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masticatory apparatus of Echinus, with its five jaws, each traversed by a tooth, and all moved by an elaborate arrangement of muscles, is still, probably, only a very specialized hardening of epithelial membrane. (*d*) A similar statement may be made in relation to the odontophore (ὀδούς, *a tooth*: φέρω, *I bear*) of the higher Mollusca. This structure, with its cartilaginous support, its long elastic strap, its transverse rows of teeth, seems to combine, to some extent, the functions of teeth and of tongue. (*e*) The mouths of the higher Annulosa present a higher type of masticatory apparatus. Their jaws are appendages of the body-segments. They are modified limbs. (i.) The simplest condition is that met with in the Myriapoda (μυρίος, *numberless*), as the Centipede (*centum*, 'a hundred'). A small labrum (*labrum*, 'the brim of a vessel') above the mouth opening, a pair of mandibles (*mando*, 'I chew') or hard, crushing jaws, a labium ('a lip') below the mouth-opening, with four side lobes. (ii.) The Arachnida (spider and scorpion) have labrum and mandibles, and two pairs of more delicate jaws, known as maxillæ. These are the four side lobes of the labium of Centipede specialized into distinct lateral jaws. In Arachnida, the mandibles are extended into prehensile and offensive claws. The maxillæ in spider are related in a remarkable manner to the function of reproduction. The specialization is therefore incomplete. (iii.) Crustacea, as the lobster, have labrum, two mandibles, four maxillæ (representative of the split labium of Myriapoda), and, in addition, three pairs of feet-jaws (maxillipedes). These last represent the six legs of Insecta. The somites, which in the latter bear motor organs, carry in the Crustacea organs that serve for mastication, but are in structure closely allied to the true legs on the succeeding somites. (iv.) In the Insecta, the labrum, labium, mandibles, maxillæ, are all met with, and present numberless modifications far too complex to be even mentioned here. All these modifications are, in the main, subservient to the function of taking in or crushing food. (*f*) Finally, whilst all the jaws mentioned above move in a horizontal plane, in the cuttle-fish (Cephalopoda) the jaws move in a vertical plane.

(6) *Stomach.*—A dilation of the alimentary canal is a stomach. No such dilation is found in some of the Echinodermata, and a very slight one in the Ascidioida. Forms of stomach.—(*a*) The most necessary and constant form of stomach is an expansion of the alimentary canal, where the food is delayed, and whereinto digestive fluids are poured. This is the true stomach, present in the majority of Mollusca and Annulosa, with the exceptions just mentioned. (*b*) The gizzard.—This has been referred to. (*c*) The crop.—An expansion of the alimentary canal, very generally a lateral one, whereinto no digestive fluid is poured. The crop serves to store up the rapidly-swallowed food until time is afforded for that food to be passed on to the true stomach. The crop does not digest. It is seen in the higher orders of Insecta.

(7) *The Intestine.*—The narrowed part of the alimentary canal succeeding the stomach. (*a*) It is straight and without convolutions in many Mollusca and Annulosa, as the star-fish, the scorpion, the centipede, and even the Crustacea. (*b*) It presents convolutions in some. These cases are more particularly met with in the Mollusca, in which group the digestive apparatus on the whole presents a higher type than that seen in the Annulosa. Even the lower Mollusca have a flexure or bend in the intestine. (*c*) Lastly, the distinction between the small and large intestine, a distinction founded on their relative diameters, not on their relative lengths, is observable in the Insecta and in many Mollusca.

THE FERTILIZATION OF PLANTS.

By Rev. GEORGE HENSLOW, M.A., F.L.S., F.G.S.

MR. DARWIN has lately published an important book, which will take its place by the side of his former ones as a standard botanical work. It treats of Cross and Self-fertilization of Plants,[1] and embodies an enormous amount of facts based upon an elaborate series of most carefully conducted experiments; and although one may demur to a few of his inferences, yet no one can fail to derive immense advantage from it who is at all interested in the subject. I purpose giving as briefly as possible some few of his conclusions.

Seven kinds of union may be enumerated between the stamens and pistils of flowers: (1) Between two genera; (2) between two species; (3) between two varieties; (4) between two individuals of the same stock; (5) between two individuals of different stocks; (6) between two flowers on the same plant; (7) 'self-fertilization,' or the union of the stamens and pistils of the same flower.

The first and second kind of unions constitute hybridization, the offspring of the first kind being

[1] *Cross and Self-Fertilization of Plants.* By C. Darwin. Murray.

called a *bigener*, and is rare; that of the second kind, a *hybrid*, and is much more common. The third kind of union, between two varieties, usually designated as a *cross*, is practised very extensively in horticulture. None of these, however, form the subjects of Mr. Darwin's experiments, which are confined to the last four kinds of union.

Dean Herbert (in 1836) remarks, in his *Amaryllideæ*, p. 371: 'I am inclined to think that I have derived advantage from impregnating the flowers from which I wished to obtain seed with pollen from another individual of the same variety, or at least from another flower rather than its own, and especially from an individual grown in a different soil or aspect.'

Now, just as Mr. Darwin by his researches on orchids and other insect-visiting plants established on scientific grounds the great value of insect agency, first advocated by Sprengel in 1790; so now he has placed on a similar scientific basis these surmises of Dean Herbert; and his conclusions have in general almost entirely confirmed them.

The most important results are obtained when plants of the same species, but grown in different localities, that is, which are of different stocks, are crossed. Mr. Darwin thus experimented on twelve different species, and then tested the results by comparing the heights of the full-grown plants, their weights, their degrees of fertility in the production of seeds, and in some cases their hardiness in withstanding cold and intemperate weather or a sudden removal from a hothouse to the open ground, also the period of flowering, etc.; and the general result was that they were immensely superior both to plants derived from *intercrossing* individuals of the same stock, as well as to plants resulting from *self-fertilization*.

These results, however, were not without exception. Thus, while cultivating for ten generations *Ipomœa purpurea* (the so-called *Convolvulus major*), in the sixth generation an individual appeared which had great self-fertilizing powers, and whose descendants surpassed in every way not only intercrossed plants of the same stock, but even the offspring from a cross with a different stock.

Again, *Eschscholtzia Californica* is a plant which is self-sterile in Brazil. Plants grown from seeds sent to Mr. Darwin by Fritz Müller set some seed in England by self-fertilization, and the offspring of these soon acquired vigorous constitutions and beat their opponents (for *pairs* of plants were always put in competition in the same pot) in every way *except* in fertility.

Such exceptional cases do not, however, nullify the general conclusion arrived at, viz. that a vast improvement is secured to the offspring derived from a cross with a new stock.

The explanation appears to be, that by such unions new but unknown constitutional elements are introduced into the system which invigorate the offspring. There is no good in the mere act of crossing; that is, the sexual process is only a *means* to an *end*, and is useless unless the cross bring with it some constitutional elements different from what are already present in the female. Similar results are secured by crossing varieties—that is, plants of the same species which differ in some slight perceptible qualities, as the size or shape of the leaves, or difference in the colour of the flowers, etc. Such unions, like those of different stocks, is also highly beneficial, and from a horticultural point of view extremely important. New varieties of all sorts are being continually thus raised, and with flowers the colouring is rendered excessively various.

The union upon which Mr. Darwin made the greatest number of experiments was that between individuals of the same stock. He cultivated fifty-four species of thirty orders for this purpose, some for as many as ten generations; and the general result was, that the crossing benefits the plant at first, or for some few generations, but that the difference in favour of the crossed offsprings gradually disappears in later years, and they become more nearly equal to the self-fertilized in every way. An example will illustrate this. The mean ratio of the heights of the intercrossed to the self-fertilized plants of *Ipomœa purpurea* for the first three generations was as 100 : 74·3, that for the next three generations was as 100 : 77·6, and that for the third three generations was as 100 : 81·6; that is, fixing the height of the intercrossed plants at 100, the heights of the plants derived year after year by perpetual self-fertilization gradually approximated to the same standard. The same result appears from fertility; for while a similar ratio gives 100 : 93 for the first year, it was 100 : 94 in the third and fourth years, and even at 100 : 107 in the fifth. A third peculiarity was seen in the colouring of the flowers: for, when they were first intercrossed, they showed great variability of colour, but they gradually became more and more uniform in tint in successive generations, but never so absolutely identical as was the 'rich dark purple colour' of all the self-fertilized offspring. From this latter feature Mr. Darwin deduced an important fact for horticulturists, that, if they wish to perpetuate any strain, they must carefully select it and then propagate it by self-fertilization. An identical fact had long been *done*, if not recognised as a *principle* before; for many years ago Mr. A. Knight raised new varieties of peas by crossing varieties then existing, and the offspring subsequently kept true for more than sixty years, because the pea (*Pisum sativum*) is habitually propagated in this country by self-fertilization alone.

The ratios of the weights were even more striking than those of the heights of plants intercrossed with

others of the same stock, and of self-fertilized plants. Mr. Darwin gives a table of seven plants which he weighed when fully grown; thus, for example:—*Brassica oleracea* (cabbage). The ratio of the intercrossed (100) to the self-fertilized plant in *height* and *weight* respectively, was as 100 : 95 and : 37.
Reseda lutea, do. do. as 100 : 85 and : 21.
Dianthus caryophyllus, do. do. as 100 : 99 and : 49.

These three cases show that the estimate of heights, though generally good, is not always a fair one of the differences of vigour; for, had Mr. Darwin not measured the weights, the ratios of the heights appearing as 100 : 95 and as 100 : 99 would lead one to suppose that there was practically little or no difference between the result of intercrossing and self-fertilization.

The next kind of union is that of crossing flowers on the same plant. It has been generally supposed that such would benefit the offspring; but, as far as the few cases Mr. Darwin tried can be trusted for generalizations, it would seem that, for the most part, such a union is useless. With *Ipomœa purpurea* and *Mimulus luteus*, the result was slightly in favour of the self-fertilized; with *Digitalis purpurea*, in favour of the crossed plant; with *Reseda* and *Abutilon* there appeared to be no benefit; but with *Eschscholtzia*, *Corydalis cava*, and *Oncidium*, a slight benefit. Now, it is observable that these last three plants are more or less physiologically self-sterile, while *Digitalis* is morphologically so, as the stamens mature much before the stigma. Hence, *perhaps*, it would prove that when any benefit is derived from crossing flowers on the same plant, such plants are more or less naturally self-sterile, a fact which indicates that the essential organs are more highly differentiated than usual; so that a cross between separate flowers becomes mutually beneficial.

Mr. Darwin's experiments, unfortunately, are too few for any safe generalizations on this kind of crossing.

There now remains but one more kind of union to be considered—that of self-fertilization. Mr. Darwin's experiments having proved incontestably the value of crossing, he draws an opposite conclusion for self-fertilization — namely, that such a process is 'injurious;' and he speaks often of the supposed 'evil effects' of it. Now here, as it seems to me, the facts do not warrant these expressions. When we consider how self-fertilization is habitually and largely carried on in nature, we find as positive facts, that—

1. The majority of flowering plants are self-fertile.

2. Very few are known to be physiologically self-sterile, *i.e.* incapable of setting seed with their own pollen; though there are many morphologically self-sterile, but which can seed freely if artificially impregnated.

3. Self-sterile plants may become highly self-fertile by various causes, such as (*a*) the withering of the corolla, (*b*) its excision (probably), (*c*) its closing, (*d*) by never opening, (*e*) in the absence of insects, (*f*) by grafting, (*g*) by loss of 'dichogamy.'

4. Highly self-fertile forms may arise under cultivation. Mr. Darwin proved this in more than one instance, when certain self-fertilized plants beat their competitors in several ways.

5. Special adaptations occur for securing self-fertilization, not less curious than some of those for intercrossing by insect aid.

6. Inconspicuous flowers and 'weeds' are highly self-fertile.

7. 'Cleistogamous' flowers are habitually and highly self-fertile.

8. The fertility of self-fertilized plants does not decrease, but may increase in successive generations, *e.g.* if the plant had been previously 'dichogamous' and then re-acquired self-fertility.

9. Free from competition, self-fertilized plants often equal the intercrossed in height and vigour.

10. They are perfectly healthy.

11. Naturalized abroad, they may gain great vigour, as our English watercress in New Zealand grows to ten or more feet long and three inches in diameter.

12. Lastly, on dispersion, the self-fertilizing plants prove themselves the best fitted to survive.

Such being the case, the interpretation I would propose is, that, assuming a plant to have a certain standard of height, fertility, etc., then intercrossing increases those elements of vigour, and the plant is thereby benefited in various degrees by the cross introducing new constitutional peculiarities by ~~which it thrives~~.

Such, as given above (excepting these facts concerning self-fertilization), are some of the results arrived at by Mr. Darwin; and I would conclude by observing that botanists and horticulturists are more than ever indebted to our great naturalist and experimenter, for his untiring zeal in advancing our knowledge both scientifically and practically of the various phenomena of plant life.

Thomé's Botany.—Botanical teachers are often puzzled by the question, 'What is the best book t read on Botany?' uttered by young students. Henceforth there should be less difficulty in answering the inquiry. Undoubtedly the best book in English is Mr. A. W. Bennett's translation of Thomé's work on Botany. This work has the clearness of arrangement of Bentley, the philosophical grasp of facts so distinctive of the writings of Henfrey, and in addition is at one with the present condition of botanical knowledge. The book is not, of course, so extensive as that of Sachs, but will be invaluable as an introduction to the exhaustive treatise of the Würzburg professor. Young botanists are apt to be puzzled and discouraged in reading Sachs' volume. If they will commence with Thomé, they will find, after reading him, little difficulty in understanding the facts and following the reasonings of his illustrious country-man.

Plant Digestion.—Professor E. Morren holds that there are three processes in the nutrition of plants: (*a*) *Elaboration*.—Occurs in parts exposed to light. Consists in the formation of carb. hydrates out of inorganic compounds. (*b*) *Digestion*.—Occurs in reservoirs of reserve material. Consists in the addition of hydrogen, evolution of carbon dioxide, and the transformation of the insoluble products of elaboration into soluble diffusible ones. (*c*) *Assimilation*.—Occurs in all organs. Consists in loss of water, formation of cellulose from glucose, and absorption by the living tissues of the digested substances.

New Ascidian.—Mr. Moseley, the naturalist on board the *Challenger*, has discovered, at the depth of 1070 fathoms, a species of Ascidian, which he

alimentary canal and the renal apparatus have but one common external aperture. Only two genera are known, — Ornithorhyncus (ὄρνις, *a bird;* ῥύγχος, *beak*), and Echidna or Tachyglossus (ταχύς, *quick;* γλῶσσα, *tongue*). Of the latter a new species has been lately discovered in New Guinea (T. Bruijnii).

Professor Dewar on the Physiological Action of Light.—(1) A frog under the influence of chinoline remains motionless. The skin at any part of the body is abraded. One electrode is placed in contact with the abraded surface, the other with the cornea of the eye. A current is obtained passing *in the wire* from the cornea (positive) to the injured skin (negative). If light fall on the eye with which the electrode is in contact, there is an increase in the electric current (positive variation) at the moment of impact; if the action of the light be continued, there is a diminution of the electric current (negative variation); if the light be shut off, there is a second increase of the electric current at the instant of removal of the light. The frog retains its sensibility to the action of light for forty-eight hours. (2) If the electrodes touch two different parts of the *skin*, there is a current, but it is not affected by light. The retina must be included in the circuit for any alteration of current under the action of light to occur. (3) Similar results are obtained in warm-blooded animals. (4) The lobster shows the largest amount of variation yet observed. . . . With the positive variation caused by the impact of light, compare the observation of Du Bois-Reymond, that with sensory *nerves* physiological action causes negative variation. (5) Electro-motive force between cornea and the posterior surface of the sclerotic in Frog = $\frac{1}{100}$ of a Daniel: between cornea and a cross section of the brain = $\frac{1}{150}$ of a Daniel.

Functions of the Cerebellum.—Many physiologists and most phrenologists have considered that the cerebellum, or 'after-brain,' was the seat of the sexual instinct. Of late the view held has been, that the cerebellum is the centre for the co-ordination of muscular movements—the grouping into one harmonious whole of the contractions of many different muscles. Professor Ousiannikoff, of St. Petersburg, has recently shown (1) that the complete removal of the cerebellum after ligature of the carotid arteries is not attended with loss of co-ordination of movements: (2) that an effusion of blood consequent on the removal of the ligature is attended with such loss.

The Internal Ear.—The order of development of the parts of the ear of higher animals, and the relative degree of development of those parts in different animals, point to the following conclusions according to Professor Lawson Tait: (1) The vestibule is the most fundamental portion, and perceives sound vibrations. (2) The utricle ranks next, and appreciates the direction of sound. (3) The semicircular canals are anatomically and physiologically additions to this last. (4) The cochlea, bearing to the saccule a similar relation to that which the canals do to the utricle, appreciates pitch.

Vision-purple.—The layer of rods and cones in the retina has, during life, a purple colour, con-