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THE SELF-FERTILISATION OF PLANTS.*

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[Plate I.]

When the discovery that plants had sexes became a well-recognised fact, the relative position of the stamens and pistil in a flower was noticed as peculiarly favouring, as was supposed, their union; and in accordance with the teleological views of the last century, the oft-quoted generalisation was made (attributed, I believe, originally to Linnæus), that whether a flower be pendulous or erect, the stigma was always *below* the anthers, so that the pollen might *fall* upon it, self-fertilisation being thus supposed to be the object in nature.

It is worth while pointing out some objections to this idea. In the first place, if nature intended the pollen to reach the stigma, why, it may be asked, is it allowed to *fall*, as it would be applied to it with much more certainty if the anthers were placed in close contact with that organ, as is actually the case in all really self-fertilising plants, so that there would be no chance of the pollen being blown away by the wind before it could fall down upon the stigma. Secondly, how comes it that flowers are monœcious and diœcious, that is, with their sexes separate, either in different flowers on the same or on distinct plants, respectively? Thirdly, many flowers, though possessing both stamens and pistil, are dichogamous, that is, the anthers mature and shed their pollen before the stigma is ready to receive it; or else the stigma matures before the anthers. Lastly, a large proportion of conspicuous flowers are irregular or else

* The subject of a paper by the present writer in the "Transactions of the Linnæan Society," to be published in the ensuing volume.

highly attractive to insects, and, as has been shown by Sprengel in 1790, and by various botanists at the present day, are specially adapted to insects who transfer the pollen from one flower to another.

The effects of the last-mentioned process have been ascertained and described by Mr. Darwin in his work on "Cross and Self-Fertilisation of Plants." He proved, by experiments, that when ordinary garden plants are crossed by others of the same stock, or by others of a different stock of the same species, the offspring generally showed greater vegetative vigour in growing taller and in bearing more vigorous and greener foliage; while in their reproductive organs there was brighter and greater variation in colour, and often more seed was set than when such plants had been continuously self-fertilised.

The results would seem, therefore, to exactly fulfil an inference which the late Dean Herbert drew from his experiments with bulbous plants, and which he has recorded in his work on the *Amaryllideæ* (p. 70), as follows:—"I am inclined to think I have derived advantage from impregnating the flowers from which I wish to obtain seeds, from individuals of another variety or another flower, rather than its own, and especially of any grown in different soil or aspect."

A very considerable amount of literature now exists on the subject of cross fertilisation by insect agency. The beautiful and exquisite adaptations exhibited by so many conspicuous flowers have attracted the attention of observers, so that whoever sets to work to examine flowers with this object in view, is pretty sure of making new discoveries of special adaptations.

So obvious, then, has the importance of insect agency been thought to be, that the inference has been drawn that cross fertilisation is necessary for flowers; and Mr. Darwin generalised this inference into an aphorism, which may be regarded as expressing the exactly opposite view to that attributed to Linnæus, namely, that "Nature abhors perpetual self-fertilisation." We may contrast these opposite poles of thought, somewhat as follows:—With Linnæus, Nature had specially designed (most?) flowers to secure self-fertilisation. With Darwin, Nature has specially adapted (most?) flowers to avoid self-fertilisation.

I add "most?" because these observers do not fail to see that there are exceptions in both cases.

Opinions have often been compared to a pendulum, whether they be political, ecclesiastical, or otherwise, in that for a time they run high in one direction; but a reaction sets in and down they go, and are then carried up to the opposite extreme. It is not till both extreme forms have been well tested that at last the excesses in both are struck off, and the truth which invariably underlies each is at last recognised, and the "golden mean" is then permanently secured in their combination, and the pendulum comes to rest.

Such I believe to be the case with the question before us; for I think I can show that Darwin's aphorism is wrong in its extreme form, if not altogether; and the object of the present paper is to endeavour to combine the twin truths which underlie the cross and self-fertilisation of plants.

Mr. Darwin's works have gone far to strengthen the belief that intercrossing is absolutely necessary for plants; and that if self-fertilisation be continued for lengthened periods the plant tends to degenerate and thence to ultimate extinction. This I believe to be absolutely false. Indeed, so strong is the general belief in the value of intercrossing, that self-fertilisation is kept quite in the background, if at all alluded to, by writers on this subject; so that flowers are now usually classed either as "entomophilous," *i.e.*, adapted to insect agency, or else as "anemophilous" or wind-fertilised.

When Mr. Darwin examined Orchids and wrote his excellent book on their fertilisation, he was struck with the singular exception of the "Bee-orchis" (*Ophrys apifera*), which is so constructed as to fertilise itself; and yet this plant is one of the most abundant of orchids, a vigorous grower, and shows no signs of degeneracy at present. Another case, amongst many others mentioned in his "Cross and Self-fertilisation of Plants," is that of the garden pea, which is constantly self-fertilised in this country, and yet the papilionaceous corolla is manifestly and specially adapted to insects. Mr. Darwin alludes to Mr. A. Knight's varieties, originally obtained by crossing, as having lasted for upwards of sixty years, by self-fertilisation alone; and the inference in both cases is, that the effects of crossing—in the ancestral form of the Bee-orchis, which doubtless required it, and in the artificial crossings made by Mr. Knight—have lasted, to the present day in the first case, and for sixty years in that of the pea.

Moreover, since a great number of plants are now discovered to be in the habit of setting seed, and that too very freely, without insect aid, a further generalisation has been made, that not only were they originally crossed, and the good effects have lasted till now, that is to say, for practically an indefinite series of ages; but that they *must* be occasionally crossed again, or they will inevitably die out in time.

Now it must be carefully noted that these generalisations are entirely subjective or *à priori* inferences, based upon the *assumed* necessity of crossing; that assumption being itself based upon the vast number of adaptations to insect agency which exist; but the fact that self-fertilisation is really of wider extent in the vegetable kingdom is ignored. On the other hand, the belief appears to be generally held that many flowers are specially adapted ("purposed") to prevent self-fertilisation. This I am convinced is an erroneous assumption.

Researches into the structure of flowers have led me to draw the following conclusions:—*

1. *The majority of flowering plants can, and probably do, fertilise themselves.* Independently of arriving at this conclusion from a study of nature, I infer it from Mr. Darwin's results; for he protected a number of plants from insects, and gives two lists of forty-nine species in each, the one of plants more or less self-fertile, and the other self-sterile without insect aid; but he adds:—"I do not, however, believe that if all known plants were tried in the same manner, half would be found to be sterile within the specified limits." †

2. *Very few plants are known to be physiologically self-sterile* when the pollen of a flower is placed on the stigma of the same flower. The genus *Oncidium* is a remarkable instance, the pollen of some species having even a poisonous action on the stigma.‡ *Linum*, as Mr. Darwin has shown, is another case, and he observes of *L. perenne* that "its own pollen is as powerless on the stigma as so much inorganic dust."§

3. *Several plants are known to be morphologically self-sterile*, in that the pollen cannot, without aid, reach the stigma, but is effective on that of the same flower. Species of Lupine and *Salvia* are in this condition.

4. *Self-sterile plants from both the above causes can become self-fertile.* Various conditions appear capable of bringing this about. A lowering of temperature seems to check the vigour of the stamens in a normally proterandrous flower, and by not affecting the pistil equally, the essential organs now mature together. Thus *Eschscholtzia*, which is self-sterile in Brazil, became, with Mr. Darwin, self-fertile in England. The mere withering of the corolla will often secure self-fertilisation, as in the case of pansies (see Plate I., fig. 12) by pressing the anthers or pollen on to the stigmas. The closing of the corolla in the evening may do the same, as with Buttercups, *Anagallis*, *Convolvulus*, and other of the Gamopetalæ, in which the stamens, being adherent to the corolla, the latter, when well expanded in sunlight, causes the stamens to spread away from the pistil, and in this condition the flowers are ready to receive the visits of insects; but by closing, the corolla carries the stamens back again, and so self-fertilisation may be secured.

* Space will only allow me to give but little more than an enumeration, but the reader is referred to my paper (*loc. cit.*), where each of these conclusions is dealt with *in extenso*.

† *Loc. cit.* p. 370.

‡ "Animals and Plants under Domestication," ii., p. 135.

§ "Forms of Flowers," p. 98.

A very common condition is for the perianth to remain scarcely at all opened, so that the stamens are never removed from contact with the stigmas. This is the case with small-flowering species of *Veronica* and *Cerastium*, while *Polygonum Convolvulus* and *Hydropiper* never, so far as I have observed them, open their perianths at all.

It would seem probable that plants habitually crossed in their native country, and well adapted for insect agency, may become quite independent of insects in another. Thus the Sweet Pea, though crossed in South Europe, is quite self-fertile here, as is also the garden Pea. The genus *Phaseolus* furnishes a very remarkable illustration, for while *P. vulgaris*, the forcing-bean, is fully self-fertile, yet *P. multiflorus*, the scarlet runner, is dependent on the visits of humble bees for its full fertility; consequently for many years there have been complaints *near London* of the failure of the crops of scarlet runners, all sorts of remedies having been suggested except the right one, which is to abandon it altogether and to grow only the kidney bean instead.*

5. *Highly self-fertile forms may arise under cultivation.* This I take from Mr. Darwin's experiments. In cultivating *Ipomœa purpurea* and *Mimulus luteus* for several generations and comparing the results of crossing and of self-fertilisation, in both cases a self-fertilising form appeared which completely outstripped its crossed competitors. In the latter case "the self-fertilised plants [of the seventh generation] consisted exclusively of this variety;" so it was useless to continue the experiments.†

6. *Special adaptations occur for self-fertilisation.* I have already mentioned a few above, such as the perianth closing or scarcely opening; and will now describe some taken from genera of the natural orders in their usual sequence.

Ranunculaceæ.—In small-flowered *Ranunculi*, as *R. hederaceus*, the stamens, instead of spreading away from the stigmas, remain arching over them, and so shed their pollen on to the stigmas. The same occurs with small-flowered *Potentillas*. Some flowers first spread their stamens away, and then incurve them afterwards, as *Agrimonia* (fig. 33) and *Alisma* (fig. 52).

Fumariaceæ.—*Fumaria officinalis.*—Mr. Darwin found this to be perfectly self-fertile when insects were excluded. The stigmas resemble two horns, each of which is thrust into a three-sided chamber formed by the three anthers, which have their filaments coherent (figs. 2 and 3).

Cruciferæ.—Large-flowered species are adapted for inter-

* See "Gardener's Chronicle," 1878, p. 561.

† For further details, see "Cross and Self-Fertilisation of Plants."

crossing, though all can probably fertilise themselves by their longer stamens. Small and inconspicuously flowering species are probably in all cases regularly self-fertilised, while some, as Shepherd's-purse, are most abundant and vigorous. The stigmas of these are not two-lobed, but capitate (fig. 1).

VIOLACEÆ.—The genus *Viola* furnishes remarkable cases. The conspicuous flowers of the sweet Violet, adapted to insects, often fail to set seed; but the cleistogamous buds seed profusely. These are degraded buds of the ordinary kind, for in strong growing garden plants transitions can be found, as shown in fig. 4, which represents a bud with the calyx removed. Fig. 5 is a spurred petal, and fig. 6 a stamen with the appendage from another bud; but neither the spur nor the nectary are now of any use. Fig. 7 is the pistil with its curved style, upon which the anthers are pressed. Fig. 8 shows the rudimentary petals of a wild cleistogamous bud of Violet. Fig. 9 is a stamen. Fig. 10 is the pistil, the ovary of which after fertilisation swells and elevates the stamens, which remain clinging to the summit. Fig. 11 is the pistil with the anthers removed, showing the curved style.

Viola tricolor has not cleistogamous buds, but self-fertilising "forms" instead. H. Müller has described one form.* Fig. 13 represents a form of var. *arvensis* which I found having a peculiar development of the placenta. It formed a pillar-like process, which rose up from the "throat" fig. 14 and protruded from the orifice in the globular "head." Pollen-tubes penetrated the centre of the pillar in abundance. Fig. 15 is another form, in which the placentiferous process was lengthened out over the "lip," and resembled a long tongue, which thus licked up the pollen from the calcarate petal.

POLYGALACEÆ.—*Polygala*, though clearly adapted to cross-fertilisation, is yet often self-fertilised. The anther cells grip the spoon-like process on either side, and pour their pollen into it; then the stigma becomes pollinated by bending back upon it according to Hildebrand, from whom fig. 17 is taken. In one form which I found, the anthers were on an exact level with the stigma, so that the pollen tubes were penetrating it from either side (fig. 18).

CARYOPHYLLACEÆ.—This order supplies many "weeds," and weeds are mostly self-fertilising. Fig. 19 represents a bud of *Spergula arvensis*, which remained quite closed (in January), but was seeding freely all the while. Fig. 20 is the same with the calyx and corolla removed. Chickweed behaves in the same way (fig. 21). Both of these, like Shepherd's-purse, will blossom and fruit all the year round as long as the weather wil'

* See "Nature," Nov. 20, 1873.

permit, but often without or scarcely opening their flowers in the winter months.

Malvaceæ.—Large-flowered species of this order are strongly proterandrous. Thus *Malva sylvestris* will have shed all its pollen before the stigmas are elevated; but *M. rotundifolia*, as Müller has shown, is self-fertile, by the stigmas maturing simultaneously with the anthers, and bending down to intertwine themselves amongst the latter (fig. 22). The curvature of the stigma to secure self-fertilisation is generally due to the more rapid growth of the pistil under confinement of the petals, so that the styles are forced back. This position is then retained on the expansion of the flower.

Linaceæ.—Though the genus *Linum* has species usually dimorphic and physiologically self-sterile, it must be understood that these conditions are not absolute and unchangeable. There is no reason for supposing they cannot be lost in any case, as indeed they often are in some. Thus the Clove Pink is strongly proterandrous, yet became self-fertilising in three generations with Mr. Darwin. *Linum perenne* was physiologically self-sterile with Mr. Darwin, yet Mr. Meehan has found an instance of its being quite self-fertile in America. *Linum catharticum* on the other hand is not dimorphic at all, and can be crossed or self-fertilised (fig. 23).

Geraniaceæ.—Our wild species of *Geranium* furnish interesting transitional conditions from the proterandrous state to the self-fertilising, the former being seen in large-flowering forms, as *G. pratense;* the latter in the smaller ones, as *G. pusillum.** The common garden *Pelargoniums* are usually proterandrous, often strongly so, as the "oak-leaved" or "lemon-scented;" but pale-flowered "scarlet-geraniums" (*P. zonale*) are perfectly self-fertilised by the stigmas being scarcely elevated above the anthers, and recurving amongst them (fig. 24).

Oxalis and *Impatiens* have cleistogamous flowers. Figs. 25–28 represent the former, and figs. 29–31 the latter.†

Leguminosæ.—The papilionaceous corolla is obviously adapted to intercrossing, and in some cases the flowers are morphologically self-sterile; but there are many small-flowered species which are self-fertilising (fig. 32).

Rosaceæ.—The remarks made about *Ranunculus*, which has many stamens like the Rosaceæ, apply to this latter order. Several small-flowered species, as *Potentilla Fragrariastrum*, retain the incurved position of the stamens; others, like *Agri-*

* For details, see Lubbock's "British Wild Flowers in relation to Insects," p. 43.

† For descriptions, see below, p. 13.

monia, spread them out on first opening, but bend them in again subsequently; while in others, though the outermost stamens may mature before the carpels, yet the inner will mature together with them, so that both intercrossing and self-fertilisation are possible.

ONAGRACEÆ.—*Epilobium angustifolium* and *hirsutum* are proterandrous, but the small-flowered species scarcely open their blossoms at all, and the pollen-tubes may be easily seen penetrating the stigmas from the grains within the anther-cells, which thus become "glued" to the stigmas. Figs. 34 and 35 represent the stamens and pistil of *Circœa lutetiana*. On first expanding, the anthers are close to the stigma, but they afterwards spread away as if adapting themselves for insect fertilisation. The stigma, however, has often become pollinated early, and is thus dragged to the side by sticking to the anther.

COMPOSITÆ.—Contrary to the general opinion, many of this order appear to be constantly self-fertilised. Fig. 36 shows how the stigmatic branches in the *Cichoraceœ* become strongly recurved so as to penetrate amongst the pollen-grains. Independently of that, however, some of the grains mostly fall into the "cleft." In Groundsel the stigmatic arms are often retained below, but separate, within the anther-tube, and so self-fertilisation is secured. Indeed the heads of this order constitute a sure way of securing seed, for the florets can impregnate one another, which is quite equivalent to self-fertilisation.

LABIATÆ.—This order, with its highly differentiated corolla, is obviously adapted to be intercrossed, but it has, like most, if not all others, self-fertilising species. Thus *Lamium amplexicaule* has cleistogamous flowers (fig. 37–39); while *Salvia clandestina* has its stigmas recurved between the anthers (figs. 40–42). *Prunella* (fig. 43) is also often self-fertilising.*

SCROPHULARIACEÆ furnishes several self-fertilisers, though of course, as in the Labiatæ, the great variations in the corollas are so many special adaptations to insects. Some genera, like *Euphrasia* and *Rhinanthus*, are dimorphic: one form with a larger corolla has the stigma thrust forward as in fig. 44, but the other and smaller flower has the stigma strongly recurved so as to reach the anthers (fig. 45). The common garden *Calceolaria* (fig. 46) is quite self-fertile, the stigma being in close conjunction with the anthers; but there are several species, such as *C. glutinosa* and *Pavonia*, forming the section "*Aposecos*" (see "Genera Plantarum," sub nom.), which have the anthers disjoined with a long connective between them, so that they oscillate exactly like the anthers of the genus *Salvia*.

PRIMULACEÆ.—The genus *Primula* has several species di-

* For descriptions, see below, p. 14.

morphic, but others, such as *P. scotica*, are not; and *Primula veris* and others which are usually dimorphic can become homomorphic, as in fig. 47, which is a short-styled form of the Primrose (according to the position of the anthers), but self-fertilising in consequence of the style having elongated. *Glaux maritima* (fig. 48) has the style often recurved so as to secure pollination.

PINGUICULACEÆ.—*P. lusitanica* is self-fertilising by the stigma being recurved and dipping into the two gaping anther-cells, as represented in fig. 51.

POLYGONACEÆ.— Conspicuously flowering species like the Buckwheat, which is dimorphic, and *P. Bistorta*, with pink flowers, are attractive to insects; but Müller has shown that *P. aviculare*, with its minute blossoms, and without honey-glands, is self-fertilising, while *P. Convolvulus* and *P. Hydropiper* appear to me to be habitually cleistogamous.

ALISMACEÆ.—The stamens of *Alisma Plantago* in the first stage of the flower are spread away as represented by the left-hand stamen in fig. 52, but subsequently they bend back; and, although the anthers are extrorse, they lie immediately over or among the stigmas, which are also bent towards them, as in the right hand of fig. 52.

ORCHIDACEÆ.—This order, as is so well known, is almost entirely dependent upon insect aid for fertilisation, yet the Bee Ophrys is self-fertilising, in consequence of the pollinia falling out of the anther-cells, and being retained by their glands, swing backwards and forwards, and so strike against the stigma (figs. 53 and 54). The other case mentioned by Mr. Darwin is *Cephalanthera* (fig. 55), of which he remarks:—" Whilst the flower is still in bud, or before it is as fully open as ever it becomes, the pollen-grains which rest against the upper sharp edge of the stigma (but not those in the upper or lower parts of the mass) emit a multitude of tubes, deeply penetrating the stigmatic tissue." *

COMMELYNACEÆ.—I have figured a case of self-fertilisation in *Tradescantia erecta*, which I found at Kew (fig. 56). It was late in the autumn of 1876, and none of the flower-buds expanded. The corolla in all cases withered within the bud, and several of the stamens were imperfect; the style was bent down beneath the shrivelled corolla, and was pollinated by one perfect stamen. The fruits set seed, which I subsequently grew.

GRAMINEÆ.—*Hordeum murinum*, as far as I am aware, is always cleistogamous. The filaments do not seem ever to escape from the closed glumes, but remain doubled or twisted back, so that the anthers lie in contact with the stigmas (fig. 57).

* "Fertilisation of Orchids," p. 106, 1st ed.

The preceding will be sufficient to prove that self-fertilisation is a great and wide-spread fact in the vegetable world; and that, so far as the plants themselves are concerned, they show no features which imply degeneracy of any kind. They are very abundant. Nearly all of our "most troublesome weeds" are habitually self-fertilising, and show no signs of extinction whatever. Their power of propagation is simply enormous.

Now arises the question as to what is the right interpretation of this fact. My idea is, that self-fertilisation is the legitimate or primeval condition of plants; that for the sole end of plant-life—propagation—extraneous aid is quite superfluous; and that plants have become adapted to insects, is, so to say, an accidental circumstance of no value at all, so far as the securing of a sufficient supply of seed is concerned; that the notion that plants *must* be crossed to be kept up is a wrong surmise, which is not really at all borne out even by Mr. Darwin's experiments.

Let us briefly review those results. One plant alone was cultivated for several years, *Ipomœa purpurea*, or the so-called *Convolvulus major.* On turning to page 53 of his work on "Cross and Self-fertilisation of Plants," the respective heights of the crossed and self-fertilised individuals will be seen exhibited in a tabular form. There is no steady increase in favour of the intercrossed, but a series of *maxima* and *minima.* On the other hand, *there is a steady decline in the heights of the crossed* when a series of averages are taken for every successive three years, a fact which Mr. Darwin does not seem to have observed. Although the actual heights of the intercrossed plants were in every year greater than those of the self-fertilised, yet the ratios taken as above proposed are as follows: For the first three years as 100 : 74·3; for the second three years as 100 : 77·6; and for the third three as 100 : 81·6. The interpretation of this can only be that while "crossing" imparted a stimulus to vegetative vigour, *it is not permanent*, but at the above rate of decrease the crossed plants would have become lowered in height, and be equal to the self-fertilised in a few more generations.*

With *Mimulus luteus* a strong self-fertilising form arose under Mr. Darwin's cultivation, so that it was quite useless to continue the experiment after seven generations, as the self-fertilised form entirely surpassed the intercrossed.

As it was with the heights so was it with fertility. The advantages gained at first were not apparent after a few generations, and the self-fertilised, then, beat their opponents.†

* 100 is the assumed standard for the intercrossed; the ratios, therefore, appear to show a steady improvement in the self-fertilized.

† For arguments and statistics I must again refer the reader to my original paper (*l.c.*).

Mr. Darwin did not cultivate any other plants sufficiently long to enable one to test the results of the permanency of the effects of crossing; but what I wish to point out is that we must not confound permanent morphological characters obtained by crossing with any physiological benefit necessarily and much less permanently resulting from it. Mr. A. Knight's varieties of peas obtained by crossing may have retained their morphological characters by which they were known in the market for sixty or more years; but to imagine that their longevity was due to the fact of crossing, is an assumption based upon no proof whatever. Mr. Darwin's experiments appear to me to prove the exact contrary, for in no case does he show that the physiological effects are more than transitory, even when the offspring are fresh crossed every year; while, on the other hand, Mr. Knight's peas were actually propagated for sixty years by self-fertilisation alone.

The reader will now ask, "What, then, is the good of crossing at all?" I reply, as far as the sole object of plant-life is concerned—that is, an abundance of seed—that the species may survive in the struggle for life, *there is no good at all*, and that self-fertilisation is the best and most certain method. And if it be asked why there are so many adaptations to insects, I reply that I believe it was an inevitable response to the irritation caused by the insects themselves. Moreover, insects often do more harm than good, when they discover that they can secure the honey by illegitimately perforating the corolla tube from without.

I believe that plants would never have had conspicuous perianths at all if insects had not visited them; but by causing a continual flow of nutrition to the external whorls, in consequence of their sucking away the juices, hypertrophy has set in, and the result is that *Man*, but not the plant, has gained the benefit, for he can appreciate the innumerable beautiful forms, colours, and scents, which so many flowers now possess. This result, however, is occasionally *at a sacrifice to the plant itself*, in that it has in some cases, but in the minority, lost the power of self-fertilisation; and, consequently, if a plant be an annual or biennial, and be not visited, it must succumb in the struggle for life, and so perish altogether. Self-fertilising plants are mostly annuals and small; both features being of great advantage in maintaining their continued existence. The rapidity of maturation and shedding of seed is perfectly astounding, generation after generation being produced in a few weeks, while the absolute amount of seeds produced is quite incalculable.

Lastly, the self-fertilised plants are the only ones, as a rule, which are cosmopolitan. I must refer the reader to my paper in the "Linnæan Transactions" for detailed lists of localities where our weeds, such as Chickweed, Shepherd's-purse, *Lepidium ruderale*, *Malva rotundifolia*, *Solanum nigrum*, etc., etc., have established themselves ; and the inference I draw is, that assuming other plants to have travelled with them, those which were entirely dependent upon insects have perished, as they were not visited ; while those that were independent, as being capable of self-fertilisation, were the best fitted to survive in the struggle for life.

The conclusion I have arrived at is that self-fertilisation is the aim of plant-life, so far as propagation is concerned ; that the existence of sexes enables a plant to diffuse itself by the production of independent offspring (seeds) far more readily and abundantly than by bulbs, and other vegetable offshoots; and that the chance of crossing is thus secured which induces variation in the offspring with greater rapidity than would spontaneously take place under self-fertilisation alone.

The cross may bring with it some new physiological peculiarities, which impart a temporary stimulus to vegetative vigour ; but there is nothing to prove that this effect is of permanent value. I believe that by the local irritation induced by insects, all the vast diversity of beauty of form, and marvellous adaptations have been effected ; but that this last, though vastly enhancing nature from the human point of view, is of no real value, but is often a detriment to the plant itself. Hence I regard self-fertilisation as being proved to be the best condition in plant-life, to enable a species to maintain its existence in the great struggle for life in the world.

DESCRIPTION OF PLATE I.

FIG. 1. Pistil of *Capsella Bursa-pastoris* to show the capitate form of stigma characteristic of self-fertilising *Cruciferæ*.

„ 2. The stigmas of *Fumaria officinalis ;* one of them is covered with pollen-grains.

„ 3. One of the groups of anthers, which form a three-sided chamber in which the horn-like stigmas lie and are thus directly pollinated.

„ 4. Bud of a cleistogamous Violet with the calyx removed, from a strong-growing garden plant.

„ 5. A spurred petal from another bud.

„ 6. A stamen retaining the nectariferous appendage, from the same.

„ 7. Pistil from the same, with curved style.

„ 8. Rudimentary petals of a cleistogamous bud of a wild form of Violet.

„ 9. Stamen from same.

„ 10. Pistil with the anthers coherent above, having been detached and elevated by the swelling of the ovary.

„ 11. Pistil with anthers removed.

Fig. 12. *Viola tricolor.* The corolla has withered, so that the spurred petal has pressed the pollen into the orifice, and has remained clinging to it. Both the petal and stamens have become elevated by the growth of the ovary.

„ 13. This represents the style and globular stigmatic "head" of a self-fertilising form of *V. tricolor* var. *arvensis,* in which the placentiferous tissue had grown up like a pillar and protruded from the orifice in the form of a knob. Pollen tubes were penetrating the centre of the pillar in abundance.

„ 14. Vertical section of the preceding.

„ 15. Another self-fertilising adaptation, in which the placenta had grown over the "lip," and was prolonged into a kind of tongue which thus "licked" up the pollen from the spurred petal.

„ 16. Apex of pistil and stamens of *Polygala vulgaris.* The anthers are emptying themselves of pollen into the spoon-shaped extremity of the style.

„ 17 (after Hildebrand). The stigma is seen to become pollinated by bending back into the pollen.

„ 18. A form in which the anthers are on a level with the stigma, into which abundance of pollen-tubes had penetrated.

„ 19. A self-fertilising bud of *Spergula arvensis* (Jan. 1874).

„ 20. Same with calyx and corolla removed.

„ 21. A flower of Chickweed. This, as also the *Spergula,* has the number of stamens reduced to three.

„ 22. The stigmas of *Malva rotundifolia* represented as recurved amongst the anthers, and becoming self-fertilised.

„ 23. Stamens and pistil of *Linum catharticum.*

„ 24. Stamens and stigmas of *Pelargonium zonale.* The stigmas are recurved amongst the anthers and becoming pollinated by them.

„ 25. Cleistogamous flower-bud of *Oxalis Acetosella.*

„ 26. Calyptriform corolla of the same.

„ 27. Anthers of same united together by filamentous processes. (It is not quite clear what these are, but probably *not* pollen-tubes.)

„ 28. Pistil of same, with anthers of two of the latter stamens in contact with the short stigmas. The lower anthers are partly aborted, two filaments only represented.

„ 29. Cleistogamous flower-bud of *Impatiens fulva.*

„ 30. Same with calyx and corolla partly detached from the pistil (after Bennett).

„ 31. Stamens of same.

„ 32. Stamens and pistil of small-flowered leguminous plant, such as *Medicago denticulata,* the ten anthers being clustered round the stigma, both maturing together.

„ 33. A stamen and a flower of *Agrimonia,* the corolla removed, with stamens incurved, some time after expansion.

„ 34. First stage of *Circæa lutetiana* on expansion. The anthers are close to the stigma.

„ 35. The second stage of the same, the anthers now spread away. The stigma having been pollinated, is drawn to one side by mechanical adhesion to the anther.

FIG. 36. Anther-tube and recurved stigmas, characteristic of the tribe *Cichoraceæ* of *Compositæ*.

„ 37. Cleistogamous flower-bud of *Lamium amplexicaule*.

„ 38. Vertical section of the same, showing the stigmas lying between the anthers.

„ 39. The pistil removed to show how the style has become bent under constriction of the corolla.

„ 40. Corolla of *Salvia clandestina*. The essential organs are quite invisible.

„ 41. Stamens of the same. The anthers stand edgeways, so that the lines of dehiscence face each other.

„ 42. The styles removed. In one, the very long stigmas are unrolled artificially.

„ 43. Stamens and stigmas of *Prunella vulgaris*. The posterior branch is being pollinated.

„ 44. Two stamens and pistil of *Rhinanthus Crista-galli* var. *major*, adapted for intercrossing by the stigma being protruded.

„ 45. Two stamens and pistil of same, var. *minor*, adapted for self-fertilisation by the stigma being reflexed.

„ 46. Stamens and pistil of the garden variety of *Calceolaria*.

„ 47. Homomorphic form of Primrose, which produced plenty of good seed.

„ 48. Flower of *Glaux maritima*, with the stigma recurved to secure self-fertilisation.

„ 49. Side view, and

„ 50. Front view of the pistil of *Pinguicula lusitanica*.

„ 51. Pistil and the two stamens of same. The stigma is inserted into the anther-cells.

„ 52. Two stamens and one carpel of *Alisma Plantago*. One stamen is spreading as for intercrossing; the other is reflexed, a subsequent condition, for self-fertilisation.

„ 53. *Ophrys apifera*, showing the pollinia falling from the anther-cells in the position for striking against the stigmatic surface.

„ 54. Pollinium removed, showing the bend in the caulicle.

„ 55. Stigma and pollinium of *Cephalanthera*.

„ 56. Self-fertilising flower-bud of *Tradescantia erecta*. The withered corolla is partially removed, the calyx not being represented. The stigma is being pollinated by the one perfect anther. The rest are aborted.

57. Stamens and pistil of *Hordeum murinum* as they occur in the permanently closed florets.