sodium, each worked out to a point, are placed on the pads of filter paper. From each of the troughs a wire passes to a key so as to enable the experimenter to stop the current at pleasure, and from thence the current passes to the galvanometer. They then lay the eye on a glass support between the cushions, and carefully adjust the clay-points so that the one touches the cornea and the other the transverse section of the optic nerve, or the one may touch the surface of the nerve and the other its transverse section. On opening the key, a deflection of the galvanometer needle is at once obtained to the extent of about 600° of the galvanometer scale, placed at a distance from the mirror of the galvanometer of about 26 inches. This deflection is a measure of the natural electro-motive force of the eye. The troughs are now covered over with an apparatus consisting of a double shell made of glass, and containing between the walls one inch of water so as to absorb all heat rays, and lastly a wooden box is placed over the whole, having a draw-shutter so as to enable the experimenter to admit light at pleasure. A gas flame is placed before the shutter. The arrangement is now complete. After observing that the deflection indicating the electro-motive force in the dark is constant, the shutter is now withdrawn so as to admit light. At that instant, that is, on the impact of light, a change is perceived in the electro-motive force. There is at first an increase, then a diminution, and on the removal of light there is another increase of the electro-motive force. Occasionally, in consequence of the dying of the nerve, there is only a slight increase, then a diminution, but the rise on the removal of light is always constant. The amount of change in the electro-motive force by the action of light is about 3 per cent. of the total. There has been no difficulty in demonstrating the effect in the eyes of the following animals, after removal from the body: *Reptiles*, Snake; *Amphibia*, Frog, Toad, Newt; *Fishes*, Gold Fish, Stickleback, Rockling; *Crustacea*, Crab, Swimming Crab, Spider Crab, Lobster, Hermit Crab. The greatest effect was observed in the case of the lobster, in the eye of which Messrs. Dewar and McKendrick found a modification in the electro-motive force by the action of light to the extent of about ten per cent. With the eyes of birds and mammals they had great difficulty. It is well known that in these animals the great source of nervous power is an abundant supply of healthy blood. Without this, nervous action is soon arrested. This law, of course, holds good for the retina and optic nerve. When, therefore, they removed the eye-ball with nerve attached, from the orbit of a cat or rabbit recently killed, and placed it in connection with the clay points, they found a large deflection which quickly diminished, but all sensitiveness to light disappeared within one or two minutes after the eye had been removed from the animal. This fact of itself shows that what has been observed is a change depending on the vital sensibility of the parts. It was therefore necessary to perform the experiment on the living animal under chloroform. By so fixing the head that it could not move, and by removing the outer wall of the orbit so as to permit the clay points to be applied to the cornea and nerve, the same results have been obtained in the case of the cat, rabbit, pigeon, and owl.

Without going into minute detail, which the space allowed for this short article will not admit of, the results of this inquiry have been as follows:—

1. That the specific effect of light on the eye is to change the electro-motive force of the retina and optic nerve.

2. That this last applies to both the simple and to the compound eye.

3. That the change is not at all proportional to the amount of light in lights of different intensities, but to the logarithm of the quotient, thus agreeing with the psycho-physical law of Fechner.

4. That those rays, such as the yellow, which appear to our consciousness to be the most luminous, affect the electro-motive force most, and that those, such as the violet, which are least luminous, affect it least.

5. That this change is essentially dependent on the retina, because if this structure is removed, while the other structure of the eye lives, though there is still an electro-motive force, there is no sensitiveness to light.

6. That this change may be followed into the optic lobes.

7. That the so-called psycho-physical law of Fechner does not depend on consciousness or perception in the brain, but is really dependent on the anatomical structure and physiological properties of the terminal organ itself, inasmuch as the same results as to the effect of light are obtained by the action of the retina and nerve without the presence of brain.

The method of investigation pursued by Messrs. McKendrick and Dewar is applicable to the other senses, and opens up a new field of physiological research. The specific action of sound, of the contact of substances with the terminal organs of taste, and of smell, may all be examined in the same manner; and we are in hopes of soon seeing results from such investigations.

ON THE FERTILISATION OF FLOWERS BY INSECTS AND ON THE RECIPROCAL ADAPTATIONS OF BOTH

II.

In what manner the hive- and humble-bees obtain the honey of the flowers

IN the last number the use the bee makes of its complex sucking machinery, when emptying the deepest honey-tubes or spurs accessible to it, was stated in detail; we have now to show the different movements and positions the separate parts of the mouth undergo, when the bee is obtaining honey less deeply placed, or when it is about to collect the pollen of flowers, or when it folds together the whole sucking apparatus into the cavity of the head in order to employ its jaws or to rest.

(2) In order to obtain the honey out of tubes or spurs of less depth the bee need not turn the cardines forward; these remain at rest in their backward position, the tongue remains consequently embraced by the maxillæ and labial palpi, and only the base of the tongue is alternately protruded and withdrawn, by which motion the terminal whorls of hairs are alternately immersed into the honey and withdrawn into the sucking-pipe.

(3) While the bee, in order to suck honey, flies from flower to flower, it carries its sucking apparatus stretched forward so as to be able to put it directly into the opening of the honey-tube, but its tongue is perfectly enclosed between the labial palpi and the maxillæ; the delicate whorls of hairs are protected by that from any injury they might receive, when introduced into the flowers, and the terminal joints of the labial palpi are not prevented from serving as feelers. Consequently during the flying from flower to flower the base of the tongue is folded into the extremity of the tubular mentum, the cardines are turned backwards, whilst the lora can be directed downwards (Fig. 4), forwards (Fig. 2) or backwards, in proportion as the bee is about to obtain the honey from shorter or longer tubes.

(4) The parts of the mouth must be held in the very same position when the bee wishes to pierce tender cellular textures by means of the tips of its maxillæ. It executes this sort of process, sometimes in order to obtain the fluids of juicy flowers which do not secrete nectar, as for instance *Hyacinthus orientalis*, *Orchis mascula*, *morio* and *latifolia*, sometimes in order to break open honey-tubes which are too deep to be emptied by the bee in the

regular way. Thus, for instance, *Bombus terrestris*, having of all our humble-bees the shortest tongue, forcibly opens the honey-tubes of *Aquilegia*, *Trifolium pratense*, *Pedicularis sylvatica*, and many other flowers; sometimes by piercing the corolla by the tips of its maxillæ, sometimes by biting through the corolla by means of its jaws, and then steals the honey by guiding its proboscis into the honey-tube through the self-made opening.

(5) When collecting the pollen of flowers the hive- and humble-bees moisten, as is well known, the pollen with honey before stripping it off with the brushes of their feet from the anthers and amassing it on the outside of the posterior tibiæ. During this process the maxillæ and the labium are commonly bent beneath the breast, as in

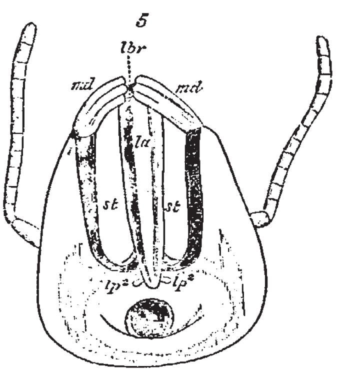

FIG. 5.—The sucking apparatus of a humble-bee (*Bombus hortorum*, L. ♀) placed in the hollow underside of the head, seen from beneath (7 : 1).

inaction, almost as shown in Figs. 5 and 6, the jaws are opened, the labrum is raised, the opening of the mouth is brought near the pollen to be collected, and a drop of honey is spit out upon this pollen; often also the bee before moistening the pollen with honey frees it while still enclosed in the anthers by chewing the anthers with its jaws.

In quite a different manner I saw the hive-bee proceed when collecting the loose, dry pollen of *Plantago lanceolata*, so easily shaken out. By vehement movements of its wings the bee maintains itself, steadily humming, at the same place in the air, close before the anthers, the pollen which it is about to collect; in this position it has its sucking-apparatus stretched forward, but the tongue quite enclosed between the laminæ and labial palpi, and spits out of the sucking-pipe formed by these parts a drop of honey upon the anthers. Then it grasps very hastily, with the brushes of its anterior legs, amongst

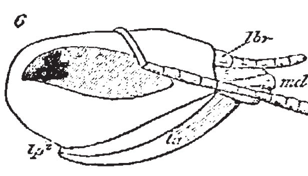

FIG. 6.—Lateral view of the same head.

the anthers, and strips off the moistened pollen from them, while the dry pollen of the neighbouring anthers also shaken out, is disseminated, forming a little cloud of dust. Consequently, also in this case the bee carries the base of its tongue folded into the mentum, and the cardines turned backward, precisely in the same manner as when flying from flower to flower, or when piercing honey-tubes by the tips of the laminæ.

Plantago lanceolata and other plants with equally loose, dry pollen, scattered by the wind, are honeyless; on the other hand the pollen of all honey-flowers is collected by the hive- and humble-bees when holding their sucking organs retracted, whilst the honey of these flowers is obtained by their sucking-organs stretched forward; hence it follows that hive-bees, humble-bees, and all the bees which are in the habit of moistening the pollen before collecting it, can never suck honey and collect pollen at the same time, but are obliged to perform alternately these two actions after having commenced with sucking honey, of which they are in need for moistening the pollen to be collected, whereas all the bees which collect the pollen without moistening it, as, for instance, the Andrena, Osmia, and Megachile, are often observed sucking honey and collecting pollen at the same time.

(6) When the bee is about to employ its jaws, or when it wishes to rest, it rests the whole sucking apparatus in the hollow in the under-side of the head, by

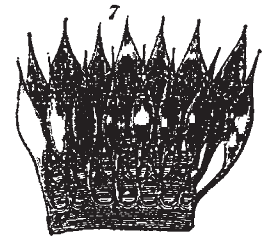

FIG. 7.—Two whorls of scales of the terminal portion of the tongue of a blue Brazilian Euglossa (or Chrysantheda); the scales of each whorl alternating with those of the following one (80 : 1).

effecting all the four foldings above described, and bends beneath the breast those parts which do not find any room in this excavation, viz., the tongue, and the labial palpi and laminæ enclosing it, as shown in Figs. 5 and 6.

Everyone who has observed in nature the activity of the hive- and humble-bees will be surprised by the ease with which the numerous movements just described are effected by them. Nevertheless, when sucking honey out of tubes or spurs, they experience a sensible loss of time by so repeatedly protruding and retracting the tongue. This loss of time seems to be avoided by a very singular contrivance lately discovered in some Brazilian bees by my brother, Fritz Müller. In these bees all the rings of the terminal portion of the tongue, from the tip to the sheath, formed by the labial palpi and laminæ, are provided, as shown in Fig. 7, with whorls of narrow-stalked, broad scales instead of hairs, and these scales, lying closely upon one another, form together a tube around the prominent

FIG. 8.—Gradations between hairs and scales.

portion of the tongue which probably enables the bee to suck the honey out of the longest flower-tubes accessible to it without needing to retract the tongue.

The first scale-bearing rings within the sheath of the tongue, offering numerous gradations by which hairs and scales graduate into each other, as shown in Fig. 8, indicate precisely the degrees of variability by which natural selection arrived at the broad narrow-stalked scales clothing the prominent portion of the tongue.

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