accessions of moisture that take place, by which this high ice-cold region of the atmosphere over a great extent and thickness, is brought to the point of saturation and condensation. Underneath this leaden-hued mass of cloud which uniformly covers the sky, but separated from it by a clear space, is extended the dense cloud covering of the *pallio-cumulus*, which is formed by the watery vapour of the atmosphere reduced to the points of condensation and precipitation. This is the true *rain-cloud*, and it is fed and increased by the rapid drifting in from below of torn masses of cumulus constituting the *fracto-cumulus* or *wind-cloud*. The fracto-cumulus may be of all sizes, has no determinate shape, is the lowest and swiftest moving of the clouds, and is whitish, greyish, or slate-coloured, as may be determined by the hygrometric condition of the air. On the return of fine weather accessions of vapour by the fracto-cumulus slacken and then cease, the pallio-cumulus diminishes in thickness and gradually clears away, showing through its intervals the pallio-cirrus above it, which in its turn is broken up, revealing still higher up the delicate tracery of the cirrus. The pallio-cirrus is negatively electrical, whilst the pallio-cumulus is positively electrical, the clear stratum between being neutral; and between these oppositely electrified strata, discharges frequently take place in thunderstorms.

The merits of Prof. Poey's work are very considerable, whether they be regarded as expository of Howard, or as a contribution to this difficult branch of meteorology; and it is just those meteorologists who have paid particular attention to the observation of the clouds who will be readiest to recognise its merits. It must, however, be conceded that, as a descriptive classification of clouds, as well as explanatory of the phenomena they present, Prof. Poey's work leaves the subject in a state still too incomplete to warrant us in recommending his system for general introduction. It is a step in the right direction, and will materially contribute to place this vitally important department of atmospheric physics on a satisfactory footing.

Toward this end, what is now urgently wanted is an extensive collection of the data of cloud-phenomena in all countries, particularly of those clouds interesting in themselves or from their known relations to weather changes. We have more than enough of unmistakeably pure typical forms scattered through the pages of weather-literature, but such do not greatly assist us. in describing and classifying many of the forms of clouds which occur. Hence what is required is faithfully accurate delineations of these forms in their different aspects, and systematic inquiries set on foot into the relations of the forms of clouds to the mode of their formation, to the states of the aqueous vapour which compose them, and to the varying elasticity, temperature, and electricity of the atmosphere.

In connection with this part of the subject, Prof. Poey investigated in 1862-64, by means of the thermo-electric pile, the temperature of different parts of the sky under different conditions, and of the clouds which passed across it. Among other highly interesting results, he has shown that the cumulus, properly so called, and the cumulo-stratus of summer are the clouds of highest temperature; then follows the fracto-cumulus, except when it comes after the rain which accompanies a thunderstorm, in which case it is of a whitish colour, very rapid in its motion, much torn at the edges, and partakes of the low temperature prevailing on such occasions. The cirro-cumulus is colder than the cumulus and the cirrus the coldest of all the clouds. These are very suggestive results. We are convinced that the key to the position in meteorology is a better knowledge of the vapour of the atmosphere in its various states and changes; and the science will not make the advances it is destined to make till meteorologists generally recognise the necessity of equipping their first-class observatories with the requisite appliances for carrying on those physical researches which are intimately allied to meteorology.

FERTILISATION OF FLOWERS BY INSECTS

V.

More conspicuous flowers adapted to cross-fertilisation, and less conspicuous ones adapted to self-fertilisation, occurring in different species of the same genus.

WHAT has been described in the two last articles as occurring in varieties of the same species (using the term "species" in its widest sense) we propose now to investigate as existing likewise in species of the same genus.

Malva sylvestris and *rotundifolia*

are two closely allied, but, as acknowledged by all botanists, undoubtedly good and distinct species, differing in their flowers in a manner similar to the two varieties of *Lysimachia vulgaris* and the other species previously considered. In both these species of Malva an oval mass of anthers in the first place occupies the middle of the flower, enclosing the stigmatic branches as yet undeveloped and lying close together (Fig. 23). At a later period the stigmatic branches, growing out of and overtopping the mass of anthers, spread and bend outwards and downwards so as to occupy nearly the same place as was before occupied by the anthers (Figs. 24, 25). Insects, therefore, seeking for the honey which is secreted and contained in five cavities between the lowest parts of the petals (*n*, Fig. 23) and covered by a fringe of hairs (*pr*), carry away on their hairy bodies the large prickly pollen-grains from younger flowers, leaving many of them on the stigmatic papillæ of the branches of the style of older flowers, which they can scarcely avoid grazing in seeking for the honey. Hence, in both species, whenever insects frequently visit these flowers, cross-fertilisation in the manner described is largely effected, whereas self-fertilisation can scarcely take place, neither spontaneously nor by means of insects, nearly all the pollen-grains having been removed before the unfolding of the stigmatic branches. Since, however, *Malva sylvestris* and *rotundifolia* grow for the most part in the same locality, and flower during several months at the same time, insects flying about and seeking for honey are much more likely to find out and visit the highly conspicuous flowers of *M. sylvestris* than the far less conspicuous ones of *M. rotundifolia*; the former, when fully opened, presenting bright rose-coloured bells of from 40 to 50 mm. diameter, the latter, on the contrary, light rose-coloured bells of only from 20 to 25 mm.

Direct observation, indeed, fully confirms this supposition, the flowers of *M. sylvestris* being always found in sunny weather visited by a variety of insects, whereas those of *M. rotundifolia*, especially when growing intermixed with *M. sylvestris*, are commonly overlooked by them all. Thus, during the six last summers, I have observed on the flowers of *M. sylvestris* and collected more than 50 species of insects, many of them very frequently (2 Lepidoptera, 3 Diptera, 5 Coleoptera, 40 Apidæ, some Ichneumonidæ); while in the same space of time I found on the flowers of *M. rotundifolia* but 5 species (4 Apidæ, 1 Hemipter), and those only in single or a few cases.

It is evident from these facts, that wherever our two species of Malva grow together in the same locality, *M. rotundifolia* would be rapidly extinguished, unless it were enabled to produce seed by self-fertilisation; *M. sylvestris*, on the other hand, is so commonly visited and cross-fertilised by insects that self-fertilisation, if it were possible, would never be effected, or only exceptionally. Accordingly natural selection must have preserved and accumulated those slight individual variations of *M. rotundifolia*, which afford facility for self-fertilisation, whereas in *M. sylvestris* the possibility of self-fertilisation being quite useless, might be lost, and, indeed, has been, completely or nearly lost. Thus in the flowers of *M. sylvestris*, when precluded from the visits of insects by covering them with a net, the anthers remain filled with pollen-grains, and never, or only exceptionally, come spontaneously into contact with the stigmatic branches, the free ends of their filaments at a later period bending downwards, and the branches of the styles remaining considerably above them (Fig. 24). Conversely in the flowers of *M. rotundifolia*, when the visits of insects are prevented, the anthers, filled with pollen-grains, remain in so high a position, and the stigmatic branches bend so far downwards as to come abundantly into contact with the pollen-grains, self-fertilisation being thus inevitable (Fig. 26).

Epilobium angustifolium and *parviflorum*

differ most strikingly in a similar manner. The flower of *E. angustifolium*, being of larger size, brighter colour, grouped in long splendid clusters, and exciting attention at a great distance, are so largely visited and cross-fertilised by insects* as never to have need of self-fertilisation, which has actually become impossible; the four stigmatic branches unfolding so long after the maturity of the eight anthers, and so far overtopping them, as to be completely shut out from the pollen of the same flower. The flowers of *E. parviflorum*, on the other hand, being of smaller size, lighter colour, and single, are so inconspicuous that insects but very rarely visit them. Accordingly, its four upper anthers so closely surround the four-lobed stigma, which is mature at the same time, as to cover it largely with their pollen, whilst the pollen-grains of the four lower anthers lying on the way to the honey, cannot reach the stigma of the same or of another flower unless transferred by insects.

Polygonum

Among the many species of the genus Polygonum which grow in our country there are two, *P. Fagopyrum* and *Bistorta*, most distinguished by their attractiveness for insects, which is due not only to the size and colour of the single flowers and to their collection into handsome spikes, but also, and even more perhaps, to their abundance of honey secreted by eight globular nectaries at the base of the filaments (n_1 Figs. 26, 27). With reference also to the frequent visits paid them by insects,† these two species have been adapted to inevitable cross-fertilisation by their visitors, self-fertilisation having at the same time become difficult or almost impossible. The manner in which this advantage has been attained being very different in the two species, it is evident that in this case the adaptation to cross-fertilisation by the visits of insects cannot have been inherited from the common parents of the genus, but must have been acquired by the single species during their evolution.

P. Fagopyrum has acquired, as shown in Figs. 26 and 27, the same kind of dimorphism which has been so fully explained by Darwin in Primula‡ and Linum.§ In both of the two kinds of flowers (which occur only on different plants) there are three styles and eight stamens, three of the stamens closely surrounding the styles and opening outwards, the five others inserted more outwards, alternating with the leaves of the perianth and opening inwards. An insect, therefore, visiting a flower for honey and pushing its head or proboscis between the inner and outer stamens into the base of the flower, cannot avoid being charged with pollen, especially in those parts of its body which, whilst it is sucking the honey, are pressed against the anthers. Now, the place occupied in one of the two kinds of flowers by the anthers, is occupied in the other kind by the stigmas, the same parts of the body of the insect which in the long-styled form were pressed against the anthers, come into contact in the short-styled with the stigmas, and conversely. Thus it is inevitable that insects effect chiefly what is called legitimate fertilisation, *i.e.* transmission of the pollen of the long-styled flowers to the stigmas of the short-styled, and of the pollen of the short-styled to the stigmas of the long-styled form. Fertilisation by pollen of the same form, however, and even of the same flower, is not impossible, and in the short-styled flowers even spontaneous self-fertilisation may happen, by pollen-grains falling down from the anthers upon the stigmas.

The same advantage which *P. Fagopyrum* has attained by dimorphism (Darwin) or heterostyly (Hildebrand), has been gained in the flowers of *P. Bistorta* by protandrous dichogamy, *i.e.* by the anthers so far preceding in their development the stigmas that in the first period of the flower (Fig. 28) only mature anthers, at a later period (Fig. 29) only mature stigmas are present, the anthers having then commonly fallen off. It is readily seen that such flowers also, when perseveringly visited by insects, are always inevitably intercrossed, no other mode of the transmission of pollen being possible than from younger flowers to the stigmas of older ones. It is only when the visits of insects are completely wanting during the first period and the anthers remain clothed with pollen while the stigmas attain their maturity, that self-fertilisation by insects or even spontaneous self-fertilisation is possible.

The least attractiveness for insects, on the contrary, among all native species of Polygonum is possessed by *P. aviculare*, its flowers (Figs. 30 and 31) being of small size, of greenish and white or reddish colour, standing singly on procumbent plants and offering only a small quantity of pollen to insects, but, as far as I have been able to see, no honey. No wonder that insects are induced only in very rare cases to visit and fertilise them,* and that, in compensation for the loss of cross-fertilisation, these little flowers regularly experience spontaneous self-fertilisation, the three inner anthers lying so close to the stigmas that their pollen-grains inevitably come into contact with them (Figs. 30 and 31).

Of the many other native species of Polygonum, which are all intermediate, as to their attractiveness for insects, between those now described, I will only remark briefly upon *P. Persicaria*, which is of more especial interest because of its flowers presenting great differences of structure. In this species, instead of eight nectaries there are only five developed, and these secrete a much smaller quantity of honey than those of *P. Fagopyrum* and *Bistorta*. Its spikes of flower, moreover, being less conspicuous than in those species, the visits of insects are somewhat rare, even in sunny weather, although far more frequent than in *P. aviculare*.† Fertilisation by insects, consequently, is by no means secured. Corresponding to this uncertain agency of insects the sexual organs of the flower are in a remarkably fluctuating condition, undecided, as it were, between adaptation to cross-fertilisation by the visits of insects, and to self-fertilisation. Thus, of the eight stamens, sometimes only the five outer ones are developed, the three others being reduced to rudimentary filaments; and this condition is apparently the most favourable to cross-fertilisation, as any honey-seeking insect must touch the anthers in every flower with one side of its proboscis, the stigma with the opposite side, to which it thus cannot fail to transfer pollen-grains

* On the flowers of *Epilobium angustifolium* I have hitherto observed 26 species of insects, 14 of them belonging to the family of bees, many of them very frequently; on those of *E. parviflorum* I found only once Meligethes, and once a butterfly (*Pieris rapæ* L.) repeatedly sucking the honey of its flowers.

† On the flowers of *P. Fagopyrum* I have observed 41 species of insects, among them 21 Diptera and 12 Apidæ; on the flowers of *P. Bistorta* 18 species of insects, among them 9 Diptera and 3 Apidæ; many of the visitors of each species very frequently.

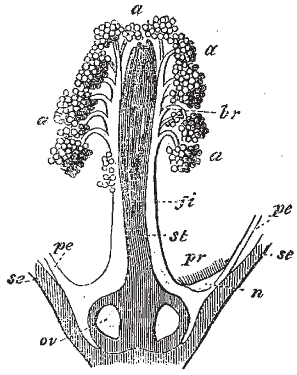
‡ On the two forms or dimorphic condition in the species of Primula and their remarkable sexual relations (Proc. of the Linn. Soc. vi. (1862); Bot. pp. 77–79.

§ On the existence of two forms and their reciprocal sexual relation in several species of the genus Linum, Ibid. 1863, pp. 69–83.

* After having repeatedly in vain watched *P. aviculare* in very hot sunny noons of the month of August 1871, I succeeded in observing some small Syrphidæ (*Ascia podagrica* F., *Syritta pipiens* L., and *Melithreptus menthastri* L.) visiting its flowers.

† I have observed in the flowers of *P. Persicaria* altogether 11 species of insects, among them 7 Diptera, and these as the most frequent visitors.

from the flowers previously visited. Sometimes, also, the three inner anthers are developed, and, completely filled with pollen, closely surround and spontaneously self-fertilise the two (in rarer cases three) stigmas, cross-fertilisation being thus almost prevented. But most of the flowers show an intermediate condition, having only one or two of the three inner anthers developed.



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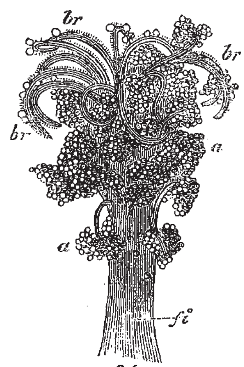

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FIG. 23.—Sexual organs of *Malva rotundifolia*, in their first period, longitudinally bisected, seven times natural size. *a*, anthers; *br*, branches of the style (*st*); *pe*, petals; *n*, nectary; *pr*, protecting hairs; *se*, sepals; *ov*, ovary; *fi*, filament-cylinder.
FIG. 24.—Side view of the same organs in their second period.

Without referring to many other genera which I have ascertained to contain species quite analogous to those just described,* we may, I think, admit as a summary of the recorded facts, the following propositions:—In many species the flowers vary and have always varied in size, colour, the quantity of secreted honey, and consequently in their attractiveness for insects. Whenever in such a varying species the one variety possesses such a degree of attractiveness for insects as to receive sufficiently frequent visits from them, those variations which afford

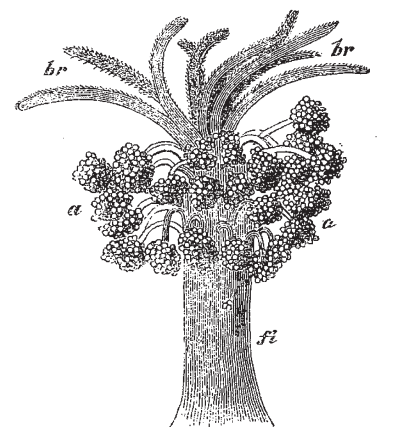

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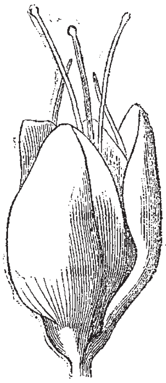
FIG. 25.—Side view of the sexual organs of *M. sylvestris*, seven times natural size.

facility for cross-fertilisation by insects have always been preserved and accumulated by natural selection, whereas the possibility of self-fertilisation has at the same time frequently been lost. Hence we may infer that cross-fertilisation is more advantageous to a plant than self-



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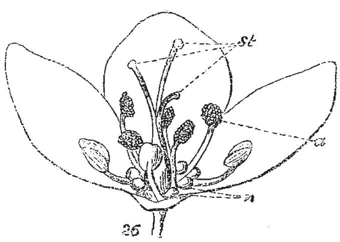

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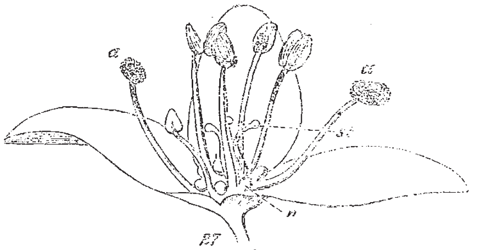

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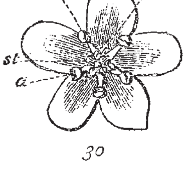
FIG. 26.—Side view of the long-styled flower of *Polygonum Fagopyrum*, two leaves of the perianth having been removed. *n*, nectaries; *a*, anthers; *st*, stigmas. FIG. 27.—Side view of the short-styled flower. FIG. 28.—Side view of the flower of *Polygonum Bistorta* in its first period. FIG. 29.—Side view in its second period.

fertilisation. Whenever, on the contrary, another variety of the same species presents so little attraction for insects as to remain commonly overlooked by them, only



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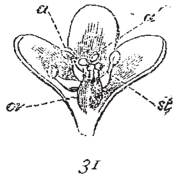

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FIG. 30.—Flower of *Polygonum aviculare* viewed from above. *a*, outer anthers; *a'*, inner anthers; *st*, stigmas. FIG. 31.—The same flower viewed laterally, two leaves of the perianth having been removed.

such individual peculiarities as induce self-fertilisation have been preserved and accumulated by natural selection, whereas cross-fertilisation by insects has frequently become very difficult, although perhaps never quite impossible. Hence we may infer that self-fertilisation is by no means absolutely disadvantageous to a plant, but only when the offspring of self-fertilisation has to struggle for existence with the offspring of cross-fertilisation.

There is another curious point about the recorded facts. We have seen that more and less attractive flowers adapted to cross- or to self-fertilisation sometimes occur in slightly differing, sometimes in well-marked varieties, sometimes in doubtful, sometimes in good and distinct species.

If we believe the principle of evolution, and view species as originated from varieties, varieties as originated from slight individual differences, we may consider the recorded facts as presenting and explaining one of the many ways in which previously varying forms have been transformed by natural selection into different and diverging species.

HERMANN MULLER

* Geranium, Stellaria, Cerastium, Rubus, Veronica, Carduus, Hieracium, and others.