from each other mainly in the varying power of consolidating and transforming these bracts.

FIG. 2.—Another specimen, less developed.

FIG. 3.—Cross section of a nut.

The disturbance reaches the carpels. The section of the nut, showing a tricarpellary structure, is especially interesting.

It is not necessary to call in hybridism to account for the phenomena. They are explainable under the theory of varying degrees of growth-energy as advocated by the author.

V. EVOLUTION BY GROWTH-ENERGY—ILEX OPACA AND CORNUS FLORIDA.

In a general view of vegetation, there seems no escape from the hypothesis of evolution. In the study of the individual plant, we know to a certainty that every organ, from the seed-leaves to the various parts of the fruit, is simply modified leaf-blade. This is the foundation of the doctrine of morphology. In this study of the individual we frequently note missing links, as, for instance, a less number of floral organs than we know might have been, the absence of leaves or buds in positions they might have occupied, or suppressions, or, indeed, productions in other instances. When we compare one species, genus or family with another, we may note the same law prevailing. We conclude that acceleration or retardation of growth—the union or the separation of parts involved in the structure of plants—are the chief foundations of the great variety we see.

How this manner of development is brought about is the great question yet unsolved. At times it seems that the whole character of the future individual should be moulded by protoplasmic action in the primordial cell. The most powerful microscope reveals to us nothing of the oak in one cell or of the elm in another, but from the invisible activities of the cell contents the final results are unerringly evolved. All this seems so logical as to account for the whole character of the individual plant. But when we make a broad study of the individuals of a group we know as species, we see so many differences that we have to conclude there must have been intervention somewhere. We see in the Rocky Mountains of Colorado what must have been originally the same species of pine, fir and spruce as are found at lower elevations on the Pacific slope. The only difference is a sturdy dense growth, and a general compactness of all the parts, which enable them the better to resist the cutting winds at a low temperature that are so destructive to the weaker branches of conifers during the winter season. We have no difficulty in deciding that this arrestation of development has been the result of environment—that is to say, the elevation of the land on which their ancestors grew. And yet, for the many ages that the Pacific forms and the Colorado forms have been under such widely different conditions, there is no difference except in this general arrestation of luxuriant growth. Again we are disappointed. Environment does not wholly satisfy us. It may induce slight geographical variations. That is all. Much greater local differences can be shown in which external conditions can have had no part. For instance, in various parts of Florida a large proportion of the holly trees, *Ilex opaca*, have saliciform foliage. Of the many thousands of leaves on a single tree there may not be one that has the margins "undulate, with spiny teeth." Not unfrequently the leaves are from two to three inches long, with here and there one with a spiny tooth to show its relationship. Only for the occasional tooth an expert in classification would with good reason regard it as a distinct species. At any rate, seeing these for the first time as I did, "a remarkable geographical form" is the mental comment. But at length we note as many or more trees with leaves as spiny as any manual of botany would describe them. Geography can have little place here, and we have to conclude, as of other agents in variation, that it cannot be a material power in effecting change.

My thought has been, as my papers to the Academy in past years indicate, that we have to look to growth-energy in connection with the rhythmic nature of the growth-waves for the true solution of the theory of evolution. My purpose in this paper is to illustrate this by a comparison of two species of dogwood, *Cornus florida*, of America, and *Cornus Mas*, of the Old World. The characters of branches and leaves are similar, the leading difference being in the greater production of twiggy branches, the absence of the large white involucre, and the pedunculate fruit that characterizes the European form. When the autumn season of rest has arrived and flower-buds for next spring formed, we find in each instance that two pairs of leaves have been changed to scales covering the embryonic head of flowers. A slight difference now occurs. The growth-energy in *Cornus florida* was expended in elongating the axis below the flower-head, forming a few bracts along its course, and then resting; in *Cornus Mas* it rests at once at the base of the flower, and then proceeds to elongate the pedicels of the flower within the bud. Vertical and horizontal sections of the buds show this clearly. When the rhythmic growth is renewed in spring the energy is directed in the same line. The bud scales enlarge slightly, but continue as small green "involucres" below the flower-buds; the energy is toward the pedicels. The flowers elongate, and we have finally the pedicellate fruits. In *Cornus florida* the energy is sufficient only to cause the expansion of the flowers, and the red fruit finally appears as a conglomerate head, the mass of the force being spent on the four winter scales, which are projected to appear as four large white structures simulating bracts.

We may look to the direction and degree of energy, in connection with rhythmic growth, as the leading factor in evolution. It explains facts otherwise unaccountable. In two plants of dandelion, growing side by side, one may have leaves so deeply laciniate that little but midrib and nerves are seen, while the other have broadly lanceolate leaves, almost entire. To compensate for this, one may have tall strong flower-stems, the other short and weak ones. The growth-force has simply been exerted in different lines, or may have been weak from the start.

Evolution, directed by varying degrees of growth-energy, reconciles many conflicting hypotheses. Granting, what must be true, that the machinery for the production of energy is all constructed by or in connection with the protoplasm in the primary cell; and that this is fed, as the plant grows, by food at its command, results must depend on the strength of this machinery. It must affect the plants variously, and indeed their several parts. The machinery at a given point may suddenly become defective, though not in a vital point; and the energy, obstructed in one direction, is diverted to another channel and we have the " sporting branch," as florists term these changes. These cells in the " sport," with the new energy imparted to them, have the same power of heredity as the original cells. In the willow leaved hollies, the energy arranged for in the original particles of protoplasm have been kept intact through the whole growth process. Above all it explains what otherwise seems a mystery, the existence of the same species in widely separated localities. There is no necessity for presupposing that all traveled from one central home. If in one locality the powers of the protoplasm in the primary cell of *Ilex opaca* is so nicely balanced that it may give us willow-leaved forms, there is no reason why they may not all do that in time, and the prickly-leaved form gradually die out. A block of hollies hundreds of miles apart might follow a similar course. We may, in fact, picture to ourselves large areas varying in a few generations by very slight changes in the mechanical arrangement of the protoplasmic particles, forming the general energy-producing machinery in the primordial cell.

VI. Cypress Knees—Their Nature and Origin.

While in Florida for a few weeks in the winter season, when ordinary botanical attractions are rare, I took the opportunity of reviewing my conclusions in regard to the nature and origin of the so-called knees of the Cypress tree, *Taxodium distichum.* During two weeks' travel these trees occupied my chief attention. It is no exaggeration to say that thousands of trees in various localities and under different conditions were under close observation. I believe them to be simply root-excrescences, of no more service in the life-economy of the plant, than are the excrescences that often abound on the weeping willow, or on other trees. Indeed, they are not uncommon on the roots of trees. As I saw on this occasion, they abound on the roots of the water oak, *Quercus aquatica,* in this case taking on a hemispherical though often depressed form.

The excrescences were not always present ; indeed, trees free from this condition were in the majority. In one case near Green Cove Springs, I found a group of many hundreds of trees that had been left standing after the great monarchs had been cut away, that had none whatever in the whole group ; nor were there any evidences around the old stumps that there had been any borne by them. In a group of several hundred trees evidently under fifty years old, none were supposed to have any; but on looking carefully over them I found ten that bore them profusely, some of the excrescences protruding over a foot above the ground.

The base of the main trunks of those trees that bear these excrescences are usually hollow, as are the excrescences themselves. In the block that had no excrescences about them the old trunks appeared to have been wholly sound. Though satisfied that there was no ground for the prevalent beliefs that the excrescences were for the purposes of affording air to the roots, for collecting surface food, or were abortive suckers—were, in fact, excrescences of no value to the plant—I failed to understand why they should be hollow, any more than the excrescences in other trees.

Since my return the clue seems to be furnished by a paper in the Eleventh Annual Report (1900) of the Missouri Botanic Garden, just issued. The author, Hermann von Schrenk, deals with "a disease of the *Taxodium* known as peckiness." In this case the wood of the trunk is eaten out in vertical holes, leaving a clear line of demarcation between the part destroyed and the part uninjured. The mycelium of a fungus is always found in connection with it, and is without doubt the cause. No fruiting organs have yet been found, and therefore the name of the fungus cannot be determined. I have examined specimens of these "knees" in the collection of the Academy. A large one is to a great extent hollow, but a portion of the outer wood several inches thick is still left. The "pecky" holes described by Mr. Schrenk are in this wood, and it is quite clear that the cavity is formed by decay induced by the fungus. The smaller one, about eight inches high, had the wood in a gnarled and twisted condition, but so far with no evidence of decay through fungus operations.

The conclusion is that the so-called cypress "knees" are mere excrescences, probably in this case superinduced by fungus action, and that the trees that show no evidences of producing these excrescences are probably free from fungus attacks. It is not to be supposed that every tree in a group, or any considerable number of trees, would be equally infested by the parasite.