FERTILISATION OF FLOWERS BY INSECTS[1]

XV.

Alpine Species of Gentiana.

IN previous articles I have attempted to show that in the Alpine region Lepidoptera are relatively much more frequent visitors and fertilisers of flowers than in the plain and lower mountain region; and that, in connection with this fact, in the Alpine region certain flowers are found adapted to cross-fertilisation by butter-

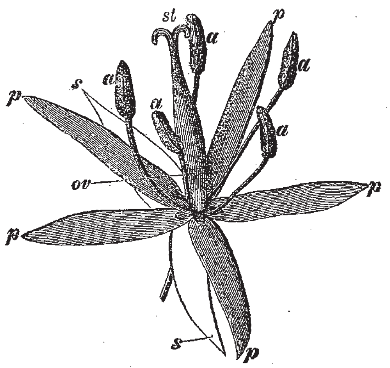

Fig. 94.

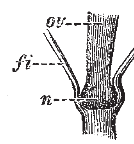

Fig. 95.

Figs. 94, 95.—*Gentiana lutea*, L.—Fig. 94.—Whole flower, a little magnified, seen obliquely from above. Fig 95.—Undermost portion of the ovary, showing the nectary and two filaments.[2]

flies and moths, the nearest allied of which, inhabiting the plain or lower mountain region, are adapted to cross-fertilisation by bees. As a further confirmation of this statement, we may consider the genus Gentiana, which, besides some species inhabiting the plain and lower mountain region, includes various beautiful Alpine forms. The former, *G. cruciata*, *G. pneumonanthe*, and *G. ciliata*,[3] are all adapted to cross-fertilisation by larger Apidæ, chiefly by humble-bees, whereas in the Alpine region, besides many species adapted to humble-bees and one accessible to insects of all orders, there are also numerous species adapted to Lepidoptera.

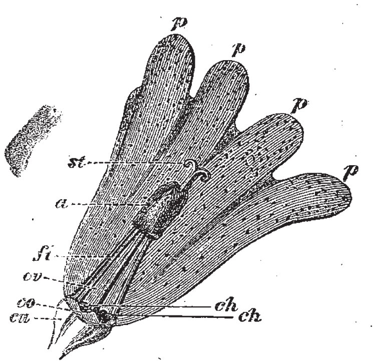

Fig. 96.

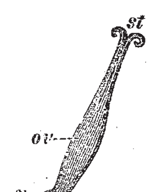

Fig. 97.

Figs. 96, 97.—*Gentiana punctata*, L.—Fig. 96.—Flower in its natural position (nearly $1\frac{1}{2}:1$), the anterior part of the corolla having been removed, as far as the filaments, which are not united with it. Fig. 97.—Pistil of the same flower.

It may be worth while considering by what modifications of structure the adaptation of one and the same genus to such different visitors has been effected.

1. *Alpine Species of Gentiana accessible to Insects of all Orders.*—By far the most simple structure of flowers among all the Gentianæ is to be found in *G. lutea* (Figs. 94, 95), which may therefore perhaps be considered as the nearest allied to the common ancestor of the whole genus. Its flowers are perfectly open; the anthers and stigma are developed simultaneously, and in some flowers one of the anthers is found in contact with the stigma, so that self-fertilisation is by no means excluded. The honey—being secreted by an annular swelling of the base of the pistil (*n*, Fig. 95) so copiously that a large drop of it completely covers the excavated base at each of the five

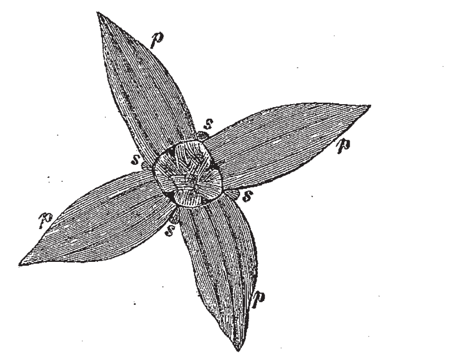

Fig. 98.

Figs. 98-102.—*Gentiana tenella*, Rottb. (*glacialis*, Thom.).—Fig. 98.—Flower seen from above ($3\frac{1}{2}:1$). Fig. 99.—The middle part of the same flower (7 : 1). Fig. 100.—Lateral view of the same flower ($3\frac{1}{2}:1$). Fig. 101.—A piece of the corolla with the adherent filaments and nectaries. Fig. 102.—Flower bisected longitudinally ($3\frac{1}{2}:1$).

petals and touches the two neighbouring filaments—is visible and accessible to flying insects of all orders, whilst ants and other insects creeping to the flowers are frequently prevented from gaining the honey by the basal lobes of the opposite leaves uniting round the stem, so as to form a kind of basin in which rain-water is collected.[1]

The splendid yellow colour of the large flowers, which are grouped in numerous whorls round stems of more than a man's height, makes them more conspicuous than the flowers of any other species, and attracts plenty of various insects, which alight on these flowers for honey and for pollen.[2] Some of them alighting in the middle of the flower will first touch the stigma and dust it with pollen from previously-visited flowers, and thus effect cross-fertilisation. This, however, is by no means secured, and many flowers, in spite of numerous visits of insects, may remain quite unfertilised by them, so that the possibility

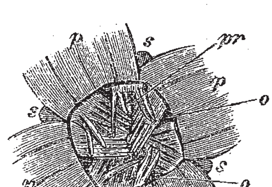

Fig. 99.

of self-fertilisation above alluded to is probably not useless to the plant.

2. *Alpine Species of Gentiana adapted to Humble-bees.*—

[1] Continued from vol xiv., p. 175.

[2] The following explanation of the lettering applies to all the figures:—*a* = anthers, *ca* = calyx, *ch* = channels conducting to the honey, *co* = corolla, *fi* = filaments, *n* = nectary, *o* = openings conducting to the honey, *ov* = ovary, *p* = petals, *pr* = protecting hairs (Sprengel's Saftdecke), *s* = sepals, *st* = stigma.

[3] *G campestris, germanica*, and *amarella*, inhabit the Alpine region, the mountain region, and the plain.

[1] See Kerner, *Die Schutzmittel der Blüthen gegen unberufene Gäste*. Wien, 1876, p. 207.

[2] Only once have I had the opportunity of watching *G. lutea*, in the Roseg Valley, near Pontresina, July 29, 1876. Here I found its flowers visited by Coleoptera: *Malthodes flavoguttatus*, some specimens; *Anthiophagus alpinus*, numerous specimens; *Epuraea aestiva*, in the largest number; Diptera: some species not yet known to me; Lepidoptera: *Agrotis ocellina*, pretty frequently, sucking; Hymenoptera: *Tenthredo* species (similar to *T. notha*), some specimens; *Anthiophora* spec., not yet known to me, some specimens; and once, *Bombus pratorum*, ☿, the last two both sucking and collecting pollen.

From flowers so simple as those of *G. lutea*, which openly offer their honey to all flying insects, but, in spite of their extraordinary conspicuousness, are incapable of securing cross-fertilisation by the various visitors, the genus Gentiana advances to such species as exclude from the honey the majority of the less industrious visitors, and at the same time compel the most industrious of the larger Apidæ, chiefly the humble-bees, to effect cross-fertilisation, whenever they fly from flower to flower. By what modifications of structure this improvement has been effected, may at once be seen in Fig. 96, which represents a flower of *Gentiana punctata*, longitudinally bisected from above to near the base. The petals, in *G. lutea*, nearly completely separated, are here united, and form an obliquely upright bell, wide enough to inclose the whole body of any humble-bee. The pistil, just as in *G. lutea*, stands exactly in the centre of the flower, and is terminated by two reflexed branches of the stigma, but the filaments, diverging in *G. lutea*, here incline together, so that the anthers, developing some time after the stigma, and dehiscing extrorsely, closely surround the pistil somewhat beneath the stigma. The honey being secreted, as in *G. lutea*, by an annular swelling at the base of the pistil (*n*, Fig. 97), every humble-bee is induced to creep towards the base of the bell-shaped corolla, and, when doing so, first touches the stigma and dusts it with pollen of previously-visited flowers, thus effecting cross-fertilisation; then with the same portion of its hairy body it touches the anthers and charges itself with fresh pollen. The exclusion of the majority of useless visitors from the honey is effected by the base of the corolla being constricted, and the base of the filaments united with it (as far as *ch*, Fig. 96); the narrow interstice between the ovary and the corolla being thus divided by the filaments into as many narrow channels as there are petals and filaments (in *G. punctata* commonly seven, in *G. acaulis*, *excisa*, and others five). By these narrow channels humble-bees may easily pass their proboscides as far as the honey, whereas saw-flies, flies, and most beetles are unable to reach the honey.

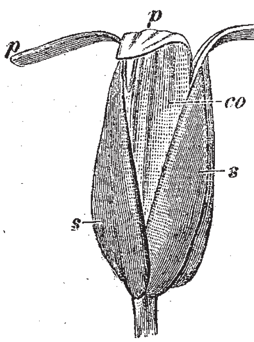

FIG. 100.

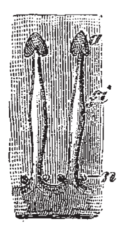

FIG. 101.

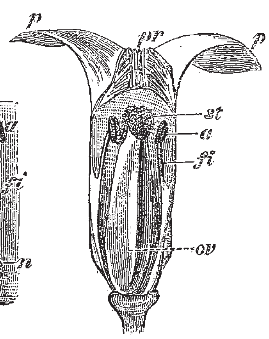

FIG. 102.

Thus the variety of visitors has been greatly diminished; but the humble-bees, for which alone the honey is reserved, are hence induced to make more eager and frequent visits; and, as by these visits not fortuitously, as in *G. lutea*, but regularly pollen is brought from one flower to the stigma of another, cross-fertilisation in the species of this group is far more certain than in *G. lutea;* and the possibility of self-fertilisation, indeed, seems to have been lost.

Of twenty-six species of Gentiana inhabiting Germany and Switzerland, eleven belong to the present group, which must almost necessarily be cross-fertilised by humble-bees; namely, besides the three above-mentioned species inhabiting the plain and lower mountain region, the following eight Alpine ones: *G. punctata*, *purpurea*, *pannonica*, *asclepiadea*, *Frœlichii*, *frigida*, *acaulis*, and *excisa*. But hitherto only three of these eleven species have been actually observed to be visited and cross-fertilised by humble-bees, namely, *G. acaulis*, by Ricca ("Atti della Soc. Ital. di Sc. Nat.," xiv. 3, 1871), *G. pneumonanthe* (H. Müller, "Befruchtung," p. 333), and *G. excisa*,[1] by myself.

3. *Alpine Species of Gentiana, adapted at the same time to Apidæ and to Lepidoptera.*—Whilst in the foregoing

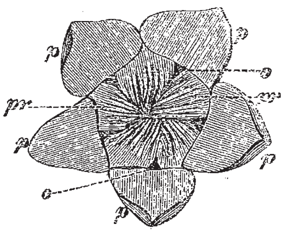

FIG. 103.

FIGS. 103-105.—*Gentiana nana*, Wulf.—FIG 103.—Flower seen from above (7 : 1). FIG. 104.—The same flower bisected longitudinally. FIG. 105.—A piece of the corolla, with petals, protecting hairs, stamens, and nectaries (7 : 1).

group Diptera and other useless visitors are prevented from gaining the honey by the base of the corolla being constricted and by the filaments dividing the interstice between the corolla and the ovary into narrow channels, in the present group (*G. tenella*, Fig. 98-102; *G. nana*, Fig. 103-105) the same effect has been attained by the entrance to the tubular corolla being barred by hairs (*pr* Fig. 98, 99, 102-105), between which only four or five small openings (*o*, Figs. 99, 103) are to be seen. The corolla, in the previous group wide enough to inclose the whole body of a humble-bee, is here so narrow that any proboscis attempting to reach the honey will graze the stigma and the anthers, and, when passing from flower to flower, will effect cross-fertilisation. But only Apidæ will be enabled to thrust their proboscides between the protecting hairs, and only Lepidoptera have proboscides slender enough to penetrate the small openings. Thus, in these flowers the visits of Lepidoptera are useful for the cross-fertilisation of the plant, while in the foregoing group they are useless.

Most probably the present group is not descended from the foregoing; besides the narrowness of the corolla and

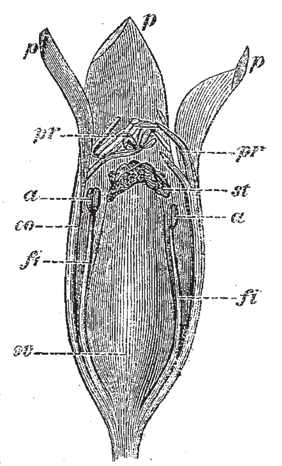

FIG. 104.

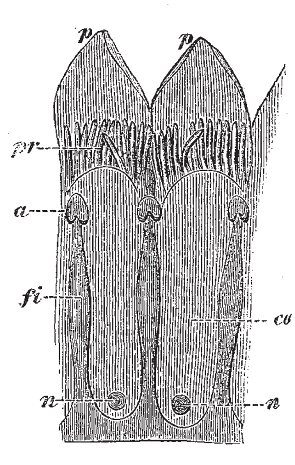

FIG. 105.

the protecting hairs, the position of the nectaries is so peculiar to this group, that it is rather to be considered

[1] I found, in the Alps, *G. excisa* visited and cross-fertilised by *Bombus lapponicus*, *F.*, and *B. mendax*, Gerst. Once, in the Albula Pass, July 28, 1876, I saw a moth, *Plusia hochenwarthi*, creeping into a flower and sucking its honey, but without touching stigma or anthers. Also some small Diptera and three specimens of a small beetle, *Haltica melanostoma*, Redt., can only be registered as useless guests.

as a separate branch, diverging from the common stem of the genus Gentiana, even before *G. lutea*. For whilst in all other species of Gentiana the honey is secreted by an annular swelling of the base of the pistil, in this group the nectaries are situated at the base of the corolla itself, between the filaments (*n*, Figs. 101, 105). As hitherto *G. tenella* and *G. nana* have been distinguished only by somewhat fluctuating characteristics, it may be of especial interest that in *G. tenella* I have found each interstice between two filaments to contain two nectaries (*n*, Fig. 101), in *G. nana* only a single one (*n*, Fig. 105).

To the same group belong *G. campestris*, *germanica*, *amarella*, and *obtusifolia*, two of which have been directly observed by myself to be visited both by Lepidoptera and butterflies. For instance, near Pontresina and in the Val del Fain, August 6-8, 1876, I saw *G. campestris* repeatedly visited by *Bombus mendax*, Gerst. ☿, but also by butterflies (*Argynnis pales*, *Hesperia serratulæ*, *Colias phicomone*, *Lycæna argus*).

The fourth group of Alpine species of Gentiana exclusively adapted to cross-fertilisation by Lepidoptera, will be treated of in my next article.

Lippstadt HERMANN MÜLLER

(*To be continued.*)

DEEP SEA MUDS[1]

DURING the present session I propose to lay before the Society several papers on subjects connected with the deposits which were found at the bottom of the oceans and seas visited by H.M.S. *Challenger* in the years 1872, 1873, 1874, 1875, and 1876.

Instruments in use for obtaining information of the deposits.

It will be convenient to introduce this first communication with a brief description of the instruments and methods employed on board H.M.S. *Challenger* with the view of obtaining information and specimens of these ocean deposits. The instrument in most frequent use was the tube or cylinder forming part of the sounding apparatus.

During the first six months of the cruise this cylinder was one having less than an inch bore, and was so arranged with respect to the weights or sinkers that it projected about six inches beneath them. The lower end of the cylinder was fitted with a common butterfly valve. This arrangement gave us a very small sample of the bottom.

In July, 1873, this small cylinder was replaced by one having a two-inch bore, and it was also made to project fully eighteen inches below the weights. This was a great improvement, as it gave a much greater quantity of the bottom in most soundings.

The tube was, in the clays, frequently forced nearly two feet into the bottom. On its return to the ship, the butterfly valves were removed, and a roll of the clay or mud, sometimes eighteen inches in length, could be forced from it. In this way we learned that the deeper layers were very frequently different from those occupying the surface.

In the organic oozes—as the Globigerina, Pteropod, Radiolarian, and Diatom oozes—the tube did not usually penetrate the bottom over six or seven inches, these deposits offering more resistance than the clays and muds. Occasionally the tube came up without anything in it, but the outside was marked with streaks of the black oxide of manganese. In about thirteen out of nearly four hundred soundings we did not get any information of a reliable nature about the deposit.

The dredge in use was a heavy modification of Ball's naturalist's dredge, and the trawl was the ordinary beam trawl of the fishermen.

Both of these instruments had generally a bag of canvas or other coarse cloth sewed into the bottom of the netting, to prevent the soft clay or ooze from being entirely washed out. In this way we, at many stations, got, along with animals, a large quantity of ooze, clay, stones, or manganese nodules.

While trawling or dredging the ship often shifted her position a mile or two, but we could not tell whether the dredge or trawl had been working over all that distance, or had merely taken a dip into the deposits. This should be remembered when comparing the captures in one locality with those of another.

Altogether there is much uncertainty about the behaviour of the trawl and dredge in deep water. It occasionally happened that when the greatest care was taken, and when it was believed that the trawl had been dragging for some hours, it came up without anything in it, or any evidence upon it or in the attached tow-nets to show that it had been on the bottom.

During the last year of the cruise a tow-net was attached to the dredging line just below the weights, which last were placed a few hundred fathoms in front of the trawl or dredge. Tow-nets were also attached to the trawl and dredge. These nets frequently came up nearly full of mud, and almost always contained minute things and fragments from the surface layers of the bottom.

At times the water-bottle attached to the sounding line came up with clay or ooze in it, or had some of the deposit adhering to its under-surface.

These then were the means and methods employed for getting information concerning ocean deposits, and collectively they have furnished us with a large amount of material. A careful examination of the specimens procured has already much increased our knowledge of the nature and distribution of ocean deposits, of the sources of the materials of which they are built up, and of the chemical processes taking place in the deep waters and on the floor of the ocean.

The Volcanic débris in Ocean Deposits and some of the Products of its Disintegration and Decomposition.

In a preliminary report to Prof. Wyville Thomson, which has been published in the *Proceedings* of the Royal Society of London, I pointed out the wide-spread distribution of volcanic *débris* in ocean deposits, and its probable influence in the formation of deep sea clays, and manganese nodules or depositions. In this paper I propose to treat of these subjects in more detail, and to give some of the results of observations which have been made since the above report was written.

Pumice-Stones.

The form of volcanic *débris* most frequently met with in ocean deposits is pumice stone.

Specimens of these stones, varying from the size of a pea to that of a foot-ball, have been taken in dredging at eighty of our stations. I have placed the position of these stations on a map, from which it will be seen that they occur all along our route.

Near volcanic centres the dredge has frequently brought them up in great numbers, as off the Azores in the Atlantic, off New Zealand and the Kermadec Islands, at several places among the Philippine Islands, off the coast of Japan, and elsewhere. As a rule, they are not numerous in shore deposits when these are distant from volcanic regions. In deposits far from land they are most abundant in deep sea clays, from which the shells and skeletons of surface organisms have been all or nearly all removed.

In the North Pacific the trawl brought up bushels of them from depths of 2,300 and 2,900 fathoms. Perhaps in no single instance have we trawled successfully on any of our deep sea clays without getting numbers of these stones. If there be an exception it is in the North Atlantic. But here it is to be remembered that while we were investigating the conditions of the North Atlantic, our attention had not yet been directed to the importance of detecting the presence of pumice, and we have not preserved such large samples of the North Atlantic deposits as those of other regions.

On the whole, pumice-stones are more numerous in the Pacific than in the Atlantic deposits.

In the Globigerina and other organic oozes, they are abundant or otherwise, according as the deposit is near or far removed from volcanoes. In these oozes they never occur so abundantly as in the clays. They are more or less masked and covered up by the accumulated remains of foraminifera, diatoms, or other surface organisms. In like manner they are obscured in shore deposits by river and coast detritus. Besides those specimens, which are sufficiently large to be examined by the hand, we detected with the microscope minute particles of feldspar in all our ocean deposits.

An inspection of the specimens which I have placed on the table will show that the majority of these pumice stones have a rolled appearance. Some of them have undergone much decom-

[1] "On the Distribution of Volcanic Débris over the Floor of the Ocean; its Character, Source, and some of the Products of its Disintegration and Decomposition," by Mr. John Murray. Read at the Royal Society, Edinburgh.