LITERATURE.

FERTILIZATION OF PLANTS.

THE EFFECTS OF CROSS AND SELF FERTILIZATION IN THE VEGETABLE KINGDOM. By CHARLES DARWIN, M. A., F. R. S., etc. 12mo., pp. 482. New York: D. Appleton & Co. Chicago: Hadley Bros. & Co. Price, $2.

In 1793, the German naturalist, C. K. Sprengel, first called the attention of botanists to the subject of the cross-fertilization of flowers, in a remarkable book entitled "The Secret of Nature Displayed." The most important discovery proclaimed by the author was that of the essential part which insects take in the fertilization of many species of plants. Sprengel's revelations were not succeeded by any further notable developments until Darwin published, in 1857, his observations upon the fertilization of the kidney-bean; and, three years later, a work "On the Contrivance by Which British and Foreign Orchids Are Fertilized by Insects." Since the appearance of the latter work, many students of Nature have been engaged in investigating the secrets of the fertilization of plants, and much valuable light has been thrown upon the inviting subject. Mr. Darwin has given more or less time to experiments in this direction during the last thirty-seven years. An interesting section of his work on "Animals and Plants under Domestication," gave many curious results of his observations, and the book now before us states the evidences gained by elven years' study of the question with particular reference to the effects of close interbreeding, and to other points connected with the subject of heredity.

The bulk of this last volume is devoted to a detailed account of the experiments practiced with plants, and of the testimony on various points which these have afforded. Every one who knows anything of Mr. Darwin's methods of study will understand how cautiously his investigations were conducted, and with what scrupulous pains and honesty their products were noted. The popular reader will be satisfied to resign to the practical botanist on examination of this portion of the book, and give exclusive heed to the final chapters, which sum up the discoveries made, and the conclusions to which they have led.

Mr. Darwin has obtained abundant proof that the majority of plants are benefited by cross-fertilization,—that is, by having their seed-germs fructified by pollen from other plants, or at least from other flowers on the same plant. Many species will not bear seed unless they are fertilized by pollen from other flowers; and, again, many species continue fertile and luxuriant, although for generations the flowers receive none but their own pollen. There is an infinite diversity in the habits of plants in this respect; nevertheless, it is conclusively shown that, in the greater number of cases, the seed is more plentiful, and the seedlings are stronger when cross-fertilization has been effected.

The means by which cross-fertilization is accomplished are: first, insects of the orders of Hymenoptera, Lepidoptera, and Diptera, and, in some parts of the world, birds; second, the wind; and, third, with some aquatic plants, currents of water. The conspicuous colors and the odors of flowers serve to attract insects which visit them to feed upon their stores of pollen and of nectar. Sprengel, Darwin, and others, suppose that not only the bright colors, but the stripes and marks on flowers, exist for the purpose of guiding insects to the nectary. Not a few flowers are both conspicuous and odoriferous. White is the most common color, and is the most often associated with fragrance. Of red flowers only 8.2 per cent smell sweetly, while of white ones 14.6 per cent are sweet-scented. Most flowers which depend on twilight or night insects for fertilization emit their odor exclusively in the evening.

All ordinary flowers are so far open when in full bloom that insects can force a passage into them, but, by being so constructed, they are liable to a great loss of pollen, from the washing of rain as well as from pollen-eating insects. To provide against injury from this loss, much more pollen is produced than is needed to fertilize the flower. A blossom of the Dandelion will produce 243,600 grains of pollen, and a Pæony, 3,654,000 grains. It has been estimated that, in the flowers of the *Wistaria*, there are 7,000 grains of pollen for every ovule. A single flower of the *Hibiscus* will produce 4,863 pollen-grains, whereas only sixty are needed to fertilize all the ovules. Insects bear the pollen adhering to their bodies, from flower to flower, over great distances. Frequent instances are recorded of their thus carrying it a half a mile.

Darwin asserts, with more positiveness than is usual to him, that we owe the beauty and the odor of flowers to the existence of insects, various modifications in their structure he also believes to have been developed for the sole purpose of attracting these winged visitors. It has been proved that large and showy flowers are much more frequently visited by insects than are small, inconspicuous ones; hence these last are completely self-fertile. As it is highly probable that showy flowers have had their colors and size developed for the guidance of insects, Darwin queries if inconspicuous flowers have also undergone a change in order to avoid the visits of insects, or if they have merely retained their primitive condition. In either case he considers it unlikely that they have been, or will continue to be, subjected to self-fertilization for a long series of generations. Were they not occasionally cross-fertilized, and benefited by the process, he thinks they would probably become permanently closed, so as altogether to prevent cross-fertilization.

The fact that bees gathering honey, and insects feeding on pollen, confine themselves as long as they can to flowers of the same species, favors the cross-fertilization of plants. Aristotle noticed this fact 2,000 years ago, and modern observers have confirmed it by finding that hive and humble-bees genrally keep to one species of flowers in a garden or field, until all in turn have been visited. The reason of this is probably to save time, as the insect, having once learned how to stand in the best position on the flower, and just where and how far to insert its proboscis, can work faster by visiting the same species than when continually changing. As to the number of flowers which bees visit in a given time, Darwin has observed that in exactly one minute a humble-bee visited twenty-four flowers of the *Linaria cymbalaria*; another visited in the same time twenty-two flowers of the *Symphoricarpus racemosa*; and a third, seventeen flowers on two plants of a *Delphinium*. Within fifteen minutes a single flower on the summit of an *Enothera* was visited eight times by humble-bees; in nineteen minutes every flower on a *Nemophila* was visited twice; and in one minute a pollen-collecting hive-bee, which works slower than a honey-sucking bee, visited six flowers of a *Campanula*. From observations on a plant of *Dictamnus fraxinella*, Darwin estimated that every one of its 280 flowers must have been visited by humble-bees thirty times in a single day. Under circumstances like these flowers can hardly escape cross-fertilization.

But bees sometimes rifle the blossoms of their sweets without returning any compensation. Humble-bees have a trick of biting a hole in

the nectary of flowers, and sucking the honey through this, instead of reaching it by the mouth of the flower, where they must nearly inevitably aid in the process of fertilization. When humble-bees have set the example of biting into a nectary from the outside, hive-bees are quick to imitate them, and often a whole field of plants of a certain species will be served in this way. It is a quicker method in the end to suck honey through an artificial hole in the flower, and Darwin suggests that the bees which stop to cut the orifice may sacrifice their time for the sake of the rest of the community.

It is supposed that the first plants which appeared upon the earth were cryptogamic, and that, when flower-bearing species were developed, before the existence of insects, they depended upon the wind for cross-fertilization. Many species still continue to be fertilized mainly by this agency, and these, as a whole, stand in a lower grade than the plants fertilized by insects. The amount of pollen produced by wind-fertilized or anemophilous plants, as they are called, is enormous, as there must be a great waste in its transport. Most persons have observed the clouds of pollen that are blown from coniferous trees, when in bloom, by every gust that passes by.

Instances are cited where basketfuls of pollen, chiefly of the conifers and grasses, have been swept to the decks of vessels near the North-American coast. Prof. Riley, the State Entomologist of Missouri, relates that he has seen the ground in the vicinity of St. Louis yellow with the pollen of the pine, which there was good reason to believe had been transported from the pine-forests 400 miles to the south. Wind-fertilized plants generally bear flowers of separate sexes, either on the same plant or on distinct plants. Nagali believes this to have been the condition of the earliest and lowest members of the vegetable kingdom. Where the male and female flowers are on distinct plants, cross-fertilization is insured; and this may be the reason, Darwin suggests, why so many trees and shrubs are thus constructed. Their long life enables them the better to sustain a possible failure of impregnation in any season; and, also, the advantage of cross-fertilization tends to promote a sturdy and enduring growth. It has been remarked that annuals rarely have the sexes separated on distinct plants.

Darwin believes that the benefit of cross-fertilization depends on the plants which are crossed having been subjected during previous generations to somewhat different conditions, as of soil, climate, etc.,—very slight differences producing decided results. This conclusion harmonizes with the fact that a cross between animals which have been subjected to slightly different conditions proves beneficial. "Why it is beneficial that the sexual elements should be differentiated to a certain extent, and why, if the differentiation be carried still further, injury follows," still remains a mystery challenging continued investigation. "It is an extraordinary fact," says Mr. Darwin, "that, with many species, flowers fertilized with their own pollen are either absolutely or in some degree sterile; if fertilized with pollen from another flower on the same plant, they are sometimes, though rarely, a little more fertile; if fertilized with pollen from another individual or variety from the same species, they are fully fertile; but, if with pollen from a distinct species, they are sterile in all possible degrees, until utter sterility is reached. We thus have a long series with absolute sterility at the two ends,—at one end due to the sexual elements not having been sufficiently differentiated, and at the other end to their having been differentiated in too great a degree, or in some peculiar manner. . . . It is equally inconceivable why some individuals of the same species should be sterile, whilst others are fully fertile with their own pollen; . . . and why the individuals of some species should be even more fertile with pollen from a distinct species than with their own pollen. And so it is with many other facts, which are so obscure that we stand in awe before the mystery of life."

The agriculturist will be able to profit by some of the conclusions at which Mr. Darwin has arrived in these studies. Among other things, he may learn that crops will be improved by sowing seed produced in a different locality, in alternate rows, with seed of the same sort grown on the spot. The intercrossing of the two stocks by this means will result in a far better yield than where all the seed has been raised under the same conditions. The breeder of stock is told that the pairing of animals which are closely related may be practiced with excellent results, provided the individuals have been raised on distant and differently-situated farms, whereby the differences in their constitution have been increased and the likenesses lessened. As some plants suffer more than others from close interbreeding, so it no doubt is with some animals. In both cases the effect is deterioration of general vigor, including fertility, with no necessary loss of excellence of form.

Like the previous two or three books of Mr. Darwin, this last is less attractive to the general public than were the earlier ones, which made their author famous as the reviver of the theory of Evolution and the originator of the theory of Natural Selection. The book, being confined to facts relating to a single question in one department of Natural Science, necessarily appeals to a somewhat limited class, viz.: those who have a special interest in Botany and enjoy a minute study of its most puzzling questions.