DARWIN ON FERTILISATION.*

Although this treatise partakes rather of the character of a treatise on a special subject, and is therefore, much less width of scope than "The Origin of Species" or "The Descent of Man," it will be found to be a storehouse of very curious and interesting observations, which are calculated to throw light on various important physiological problems regarding the benefits derived from slight changes in the conditions of life, whether animal or vegetable; on the origin of the two sexes, and their separation or union in the same individual; on the whole subject of hybridism, and through these, in a very direct manner, on the general theory of evolution. It also contains lessons of practical value to horticulturists and florists (and the results may be generalised by stock-breeders) in regard to the important questions of close breeding and cross breeding.

The first six chapters are devoted to a minute detail of a long series of experiments on plants of widely distinct families, inhabiting various countries — convolvulaceæ, scrophulariaceæ, gesneriaceæ, cruciferæ, papaveraceæ, leguminosæ, solanaceæ, and many others. The object was to investigate the effects produced through several generations on the progeny of the same plant when one series of the seedlings were derived from flowers continuously fertilised with their own pollen, or with pollen from another flower on the same plant, or what in other words the author calls self-fertilised plants, the products of self-fertilisation; the other series, against which the former were compared, being derived from flowers fertilised with pollen from a distinct plant of the same species, being what Mr Darwin calls cross-fertilised plants, or plants of crossed parentage. Mr Darwin propagated plants of the same species, under as nearly as possible the same conditions, side by side, through many generations—the one set being always the products of continuous self-fertilisation, the other the products of crossing. The comparative height and weight of the crossed and of the self-fertilised plants, generation after generation, are given in great detail; and the differences between them in fertility, in constitutional vigour, in the number, weight, and germination of their seeds, in their power of resisting unfavourable conditions of growth, of competing in the struggle for existence, in their tendency to produce monstrosities and sports, to vary in colour and in other respects are minutely noted. In the three following chapters the observations are tabulated, arranged, analysed, and reduced as far as possible to statistical form. Chapters x., xi., and xii. are occupied with the discussion of various related points and questions of general interest, such as the means of fertilisation of flowers by insects or by the winds — the distinctions between these "entomophilous" and "anemophilous" species, as they are called — the relation between the structure of flowers and the habits of insects—the prepotent power of pollen from a distinct plant—the separation of sexes in flowers and trees—the instincts and habits of bees and other insects in exploring the structures of flowers and distributing the pollen; and, finally, the general results, theoretical and practical, which we have already indicated as capable of being deduced from the whole investigation. The tables show most strikingly the beneficial effects during successive generations of a cross between distinct plants and the evil effects of perpetual self-fertilisation. Thus, during ten generations of one of the convolvulaceæ, the *Ipomœa purpurea*, the average comparative height of the crossed plants to that of the self-fertilised plants was as 100 to 77. "The difference in height between the crossed and the self-fertilised plants will perhaps be best appreciated by an illustration:—If all the men in a country were on an average 6 feet high, and there were some families which had been long and closely interbred, these would be almost dwarfs, their average height during ten generations being only 4 feet 8½ inches." With respect to fertility, by whatever standard they are compared, the crossed plants are always in some degree more productive than the self-fertilised. The former produce a much greater number of capsules, although the capsules do not, on the whole, contain a larger number of seeds. Thus, in the third generation of the *Ipomœa*, the crossed plants yielded capsules in the ratio of 100 to 38, whilst the seeds in their capsules were to those in the capsules of the self-fertilised plants only as 100 to 94. The seeds of the crossed plants, as a rule, flowered before their self-fertilised competitors, and the impaired fertility of the latter was also shown by their anthers being smaller than those of the former, and containing about half the quantity of pollen; by the first formed flowers, as in hybrids, being sterile, and by a tendency which manifested itself in the later generations to produce monstrosities of formation. The relative average weights of the crossed plants and the others in *Ipomœa* were as 100 to ...; in *Petunia violacea* as 100 to 22; in *Dianthus caryophyllus*, 100 to 49; in *Brassica oleracea* as 100 to 39, and so forth. It is only necessary to glance down the tables to see still more striking proof of the good effects of crossing, in experiments in which a late generation of the self-fertilised plants was at length crossed with a fresh stock, grown in another locality and under different conditions, or with another sub-variety, instead of crossing with pollen derived from distinct individuals propagated (though by continuous crossing) from the original plant, and which were consequently closely related to the plant to be crossed. The tables show at a glance what extraordinary advantage in height, weight, and fertility the plants derived from a cross with the fresh stock or sub-variety have over the self-fertilised plants and also over the intercrossed plants of the same old stock. The seedlings thus raised by crossing the eighth generation of self-fertilised plants with a fresh stock were to the self-fertilised plants of the eighth generation as 100 to 52 in height, and as 100 to 3 in fertility! They were also to the intercrossed plants derived from crossing two of the self-fertilised plants of the eighth generation as 100 to 56 in height, and as 100 to 4 in fertility. And to prove their hardihood, the offspring of the eighth self-fertilised generation of *Mimulus*, crossed by a fresh stock, survived a frost which killed every self-fertilised and every intercrossed plant of the same old stock. The effect of a cross from flowers on the same plant appears not to differ from the strictest self-fertilisation.

From the experiments, Mr Darwin deduces this important consequence, that the mere act of crossing two distinct plants which are in some degree interrelated, and which have long been subjected to nearly the same conditions, does little good as compared with that from a cross between plants belonging to different stocks or families, and which have been subjected to somewhat different conditions. The injury from the close breeding of plants (and of animals) does not, he considers (p. 458), necessarily depend, as is often supposed, on any tendency to disease or weakness of constitution common to the related parents, and depends only indirectly on their relationship in so far as they are apt to resemble each other in all respects, including their sexual nature. And the advantages of cross-fertilisation depend apparently on the sexual elements of the parents having become in some degree differentiated by the exposure of their progenitors to different conditions, or from their having intercrossed with individuals thus exposed. That this differentiation in the sexual elements, which are so extremely sensitive to modification from external influences, and partake of all the modifications which any of the other elements of the plant undergo, is within certain limits the condition of perfect fertilisation, and of full health in the progeny, and that, when carried beyond those limits, and fixed, as it were, by the long habituation of each plant to its own conditions, and when the sexual elements of the differentiated plants have thus acquired firmly fixed affinities, this differentiation becomes too great or too inflexible for cross-fertilisation, and thus produces the so-called pure and distinct species. These seem to be the main contributions of the book to the scientific conception of species and varieties. Mr Darwin suggests that the fertilisation of a plant, depending on the mutual action of the contents of the pollen grains and ovules, and which is favoured by some degree of differentiation in the elements which interact and unite to form a new being, may have some analogy with chemical affinity or attraction, which, generally speaking, obeys the law that the greater the difference in the properties of two bodies the more intense is their tendency to mutual chemical action, while between bodies of a similar character the tendency to unite is feeble. But the differentiation, as he suggests in another passage, may become so great or may be so peculiar in character and may by perpetuation through a long series of generations have become so unyielding and inflexible that instead of inducing fertilisation it injures or destroys it. "It is an extraordinary fact that with many species flowers fertilised with their own pollen are either absolutely, or in some degree, sterile; if fertilised with pollen from another flower on the same plant they are sometimes, though rarely, a little more fertile; if fertilised with pollen from another individual or variety of the same species they are fully fertile; but with pollen from a distinct species, they are sterile in all possible degrees until utter sterility is reached." We have thus a long series with absolute sterility at each of its two ends—at one end due to the sexual elements not having been sufficiently differentiated, and at the other end, due to their having been differentiated in too great a degree or in some peculiar manner. After alluding to the many forms of a sexual propagation of organisms, Mr Darwin asks, why have the sexes been developed? why do male plants and animals exist, seeing they have not the faculty of producing offspring themselves? "The answer lies, as I can hardly doubt, in the great good which is derived from the fusion of two somewhat differentiated individuals, and, with the exception of the lowest organisms, this is possible only by means of the sexual elements, these consisting of cells separated from the body containing the germs of every part and capable of being fused completely together." In short, after having shown, by his elaborate and protracted experiments, that the offspring from the union of two distinct individuals, especially if their progenitors have been subjected to very different conditions, have an immense advantage in height, weight, constitutional vigour, and fertility over the self-fertilised offspring from one of the same parents, he says that "this is amply sufficient to account for the development of the sexual elements, that is, for the genesis of the sexes." "No injury, but, on the contrary, good, resulted from one-half of all individual organisms (or the males) failing to produce offspring."

With regard to the subject of hybridisation, which is admittedly one of the greatest obstacles to the general acceptance and progress of the great principle of evolution, Mr Darwin points out that the results of his experiments in self-fertilising and cross-fertilising plants, and the experiments he has previously published on the uniting in various ways dimorphic or trimorphic heterostyled plants of the same species, give us two grand classes of cases which correspond in the most striking manner with those phenomena of hybridism which follow from the crossing of what are called true and distinct species. He maintains that the tendency of his experiments is to prove that we have no right to assert that the sterility of species when first crossed, and of their hybrid offspring, is determined by any cause fundamentally different from that which determines the sterility of the individuals both of ordinary and of heterostyled plants when united in various ways. "Nevertheless, I am aware that it will take many years to remove this prejudice."

A very singular and interesting result obtained in the case of more than one of the families of plants experimented on was the appearance in the third, fourth, and sixth generations of three families, the self-fertilised plants of an individual which, unlike its sister plants, displayed such vigour, such height and weight, and such a high degree of self-fertility as enabled it to contend victoriously against its inter-crossed competitors, and, what is more, to transmit its qualities to its children, grandchildren, and great-grandchildren, and it seems to have acquired for itself, and transmitted to its descendants, a special power of growth and constitutional vigour, connected in some mysterious way with self-fertilisation, opposed to fertilisation by crossing, so that its great-grandchildren where crossed with a fresh stock derived no advantage from the crossing, as other self-fertilised seedlings always did, but rather, indeed, suffered injury.

It is impossible with the brief limits at our disposal to discuss or even to explain the numerous other glances one obtains, or thinks he obtains, into many of the mysterious problems of life in following Mr Darwin through his long course of observation, and the profound suggestions which he throws out. Still less is it possible to follow him into such minute details as those regarding the relation between the habits and instincts of insects and the forms of plants and the like, which give a peculiar charm and value to this as to all Mr Darwin's books. We have no doubt, however, that, independent of all the importance the volume has for the scientific botanist and for the biologist, its practical interest for the agriculturist and horticulturist, and the fascination of its curious details for the general reader, will be found so great that it will soon become as well-known as any of the famous naturalist's previous productions. We shall devote the remainder of our space to random notes of curious points, in which the book abounds.

With regard to the colour of flowers, Mr Darwin found that plants self-fertilised and grown under similar conditions for several generations, although originally raised from parent plants which varied greatly in the colour of their flowers, became in time absolutely uniform in tint. The inter-crossed plants of the same lineage, being all more or less closely inter-related, also became more uniform in colour than the original parents, but much less so than the self-fertilised plants; but these, again, once crossed with a fresh stock, yielded seedlings which were wonderfully varied in tint. It therefore appears that new and slight shades of colour may be quickly and firmly fixed, independently of any selection, if the conditions be kept as nearly as possible uniform and no inter-crossing permitted.

The chapters on the means of cross-fertilisation are replete with curious matter. Insects—hymenoptera, lepidoptera, and diptera—and in some parts of the world birds, are the most important carriers of pollen from the anthers to the stigma of the same or of different flowers. Next in importance, but in a quite subordinate degree, is the wind, and with aquatic plants the stream. Mr Darwin finds the explanation of the conspicuous colouring of flowers and the bright tints of adjoining parts, bracts, peduncles, &c., in the advantage to the flower of cross-fertilisation by insects which are attracted by colour. There is also reason to believe that flowers differ in colour in accordance with the kinds of insects which frequent them. The odours attract insects; artificial flowers scented with essential oils unmistakably attracted insects, while those unscented were left unvisited. The greater proportion of flowers are white, and of these the larger portion are odoriferous—depending on fertilisation by moths, and requiring the double aid of conspicuousness in the dark and of odour. "But so great is the economy of nature that most flowers which are fertilised by crepuscular or nocturnal insects emit their odour chiefly or exclusively in the dark." The details showing that nature has provided means for ensuring cross in preference to self fertilisation are very curious, and among these means the most curious is the prepotent fertilising power of pollen from a distinct variety over the plant's own pollen, both kinds being placed on the stigma together. The nature and relations of the anemophilous plants, or plants which are cross-fertilised by the wind; the probability that all the earliest terrestrial plants, the coniferæ and cycadeæ, and so forth, which existed at a period when winged insects, which are now chiefly concerned with the transport of pollen, did not exist, were anemophilous; the instances indicating a transition being possible from anemophilous to entomophilous fertilisation, which are found in certain plants that at present appear to be in an intermediate condition; the enormous, and one would at first say wasteful, amount of pollen produced by the wind-fertilised plants, and its extraordinary lightness; the facts that indicate the return, in special circumstances, from the ordinary to the anemophilous state (as in the pringlea of Kerguelen's Land, where there are no winged insects, the pringlea being the single plant in the great order of the cruciferæ which is now anemophilous)—the fact that most anemophilous plants are diclinous (or with the sexes in separate flowers on the same or distinct plants), while the great mass of plants in which the sexes are found together in the same flower are not anemophilous, a fact which may be attributed to the anemophilous plants having retained in a greater degree than the others a primordeal condition in which the sexes were separate; all these subjects are full of interest and charm. Not less so are the pages on the habits of insects in relation to the fertilisation of flowers. Humble bees and hive bees, it seems, are good botanists, and keep as long as they can to flowers of the same species before going to those of another species, and "they know that varieties may differ widely in the colour of their flowers and yet belong to the same species"—a wonderful provision for making their transport of pollen useful. "I have repeatedly seen humble bees flying straight from a plant of the ordinary red *Dictamnus* to a white variety," &c., &c.; and it appears that some species of flies keep to the same species with almost as much regularity as the bees. There are details of great interest with regard to the felonious or burglarious habits of bees in biting holes from the inside through the corolla of plants which they cannot readily enter, in order to get at the nectar. There are a hundred other similar curious observations which the lover of nature will linger over with interest, and that independent of the larger issues connected with the great doctrine of Evolution, on which they all more or less directly bear. Altogether this is a charming volume, and one which we have no doubt will soon become a popular favourite.

* The Effects of Cross and Self Fertilisation in the Vegetable Kingdom. By Charles Darwin, M.A., F.R.S., &c. Murray, Albemarle Street, London.

EXPLORING BALLOONS.—The circumference (not the diameter) of the exploring balloons for meteorological purposes in Paris is ninety centimetres. They have an ascensional force of about thirty grammes.

CATTLE DISEASE IN IRELAND.—At a meeting of the Council of the Royal Agricultural Society in Dublin, a resolution was adopted expressing the conviction that nothing short of the prohibition of the importation of live stock from European ports to the United Kingdom would prevent the outbreak and spread of rinderpest and other contagious cattle disease.

FATAL RESULT OF AN ACCIDENT.—Mr John Whitty, a retired major of the 93d Highlanders, has died in a private hospital in Dublin from injuries he received on the 23d instant by falling over the balustrade of the Portobello Hotel, where he was staying. The fall to the ground was about 20 feet. His right leg was broken in two places, and his head was severely injured.