Charles Darwin's Conclusions in Reference to Cross-Fertilization.

"THE EFFECTS OF CROSS AND SELF-FERTILIZATION IN THE VEGETABLE KINGDOM. By Chas. Darwin, M. A. F.R.S., etc., etc. Appleton & Co., New York. For sale by Gray, Baker & Co., No. 407 North Fourth street, St. Louis."

The painstaking disposition and the wonderful ability for research into every department of natural history displayed by Mr. Darwin are so well known that no one feels in the least surprised at a new volume from his pen every year. The mystery of his rapid work, however, is fully explained when we learn that the researches which are recorded with so much accuracy and in such strict chronological order have been made at intervals during the last fifty years, and conscientiously noted down at the time, so that from day to day the mass of material grew, and all that now remains to be done is to arrange it in presentable shape, collate it, draw out at suitable length the conclusions to be deduced from it and prepare the whole for the printer. Most people have small idea of the amount of work that can be accomplished by doing a little every day, and such need only to be referred to the ponderous volumes of Darwin, filled not with speculations, but with stubborn facts and figures, from which others may draw whatever conclusions please themselves. Those who think of Darwin only as a man who believes the human race descended from monkeys, greatly misconceive the character of the man, and need to inform themselves by the perusal of his later works.

FERTILIZATION OF PLANTS.

The last book of Dr. Darwin is on a subject not at all popular, but nevertheless of far more importance than might, at first glance, be supposed. The question of the fertilization of plants is one which in effect concerns all animated nature, since, were the flowers of plants not fertilized, the plants themselves would leave no successors, whole species would become extinct, ere many years there would be no green thing upon the earth, and consequently no life of any kind. The fertilization therefore becomes a matter of considerable consequence, which is not at all diminished by the fact of its being silently and almost imperceptibly carried on. The attention of botanists has often been called to the fact that many classes of plants are self fertilizing, a flower deriving the pollen which renders it fruitful either from some part of itself, or from some other flower on the same plant. Though this curious circumstance was frequently mentioned, and occasionally commented on, no one ever appeared to suspect that it had anything whatever to do with growth or development of plants, and until Darwin entered the field of research, nobody ever thought of enquiring what was the effect of this self fertilization. The great author of the "Descent of Man" was therefore the first to make original investigations in this field, and ascertain by actual experiment, and observations continued at intervals through many years, the truth in this matter.

CROSS-FERTILIZATION.

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There is weighty and abundant evidence that flowers of most plants are constructed so as to be occasionally or habitually cross-fertilized by pollen from another flower, produced either by the same plant or by another of the same species. This is sometimes ensured by the sexes, for plants have sex as well as animals, being separated, and in a large number of cases by the pollen and stigma of the same flower being matured at different times. It is made certain in other instances by mechanical contrivances of wonderful beauty, preventing the impregnation of the flowers by their own pollen. In others the same end is effected by the irritability of the stamens, which when touched by insects, fly up like released springs, and dust the intruders with pollen. This is in this manner transported to other flowers, and these are fertilized. There is a class of plants which absolutely refuse to be fertilized by pollen from the same plant, but can be fertilized by pollen from any other plant of the same species, and not a few classes are sterile with their own pollen. There is finally a large class in which the flowers present no obstacle to self-fertilization, but, notwithstanding this fact, these plants are frequently crossed, owing to the greater potency of pollen from other plants over that of their own. These facts, with many of kindred nature that might be cited, determined Darwin to investigate the whole subject, and see what advantage, if any, accrued to plants from cross-fertilization.

THE ADVANTAGES.

Since plants are adapted by such diversified and effective means for cross-fertilization, it might be inferred from this fact alone that they derive some great advantage from the process, and it is the object of Dr. Darwin's work to show the nature and importance of the benefits so derived. There are, however, some exceptions to the rule of plants being constructed so as to favor cross-fertilization, for some plants seem to be invariably self-fertilized; yet even these retain traces of having been formerly so adapted. The exceptions, however, need not make us doubt the truth of the above rule, any more than the existence of some few plants which produce flowers, and yet never get seed, should make us doubt that flowers are adapted for the production of seed and the propagation of the species. The fact should always be kept in mind that the production of seed is the chief end of the plant, and the direct object of the act of fertilization, and this can be gained with more certainty by self-fertilizing plants than by others. Yet it is as plain that innumerable flowers are adapted for cross-fertilization as that the teeth and talons of a carnivorous animal are adapted for catching prey. Flowers, therefore, are constructed so as to gain two objects, which are to a certain extent antagonistic, and this explains many apparent anomalies in their structure. Some flowers are closed in such a manner that self-fertilization can not but ensue, while others are open, because there must necessarily in cross-fertilization be a great waste of pollen, in order that by insects and other means a few grains may reach their destination.

DARWIN'S EXPERIMENTS.

The adaptation of flowers for cross fertilization was made the subject of experiment by Darwin for thirty-seven years, and the accuracy of knowledge at which he arrived was wonderful. To cite a single instance, he discovered in the case of the *pasoqueria fragrans* that the stamens were irritable, so that as soon as a bee or moth visits a flower the antlers explode and cover the insect with pollen; one of the filaments, broader than the others, then moves and closes the flower for about twelve hours, after which time it resumes its original position. Thus the stigma can not be fertilized by pollen from the same flower, but only by that brought by a moth from some other flower. Numerous other beautiful contrivances for the same purpose could be specified. It occured to Darwin that it would be advisable to try whether seedlings from cross-fertilized flowers were in any way superior to those from self-fertilized flowers. But as no instance has been known with animals of evil occurring from the closest possible interbreeding, he thought the same rule would hold good in regard to plants, and that it would be necessary to experiment at too great length and with too many successive generations of plants. He was induced to enter upon the experiments recorded in this volume of 500 pages by accidentally planting close together two beds of self-fertilized and crossed seedlings from the same species of common *Linaria*. To his surprise, the crossed plants, when fully grown, were plainly larger, taller and more vigorous than the self-fertilized. Believing it impossible that a single act of self-fertilization could produce such results, he sought for some other cause, but could find none, and therefore was compelled,

somewhat reluctantly, to admit that there was more in the theory than he could account for.

HIS METHOD OF PROCEDURE.

His attention being fully aroused by this queer discovery, he proceeded to institute a series of observations not confined to any one species of plants, but extended indiscriminately to all. He selected certain plants and in order to be absolutely certain that no fertilization from the pollen of other plants had taken place, he covered the entire plant with a netting which effectually kept away all insects. The flowers of these plants were artificially and with great care fertilized with their own pollen, and when the seeds were ripened they were gathered, laid away and marked for future experiments. Care was taken that the seeds were thoroughly ripened before being gathered. Afterwards the crossed and self-fertilized seeds were placed on damp sand on opposite sides of a glass tumbler, covered by a glass plate, with a partition between the two lots, and the tumbler was placed on the chimney-piece in a warm room. He was thus able to observe the germination of the seeds. Sometimes a few would germinate on one side before any on the other, and these were thrown away. But as often as a pair germinated at the same time, they were planted on opposite sides of a pot, with a superficial partition between the two, and he thus proceeded until from half a dozen to a score or more seedlings of exactly the same age were planted on the opposite sides of several plots. If one of the plants became sickly or was in any way injured, it was pulled up and thrown away, as well as its antagonist on the opposite side of the same pot. The remaining seeds were sown very thickly on the opposite sides of single pots, and when the plants began to grow there was, of course, a very severe struggle for life between them. The hardiest survived and were carefully measured, and the difference in growth ascertained in every possible way. The eye alone was never trusted in determining any difference; close measurements alone were used in all cases. This plan, pursued through several generations of plants, and with the exercise of the utmost care in order that all might be subjected to exactly the same conditions, was productive of some very singular results.

As already stated, the experiments were not limited to any family or species of plants. Hundreds of every kind were subjected to the same conditions, and in the majority of cases, with the same general results. The *Convolvulaceæ*, the *Schrophulariaceæ*, *Gesneriaceæ*, *Labeatæ*, *Cruciferæ*, *Papaveraceæ*, *Resedaceæ*, *Geraniaceæ*, *Leguminosæ*, *Onagraceæ*, *Solunaceæ*, *Primulaceæ*, *Polygoneceæ*, with all their subdivisions, were experimented on, and in every case but one or two, the result of the experiments showed that the self-fertilized plants were inferior in size, strength, hardiness and other important particulars to those cross-fertilized. A curious exception was furnished by a specimen of the *Convolvulus Major*, which Darwin named "Hero." This plant, though self-fertilized, grew to a height far exceeding that of the cross-fertilized plants, and strange to say, transmitted its power to its descendants, so that the average height of six seedlings derived from it was seventy-four inches, while that of cross-fertilized plants was only 62 inches. This difference was more apparent in the seedlings still further removed, since the descendants of Hero continued to increase in size and strength as long as Darwin continued his experiments. One curious result of self-fertilization, which neither he nor any one else had ever before observed, was the fact that the flowers of self-fertilized plants were always of the same hue, and each was in every respect a counterpart of all the rest, while the flowers of cross-fertilized plants were full of variety and diversified beauty. This was observable not only in flowers, but in the seeds or fruit also, and an easy explanation is here found for the appearance in nature of new species of plants, the cross-fertilization carried on by insects and other means readily giving rise to novel forms of vegetable growth.

THE HABITS OF INSECTS.

The habits of insects have much more to do with the growth, development and fertilization of plants than is generally supposed. Bees and various other insects appear to search for nectar and pollen by instinct, but their instinct is by no means infallible, since they often visit flowers which secrete no nectar whatever, and still oftener those which have already been exhausted by other insects. All kinds of bees usually visit the same species of flowers as long as they can before going to others. This fact was noticed by Aristotle, and has been repeatedly commented on by him and others. Humble bees and hive bees are good botanists, for they know that flowers may differ widely in color and yet belong to the same species. They are evidently guided, however, in no small degree by color, for Darwin found that by cutting off the bright colored petals of certain flowers the bees passed by the nectar contained in the remaining portions, though every adjacent flower was pumped completely dry. The habit of sucking the nectar from the flower generally brings the insect in contact with the pollen, which is thus transported in its body to other flowers, and thus cross-fertilization is carried on. It is strange that either the taste or the odor of the nectar of certain flowers must be unattractive to bees, for there are flowers which produce nectar in large quantities of which the bee will not take a drop, while other flowers secrete a very small amount which is eagerly sought after by all kinds of insects. Some flowers secrete nectar only when the sun is shining, and the bees visit them at no other time, for Darwin noticed that as soon as the sun was overclouded, the visits of the bees slackened, and soon ceased. There are other flowers which are so deep or so peculiarly constructed that insects can not reach the nectar in them, and the humble bees get round this difficulty by cutting a hole in the side of the flower, advantage of which is immediately taken by all other kinds of insects.

"As busy as a bee" has long ago passed into a proverb; but one needs to read Darwin's last book to appreciate the full force of the adage. Bees endeavor to lose as little time as they can, and it has often been noticed that, when a flower has several nectaries, they try one, and, if it is empty, they do not touch the others, but instantly leave. They thus traverse a great deal of ground before returning to the hive. Even in the case of social plants, of which hundreds of thousands grow together—as with clover and heath—every single flower is visited. They fly very quickly from plant to plant. Darwin noticed that in one minute a humble-bee visited twenty-four flowers, while in the same time another visited twenty-two, and a third seventeen. In the course of fifteen minutes a single flower was visited eight times, by as many humble-bees, while in nineteen minutes every flower on a plant of *Nemophila* was visited twice. In one minute six flowers of a campanula were entered by a pollen-collecting bee, and bees when thus employed work slower than when sucking nectar. One plant bore 280 flowers, and each flower must have been visited at least thirty times a day for several days. The frequency of the visits of bees is also shown by the manner in which the petals are scratched by their hooked tarsi. Large beds of flowers are often seen with their beauty sadly defaced. The humble-bees are often unable to enter flowers, and generally cut holes in such varieties, but it is very curious to see how the hive bees immediately profit by the holes thus made, and resort to them instead of going to the petals. So persistent is the force of habit, even with a bee, that Darwin has seen the hive bees, after visiting specimens of Phascolus which had been bitten by the humble-bees, go to one that had not been perforated, and finding no hole, instantly fly away instead of going to the petals, as they are able to do. The impulse which prompts bees to cut holes in flowers is evidently a desire to save time, since it is no easy task for them to climb in and out of large flowers, and much time is thereby lost. The co-operative system, so profitable to social insects, is thus traced out in an unexpected direction to an unlooked-for conclusion.

THE GENERAL RESULTS.

The conclusions drawn by Darwin from his observations are such as become his talents and aptitude for research in natural history. The first and most important is that cross-fertilization is generally beneficial in plants as in animals, and self-fertilization more or less injurious. Of the latter proposition there is abundant evidence,

even more perhaps than in the case of the former. It is true that plants can be propagated by self-fertilization through many generations, but the tendency is always to decline, and there is no doubt that extinction will ultimately result. The benefits of cross-fertilization, on the other hand, are traceable in the extraordinary number, character and ingenuity of the means for the end. Self-fertilization assures the production of a large supply of seeds, and the necessity of this will be determined by other conditions in the life of the plant. The possibility of cross-fertilization depends mainly upon the presence and number of certain insects, and on the degree to which they are attracted by certain flowers in preference to others, all circumstances likely to change. The advantages of cross-fertilization do not follow from some virtue in the pollen of one that is not possessed by the other, but from their having been subjected for generations to different conditions, or to their having varied in a manner commonly called spontaneous. The next most important conclusion is that the injury from self-fertilization follows from the want of some vivifying principle supplied by another plant. The utility of these and similar observations is sometimes questioned by persons who are unable to see what good will directly result from them. But it is safe to say that no increase to the sum total of human knowledge is without good. It is the patient observer, laboring in obscurity, and often in poverty, through scores of years, unrecognized by the world, unknown and uncared for by the mass of mankind, who gathers data from which the grand edifice of principles underlying the entire philosophy of the age is constructed.