ARE INSECTS ANY MATERIAL AID TO PLANTS IN FERTILIZATION? By THOMAS MEEHAN, of Germantown, Penn.

THOSE of us who are growing gray remember, when our Botany was young, the pleasure it gave us to note the floral arrangements we thought so perfect for insuring self fertilization. For instance we would take a Fuchsia, and note its pendulous flowers, and that the anthers were so placed that the pollen must fall on the stigma. But modern science checks this young exuberance. The pollen of the Fuchsia is gelatinous and does not fall, and what can we say? Yet if we had looked deeper, we might have noted that allied genera as Gaura, Epilobium, Œnothera, and even some Fuchsias had their sexual organs of the same relative positions, and yet with their stamens erect. But it seems to be the misfortune of popular science that it fails to see facts, except as they seem to favor some popular theory which it becomes fashionable to adopt. It is the object of this paper to show that we are in danger of a similar prejudice in favor of the theory of insect fertilization.

At our last meeting in reply to a question by Professor Cox as to why Apocynum caught insects, no better thought could occur to Professor Asa Gray than the playful remark that it was simply an illustration that even here evil had found an entrance to the world. But while Professor Gray was cautiously feeling his way here, Dr. Hooker on the other side was more venturesome. He was asking us to imagine a time when plants accidentally permitted the accumulation of insects in some parts of their structure, and the practice became developed because found useful; and he would probably have said that Apocynum was simply experimenting as to what use it could make of the insects it had caught. This reference illustrates the tendency of thought in regard to insect fertilization. Müller and others teach that plants came in time to abhor in-and-in breeding, to desire cross fertilization; and, excluding a few cleistogamous forms and some which employed the winds, took on themselves color and sweet odors, as if directed by a sort of foreknowledge that in this way they could entrap insects into their service. Müller indeed contends that some plants came in time to be very choice in the selection of lovers, and contracted their pistils, and extended their corollas, so that only a certain class of insects could enjoy their favors. I have, I know, placed the plant as an actor, more strongly than the distinguished

gentlemen would who are working in this field. They take the progression in a more passive light. I am referring to popular apprehension — and after all this is but a metaphysical distinction of little moment here.

In any interpretation of this kind, it greatly changes our views of nature. It is not for us to say they are not correct, but we have a right to insist that the facts shall be subject to every test that sound reason may suggest.

I have thought it best to take as my text the exact words of a popular teacher of science. He says:—"All plants with conspicuously colored flowers, or powerful odors, or honeyed secretions, are fertilized by insects; all with inconspicuous flowers, and especially such as have pendulous anthers, or incoherent pollen, are fertilized by the wind. Therefore before honey feeding insects existed the vegetation of our globe could not have been ornamented with bright colored flowers." This view is the general one, and thus has arisen a classification to which all flowering plants are referred. They are either *Anemophilous*, wind lovers, or *Entomophilous*, those which desire insect aid.

I may here remark that a sort of necessity for cross-fertilization was perhaps suggested by a belief in a popular impression that is probably erroneous. We thought nature had a horror of in-and-in breeding. Our selected breeds of cattle are the results of this sort of selection; and they have proved just as healthy and productive as the veriest scrub. But it was thought they would at least revert to their originals when the hand of man was taken away. But at our last meeting Professor Brewer showed this was also a mistake. Quite recently Mr. George Darwin has shown, in a remarkable paper made up of an extensive study of the old families among the English nobility, where intermarriages among relatives have been a sort of social necessity for ages, that the popular idea is erroneous. These intermarriages have resulted as productively and as healthily, mentally and morally, as the average marriages of the rest of the world. The question of insect fertilization is, therefore, no longer a question of necessity; it has to stand on the facts alone as they are adduced.

That some plants require external aid is certain. Yucca and Orchideæ are familiar examples. But there are general considerations which show how limited insect aid must be. The flowers of the Rocky Mountain region are beautifully colored; but Fremont

pathetically describes the solitary bee that rested on his shoulder on the top of Pike's Peak. On my first visit the comparative absence of insects proved very annoying to the entomologists who accompanied me. It was a frequent subject of conversation whether Fremont's Bee was not apocryphal, and though a visit some years later found some humble bees on *Polygonum bistorta* on Gray's Peak, enabled me to do justice to the veteran explorer, the incident shows how rare such insects are. Indeed the paucity of animal life of all kinds in the Rocky Mountains is well known; but there is no more scarcity of seed in the colored flowering plants, than in similar ones elsewhere. Nearer home we see the same thing. In many of our woods spring flowers abound, but any observer of woodland flora must have been struck, especially in early spring, with the rarity of insects about them. But all these plants, without any remarkable exceptions, seed well. Again red clover fields are favorite pasture grounds for humble bees, but when, as is the case in my vicinity, the white clover abounds in blossom, they totally abandon the red clover fields. I have watched red clover fields carefully several times a day for a week at a time, after their abandonment by the bees, without seeing any thing but a few, very few, diurnal Lepidoptera on them occasionally, and certainly of no consequence for fertilization to this immense extent, yet the flowers bore seed as fully as the most insect-frequented field would do.

General evidence of this kind is, I think, fair presumption against insect agency to any material extent.

But the direct and positive evidence is what we want; and here I find it in great abundance. Many flowers are so constructed among the so-called entomophilous class, that they must of necessity fertilize themselves. I do not refer to the cleistogamous plants, which seed without perfecting their corollas, but in regular flowers where it is not usually suspected. In *Melampyrum Americanum* the curved apex of the pistil is clasped by the stamens, and held in contact with the pollen just as in a cleistogamous violet. A large number of plants have their pistils covered by their own pollen before the flowers open. Of these I have especially for this paper gone over observations previously made with species among Wistaria, Glycine, Cercis, Genista, Lathyrus, Colutea, Ballota, Leonurus, Phaseolus, Pisum, Linaria, and some others. This is particularly the case early in the season; later

the pollen sacs burst more generally about the same time with the opening of the corolla. It may be objected that the covering of the stigma with pollen is not fertilization, as it requires a peculiar condition of the pistil to receive it. But pollen has a long vitality. Carriere has found its fertilizing power unimpaired after three months old in one species, and other cases have been recorded. Not to leave this point open, I had some unexpanded flowers of *Wistaria sinensis* examined by my friend, Dr. Gibbons Hunt of Philadelphia, the accomplished microscopist, who reports that the pollen tubes had actually made their descent through the pistil towards the ovarium.

But what I regard as remarkable is that many flowers which have been taken by European observers to illustrate the necessity of insect fertilization, not only fruit abundantly, when they are fertilized before they open, but in many cases fruit when not visited by insects, and in some cases, as in *Melampyrum*, have arrangements for self fertilization. Thus Dr. Farrar's observations on the Garden Bean, in 1869, Dr. Ogle's in 1870, on the Scarlet Runner, Mr. Bennett's on the Pansy; and I think I may include Mr. Darwin's on Clover, and those by the author of this paper on *Linaria vulgaris*. In my garden, I have rarely seen an insect on the Common Pea; yet every flower bears its pod. Its pistil is clothed with hairs on the upper surface, and curved towards the standard, with the anthers on the upper side. As soon as the anthers burst, they pass downward, brushing their pollen against the stigma and covering it with it. The Lima and Bush Beans are also rarely visited on my grounds, where clover abounds; but are abundantly fertile. The pistil protrudes in many of these papilionaceous plants, as noted by authors above quoted, when an insect or any pressure is made to bear on them; but it will be found that in many cases, the very movement makes them clutch as it were their own pollen. In the Violet and Pansy, the lifting "apparatus" certainly throws the pollen on the entering insect's back; but only to draw it against the stigma on the exit. In the White Clover Mr. Darwin's experiment nearly staggered me. It is so rare there is any mistake about his facts. He says he protected some from bees, and they bore no seeds; some exposed to bees perfected thousands. I am satisfied that in all cases I examined of flowers just before expanding, and before any insect had interfered with them, the pistil had received its own pollen. Mr. Darwin does

not say how he protected his flowers. Nutrition is often interfered with by "protection;" and failure to seed follows. I endeavored to repeat the experiment of protection for this meeting. I covered a patch of clover with a sieve having one-eighth inch meshes. No bees could get to them. I think I may say every flower perfected seed. Unfortunately I found on one examination a small sand-wasp had ventured through, and was collecting pollen from a flower. I do not think any but this one entered, still it diminishes seriously the value of the experiment. I do not care to take the time of the meeting to refer in detail to the immense number of plants which cover their pistils with their own pollen, and which must limit seriously the extent of the entomophilous class; as any one, and I hope he will look, can find them easily. Even Müller himself admits that the four short stamens in *Hesperis tristis* is for self fertilization, in case the two long ones should fail to meet with insects, for whose use he thinks they were intended, and this ought to be as true of all tetradynamous plants. And yet so thoroughly has the idea that all petaloid flowers must have insect aid, that because a plant of this class brought to prominent notice by the Challenger expedition, a *Pringlea*, was apetalous, Dr. Hooker was led to suggest that it must have the pollen of anemophilous plants. As this was found to be so, it is regarded as confirming that view, and yet with us *Thlaspi bursa-pastoris*, which has no visiting insects of consequence with us, has abundance of seed as the horticulturist knows to his great annoyance.

Indeed the interpretation of the uses of structure often has two sides. I believe I was among the first to suggest that the lever-like false anther in *Salvia* was an aid to cross fertilization through insect agency, yet I subsequently noted in the "American Naturalist" for 1871, that if the plant had "sense" enough to plan such a contrivance, it parted with that good sense in *Salvia involucrata*, where the contrivance is perfect, but a subsequent patent spoiled the first. The *Lobelia* is a much used illustration of the beautiful contrivance to insure insect agency. I confess I do not understand how self fertilization is accomplished here, but I do know that *L. erinus*, entirely protected from insects under glass, seeds abundantly. Professor Gray says of *Habenaria tridentata*, that in this species the summit of the sterile anthers receive pollen and are penetrated by pollen tubes; how far similar processes extend in nature, it will do no harm to consider, though out of place somewhat in a paper in which speculation is not in order.

But suppose that cross fertilization by insect agency be all that is claimed for it? Let us grant that there has been an effort on the plant's part to avoid self fertilization, and to effect cross fertilization by insect aid. The question follows, what has the plant gained by it? If it is not proved that in-and-in breeding — self fertilization — is a detriment to continuous existence, the case, theoretically, is gone. But we have facts. *Specularia perfoliata* is said by the books to have its earlier flowers cleistogamous; but this is only so in open places. In shady situations all the flowers are of this character, and it is wonderful how productive and strong they are. I know an open wood in which the plant is a peculiar characteristic of the surface vegetation. I never saw one petaloid flower on these plants. Most of the seminal increase in the Violet, especially those which grow in woods, in those which produce cleistogamous flowers, is from this class. These species have held their own better, are more widely distributed, are in greater numbers, than those which depend on increase from petaloid flowers alone.

In any theory of the survival of the fittest, we must take those to be the most fit to survive, which produce the greatest quantity of seeds, all other conditions being equal. A plant which perfects a thousand seeds, will have a better chance of posterity than an individual of the same species that perfects but a hundred. If a plant thought, as one might almost say in view of popular theories, that it would gain any benefit by escaping from possible injury through in-and-in breeding, and thus changed its structure so as to favor only fertilization by insect aid, we see at once that it places itself in the position of all of us who give up to others the doing of our own work,—it is often not done at all. This is actually the case with non self fertilizers. The *Geranium* is an example within general reach. In my garden I have paid most attention to *Geranium sanguineum*. The petals expand before the rupture of the pollen sacs. Five stamens elongate, and no sooner have they reached their full length, than the pollen cases burst and the anthers fall off. The other five follow in the same way, all before the pistils have made their full growth. The filaments are persistent, close up among the pistils, and seem really in their utterly useless condition to say that something had gone wrong with the plant in its efforts at cross fertilization. The seed time tells the same story. More than half the flowers are without seed, large numbers with only one out of the five, and very rarely

indeed are the full five carpels fertile. It may be said this is not its native country; insects in its own would have paid more attention to their duties. But granting this, it has lost the power which a self fertilizer possesses of taking care of itself both at home and abroad. What has Yucca gained? It is one of the most local in its distribution. Each species is confined to limited areas in comparison with self fertilizers. Some seasons when the insect fertilizer is scarce, as insects of many species often will be, there is barely a seed, as I have witnessed myself in the chief localities for *Yucca angustifolia* in Colorado. Indeed its existence depends on its persistent roots. If it were an annual I believe the whole genus would now be well nigh extinct. It is the same with Orchideæ, another family that has a difficulty in self fertilization. If one, without regard to any theory, but in the light of well known facts in botanical geography, were to be asked which family he thought the most likely to first disappear, I think he would say Orchideæ. They must stay where their especial insect lords are, and they have to endure the great chapter of accidents, without the chance of escape to foreign lands. Surely we see that self fertilizers have the advantage in the great struggle for life. If we were to credit plants with a common sense with which in some quarters they have been almost invested, I think we must award the point of greatest wisdom to those which catch insects and eat them, rather than to those which dally with them to their own final ruin.

There are plants which cannot fertilize themselves; but why must we be driven to the opinion that this is a selection,—a choice? May it not be rather what popularly we should call a necessity? In the course of ages may there not be a failure of nutritive power which would interfere with the relation of the sexual organs? This suggestion is borne out by facts. I have already shown the members of this Association by numerous facts in several papers, that the male and female sex in plants, that is whether the male or female organs in the flower are most favored in development, is wholly a question of nutrition. In this paper I have shown a similar law. In the earlier flowers of the season the anthers usually, in many species, burst just before the flowers open. Later in the season when vitality is nearer exhausted the male has not the same active development, and perfects its pollen only after the expansion of the petals. This overlooking of vital

power, and looking to fertilization merely for fruitfulness, is I believe one cause of error in the discussion of the present question. A flower has perfect pistils and stamens. It does not fruit, therefore it was not fertilized. This is the argument. Indeed I may here quote again the exact language of the author from whom I took my text. "Farmers on the banks of the Rhine reported, years ago, that orchards in which bees are reared are more productive than those in which there are none." But American experience now is as good as Rhine experience long ago. Our orchards are often white with bloom, and hardly a fruit follows; and again very few flowers, but most of them set. There may be no difference in the number of bees about them. It is wholly a question of how favorable were the influences of nutrition on the maturing flower buds the fall before. I have already shown that the Wistaria is actually fertilized by its own pollen, and yet it is notorious that the Wistaria rarely seeds in this country, the forces of nutrition not favoring it. Very slight local causes often determine these matters. I once had a very large white Noisette rose, called "Woodland Margaret," trained to the roof of a greenhouse in which was abundance of light, though little sunlight; but it would not flower. In summer, however, a few branches would get through a ventilator kept open, and these always blossomed freely. All cultivators of winter flowers know the influence which direct sunlight has over reflected light in the formation of flowers. So a ringed branch produces flowers, when one untouched does not. This illustrates the influence of varying phases of nutrition on the floral organs, and I have no doubt that the difference in the conclusions arrived at by Mr. Darwin and myself in white clover, would be accounted for in this way, if all the circumstances were known. Many instances illustrating this nutritive influence might be given. I will give but one more. In our region the *Cercis Canadensis* is very irregular in seeding. A tree this year loaded, may not have one seed vessel next year. In older times "late frosts" furnished the explanation, but more recently imperfect fertilization. I have a row of fifty-two trees about fifteen years old. These are all apparently alike in general health and vigor. Most have no seeds; but nine have a profusion. They were all exactly alike as regards fertilizing conditions. Some peculiar phases of nutrition aided the productive trees.

I have not thought it necessary to occupy your attention by a

long array of facts. What I have adduced is sufficient I trust to prove:—

First; that the great bulk of colored flowering plants are self fertilizers.

Secondly; that only to a limited extent do insects aid fertilization.

Thirdly; self fertilizers are every way as healthy and vigorous, and immensely more productive than those dependent on insect aid.

Fourthly; that where plants are so dependent, they are the worse fitted to engage in the struggle for life, the great underlying principle in natural selection.

CARNIVOROUS PLANTS. By W. J. BEAL, of Lansing, Michigan.

THIS is a new term which has lately been applied to plants that catch insects by various contrivances.

In 1768, over one hundred years ago, Mr. Ellis discovered that the Venus fly trap of North Carolina, catches insects by a peculiar construction of the tips of its leaves like a steel trap. Numerous experiments have satisfied botanists that flies are not only caught, but digested by a fluid poured out by the plant, and the materials absorbed into the tissues of the plant. In 1780, ninety-five years ago, the sun-dew (*Drosera*) was found to catch insects by its sensitive hairs with a sticky gland at the end of each.

Drosera rotundifolia, a common little plant of our marshes has a round leaf, about the size of a cent, sometimes containing eighteen small flies. The glandular hairs move towards the fly when irritated.

Drosera longifolia has a very long slender leaf also covered with glandular hairs. It rapidly coils up from the tip catching flies which it devours and absorbs.

North America has eight species of pitcher plants (*Sarraceniaceæ*), the leaves of which catch insects. They have stiff hairs inside pointing downward which prevent the escape of most insects. Some have a sweet secretion below the opening at the top on the outside. This grows sweeter and sweeter and more abun-