fibre, &c., by the penetration of their points into such foreign substances. It seems not improbable from their association

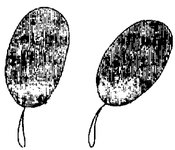

FIG. 3.

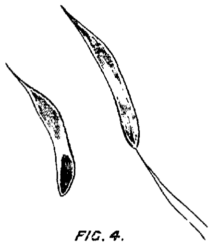

FIG. 4.

that these oblong bodies may be connected genetically with the little infusorian parasite. For the infusorian I propose the name *Undulina ranarum*. I have not been able to find any record of its occurrence hitherto, though I cannot but think it extremely likely that it has been seen and described. Undulina is a mouthless infusorian, closely allied to the Opalinidæ, from which, however, it differs essentially, as well as from the *Infusoria ciliata* generally, in possessing no cilia. In Undulina a wide flattened portion of the infusorial sac produced into a ribbon-like flagellum takes the place of cilia. We have indeed here an exemplary case of an "undulating membrane." On this account Undulina must be separated from the other Infusoria, logically indicating a new group of these animals characterised as devoid of mouth (as is Opalina) and devoid of cilia, but provided with a broad crest-like undulating membrane.

On the CIRCULATION *in the* WINGS *of* BLATTA ORIENTALIS *and* OTHER INSECTS, *and on a* NEW METHOD *of* INJECTING *the* VESSELS *of* INSECTS. By H. N. MOSELEY, Radcliffe Travelling Fellow, Oxford Univ. (With Plate XVII.)

WHILST working in the laboratory of Prof. Ludwig, at Leipzig, this spring, I obtained a number of specimens of *B. orientalis*, to look for nerve-endings in their salivary glands. I happened to examine their wings under the microscope, and finding a remarkably perfect circulation in them, was led to examine the wings of other insects, and study the subject somewhat closely. Several observers who have written on the circulation of insects have given lists of the insects in which they have observed the phenomenon.

Amongst these I have not found *B. orientalis;* and yet, as far as my observations go, owing to the large size and number of the corpuscles and the absence of dark pigment from the vessels of the wing, the circulation is here to be observed to more advantage than in any other insect. Insects are rather troublesome to tie down, and *B. orientalis* is particularly wild and difficult to keep quiet.[1] The small apparatus (fig. 1) will be found very convenient for fastening this insect for examination. To make it, a shallow rectangular box of the size of the figure should be taken, and filled with wet plaster of Paris, and into the upper surface of this, and near the edge, as seen in the figure, a dead blatta should be pressed down. When the plaster is set the insect should be pulled out, and a rectangular hole cut through the plaster slab opposite the impression. *a, a* are strips of paper glued on to the plaster, covering up the immediate front and hind portions of the impression, and also serving to hold in position a thin glass which covers the rectangular hole.

The Blatta to be examined is placed in the impression in the plaster, with his head under the front paper band and his tail under the hind one. *b* is a loop formed of a bent pin, with its two ends driven horizontally into the plaster. To it are attached two pieces of cotton, which are passed over the body of the insect, involving the wings not under examination, but leaving the others free, which are brought between the edge of the thin glass and the animal, and beneath the slab, to be fastened firmly to *c, c,* similar pins to *b.* This binding will generally suffice to hold the Blatta quiet; but it may be necessary to pass another cotton from *e* round the thorax under the slab and back. The front wing is now to be drawn forward, and may be fastened by means of a stout pin; or a piece of cotton may be tied round its lip, and may be strained to the pin *e.* The very tip of the hind wing should now be caught up in a loop of cotton and firmly fixed, and by straining this cotton more or less to the pin *d,* the whole hind wing will be fully expanded over the thin glass and rendered ready for examination.

The corpuscles in Blatta are so large that the circulation may readily be seen with a high power of a simple dissecting microscope. This is the most convenient method for making out the general direction of the currents in the wing. But with the wing fastened in this way it is quite easy to bring a Hartnack's No. 7 to bear on it. If an insect be carefully tied, the circulation may be observed in action for as long as

[1] N.B.—I have tried curare, but found that it had no effect on Blatta, even when used in a very concentrated form.

twelve hours. A freshly caught vigorous specimen should be chosen for examination (of course a male, the females have no wings), or one which, whilst in confinement, has had plenty of moist food. If specimens of Blatta be kept in a glass vessel for several days without food or water, the circulation will be found very feeble or almost absent. The animals' blood is almost dried up by evaporation, and if a few drops of water be given them they will drink it greedily.

Fig. 2 is a drawing of the hind wing of *B. orientalis*. N.B. —The circulation is also to be seen in the fore wing; but as there is more pigment present here, and the wing is thicker, the hind wing is more favorable for examination. The broad shaded vessels are the main vascular trunks, which are deeply pigmented, the transverse smaller vessels which connect them being nearly colourless. The dark filaments which follow the middle line of the main trunks are fine tracheæ. The direction of the blood-current is marked by the small arrows.

C. G. Carus[1] showed that in the antennæ and legs the blood-stream always flowed up on the anterior margin and back towards the body on the posterior margin. This is easily seen to be the case in the long antennæ of the male Blatta.

In the wings, as will be seen from the diagram, this rule is followed only in a general manner in Blatta. *a, a'* are the main arteries of the wing; but in *b* and *e, e, e* the blood also flows in a peripheral direction. The main veins are *e, e, e, e,* but there are also *a, a, a,* and the two vessels which lie one on each side of *b*, which convey blood in a centripetal direction.

It must not be supposed that the blood is always to be seen flowing in these directions. From comparing a number of healthy fresh specimens, I believe this to be its ordinary course. When a specimen is exhausted, or stasis from some cause occurs in one of the principal vessels, or the heart is rendered irregular in action from too tight ligatures, the course may be considerably changed for awhile. Thus, the current in *b, e, e* and *c, c* may be reversed. In *a* and *a'* I have never observed any but an arterial current. The veins *e, e, e, e* communicate with a venous trunk, which may be seen to pour blood into the body at the hind margin of the wing; but all the blood coming from these veins does not thus at once return to the venous sinus; but the vessels *e, e, e* also open into the venous trunk, and a large part of the corpuscles may be seen to turn off from the main stream in this

[1] Fernere Untersuchungen über Blutlauf in Kerfern. Verhandlungen der Kaiserlichen Leopoldinisch Carolinischen Akademie der Naturforscher *7a*, Bd. 2te Abtheib, Breslau, Bonn, 1830.

latter vessel and pass up these three channels, thus taking a second course through the vessels of the wing. The same occurs with part of the blood returning by the veins *a*, *a*, *a*. This passes by a small branch into the artery *a*, and so on back into the wing, whilst the remainder flows on into the body.

We can hardly look upon this system of blood-vessels in the wing of Blatta as ensheathing the tracheæ.[1] These latter are very small in comparison with the former, and, moreover, do not send any branches into the transverse connecting vessels at all. The principal blood-vessels rather have small tracheæ running inside them. In many coleoptera the tracheæ are absent from these blood-vessels. In *Melolontha vulgaris* there are fine tracheal branches at the commencement of the principal vessels only. In most Lepidoptera they are very large, the expansion of the wing after emergence from the pupa being probably effected by a combined increase of pressure of air in these large tracheæ, and of blood in the vessels in which they lie. Of course the extensive circulation in a thin and generally moist membrane, such as is the wing of Blatta, must cause this latter organ to exercise to a great extent the functions of a lung; hence, perhaps, the smallness of the tracheæ. It is possible also that the absence of these aerating organs is compensated in the female Blatta by the very much larger size of the salivary glands.

In a paper published in the last number of the 'Cambridge Journal of Anatomy and Physiology,' Mr. Ainslie Hollis has come to the conclusion that the so-called salivary glands of Blatta perhaps act directly as aerating organs; but this author seems not to have met with the monograph of J. Basch[2] on the digestive and renal systems of this insect, where it is shown that these glands are capable, not only of converting starch into sugar, but also of digesting albumen. Moreover, on opening living specimens of Blatta I have more than once found the salivary receptacle, which Mr. Hollis has found always full of air, filled with a transparent fluid. It is possible that he may always have killed his specimens first, and that they may have ejected the contents of the receptacle in dying. If, therefore, the larger glands of the female compensate the wings of the male, I consider that they do so as excretory organs rather than as direct aerators.

Fig. 3 represents one of the transverse colourless vessels which connect the main trunks. It is drawn from a wing hardened in perosmic acid under a Hartnack's 7. On either

[1] Carpenter's 'Comparative Physiology,' 238.

[2] 'S. Basch Sitzungsberichte, Kaiser Akad. Wiss. Wien,' vol. 33, 1858, p. 234, Matt. Nat. Classe.

side are seen the large trunks, containing each a trachea, that on the left side branched, and also a nerve-fibre which accompanies the trachea in all the larger vessels in all insects which I have examined, and is present in the Melolontha where the trachea is absent. The transverse vessel is seen to have a thick lining of elongated, nucleated, closely packed cells. This layer of cells is present also in the main trunks, but is there, of course, not so easy to investigate, owing to the pigmentation and thickness of the outer chitinous investment. I have injected the vessels of the wing with silver solution, but have been able to find no other endothelial lining to the vessel than this thick stratum of cells.

Fig. 5 gives a group of the various forms of corpuscles, and fig. 4 shows one of the main trunks during active circulation. The direction of the current is shown by the arrows. The corpuscles behave in much the same manner as in the capillaries of a frog. Thus they change their form readily, the spindle-shaped ones doubling up in order to pass crossways through a narrow aperture, as seen in the one coming to the main trunk from the small transverse vessels on the left hand side of the figure. Moreover the corpuscles attach themselves to the inner wall of the vessel, and even seem to bury themselves a short way in it; though, of course, the chitinous investment renders diapedesis impossible. In the irregularly formed corpuscles, which seem to represent leucocytes, amœboid movements may be observed. Corpuscles pass freely above and under the tracheæ, showing that these latter lie free in the vessels.

Thinking that the cells lining the blood-vessels might be contractile, and that the nerves accompanying the trachea might be to some extent vaso-motor, I introduced fine wires into the hinder legs of a Blatta, and applied stimulus by means of an induction coil, but could not produce any effect. However, on repeating this experiment with *Melolontha vulgaris*, I found that there was an elongated sac projecting free into the main artery of the hind wing, which contracted readily on very slight stimulus being applied to the legs. If the stimulus were prolonged this sac remained in a state of tetanic contraction, but expanded again immediately the current was broken. This sac is one of the contractile organs which have been described as occurring in the limbs and wings of insects, and which assists the heart in maintaining the circulation. In the hind wing of some small hymenoptera occur three rhythmically contractile sacs, or rather dilatations of the vessels. They are represented in fig. 6, the contractile spots being marked with a cross. If electrical stimulus applied to the body these sacs immediately contracted, and were thrown into tetanus by prolonged stimulus, as in Melolontha. These vessels seem therefore to behave somewhat like the small arteries in vertebrata, as seen in the rabbit's ear or skin. The contractile vessels continue to contract feebly for a short time after the wing has been severed from the body, as is evidenced by a backward and forward motion of the blood-corpuscles when a wing possessing them is placed immediately after separation under the microscope.

The blood-vessels of the wings of most insects which I examined (Blatta, Dytiscus, Hydrophilus, Melolontha) are infested with parasites, which attach themselves to the tracheæ, and always occur in greatest abundance in the main arterial trunks. These parasites seem to differ considerably in each species. Fig. 2 is taken from a wing hardened in perosmic acid, which stains the parasites which are filled with oil-globules black. They therefore appear in the figure as dark elongated spots attached to the central trachea in the main artery (*a*). I hope shortly to make a communication to the Journal on the subject of these parasites.

Blatta Orientalis casts its skin at certain periods, the chitinous investment splitting up the back, and the animal coming out, after several hours' labour, quite soft and milk-white. I have as yet only been lucky enough to obtain one specimen, a female, in this state. The insects, when thus fresh from the old skin, are very transparent. Light may be thrown right through their bodies, and the action of the heart and valves observed to great advantage. A venous sinus surrounding the heart can be clearly seen, and also that the corpuscles within it move towards the posterior extremity of the body. Moreover, the blood may be seen entering the heart by side apertures from the sinus, and apparently leaving it by others.

Although a good many fine tracheæ could be seen in the body quite distinctly, and though the power used was quite high enough to show corpuscles distinctly, no circulation taking place around these tracheæ was to be observed in the manner supposed by M. Blanchard. On account of the large size of the corpuscles, *B. Orientalis* is remarkably favorable for investigations of insect circulation. Unfortunately, these white insects rapidly—*i. e.* in a couple of hours—become so brown as to be no longer transparent, and rapidly become black.[1]

[1] Thinking it just within the limits of possibility that this brown coloration might be due to the presence of silver, I analysed one pound weight of Blatta; I found no silver, but plenty of iron, and a remarkable quantity of manganese.

A ready method for injecting the circulatory system of insects has long been a desideratum. The injection from the heart is beset with many difficulties, owing to its brittleness, and has led, as yet, to no certain conclusions, the connection of the large afferent and efferent blood-vessels in the wings with the heart being still uncertain. It may be well here to add a short account of a method which, I believe, may be of much assistance in clearing up such points as these, and which may also yield some interesting physiological results.

When the fore wing of a large living Coleopterous insect (*Dytiscus marginalis*, *Hydrophilus piceus*, and *Melolontha vulgaris*, *e. g.*) is cut transversely in two with scissors, a row of blood drops may be seen along the edge of the cut, which proceed from the large vessels divided by the operation. At the front border or costa of the wing this bleeding is most profuse, since the largest artery occupies this position. At this spot a very fine-drawn-out glass tube can easily be introduced either into the half of the wing still attached to the body, or the corresponding half which has been cut away. I have found it most convenient to use as a pressure apparatus a simple short india-rubber tube filled with injecting fluid, having the canula at one end and stopped at the other. By pressure with the finger on the tube the fluid may readily be forced into the vessels. If the wing of *Dytiscus marginalis* be thus injected with indigo-carmine (which I have found to run best) or Berlin blue solution, a very beautiful preparation is obtained.

By injecting the other half of the wing in the direction of the body the heart may readily be filled. When an insect (Cockchafer or Dytiscus) has thus its blood-system filled with indigo-carmine, this pigment is rapidly excreted by means of the kidney tubes, just as is the case when the same experiment is made on mammals, as in Crzonzwesky's experiments. Basch has shown that the kidneys in *Blatta Orientalis* contain uric acid. This observation tends to show a further identity of function between these organs and the mammalian kidneys. The excretion takes place very rapidly, the tubes in *Blatta Orientalis* being filled with blue pigment a few hours after its injection into the heart. In *Hydrophilus piceus* a series of simple circular glands, with which the intestinal wall is crowded, also excrete this pigment; nearly the whole intestine, shortly after the injection of the indigo-carmine, becomes blue, and on microscopic examination the pigment is found collected in the lumen of these glands.