XIX. *Notes on some points in the Anatomy of* Rotatoria.

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(Plate XLVII.)

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THE object of this paper is to point out some important particulars in the structure of certain *Rotatoria*, which I hope will serve to supply certain deficiencies in the general and special anatomy of this interesting group of animals.

In reading monographs on Rotifera, I have remarked an uncertainty in the determination of the corresponding aspects of different forms: the terms *dorsal* and *ventral* are often used in describing their anatomy, but authors not uncommonly represent structures really dorsal as placed on the side, or even, in comparing genera, make the ventral side of one genus correspond to what is truly the dorsal side of another; yet the characters of the dorsal and ventral sides of Rotatoria are constant, and may be recognized without much difficulty.

In every Rotifer there is a median plane, on either side of which the lever- and muscle-systems are symmetrically developed; the lines wherein this imaginary plane cuts the integuments above and below are respectively the *dorsal* and *ventral* median lines: we require to know which of these lines is dorsal and which ventral.

Many actively moving genera have firm tunics, one side of which differs in an obvious way from the other; on the other hand, some roving, and all stationary genera are in transverse outline more or less rounded. In those roving genera which have one side arched and the other flat, it has long been well known that the intestine runs down on that side of the ovary which is towards the arched side of the body: the mouth in these Rotifers is always in that side of the cephalic disk which is towards the flat side of the body: the eye or eyes are always on that side of the alimentary tube which is towards the arched side: in the middle line of the same side is an organ which may be generally described as a small round space bearing motionless hairs or setæ; this organ may be sessile or it may be stalked, but it is constantly in one relative position; and that is, on the same side of the œsophagus as the eye, and just on the anterior end of the body when the head is retracted: lastly, the cloaca—the common outlet of the intestine, ovary, and so-called water-vascular system—opens in the middle line on the arched side of the creature's body.

Thus in these Rotatoria there are, as distinguishing characters of the arched side, 1st, the course of the intestine towards it; 2nd, the position of the eyes on that side of the œsophagus; 3rd, the position of the median feeler (setæ-bearing spot) on that side; 4th, the opening of the cloaca upon that side; 5th, the mouth turned away from it; 6th, further, it is to be noticed that the animal, in moving over surfaces, keeps the arched side upwards.

These characters, but especially the second and fifth, serve to show that the rounded or arched side of the creature's body is dorsal, the flattened side accordingly being ventral; for in no creature are the eyes on the ventral side of the alimentary tube, nor is the mouth in any turned to the dorsal side of the body.

In those Rotifers whose dorsal side does not differ in contour from the ventral, the corresponding side is nevertheless shown by the above-enumerated characters, which will always serve to determine the dorsal side of a Rotifer.

Some Rotatoria lose part of these characters in adult life; for the eyes disappear in the stationary genera, and the mouth, in *Floscularia* and *Stephanoceros*, opens out as a great bell-shaped cavity, whose wide orifice is but slightly if at all turned to the ventral side; yet these Rotifers whilst young and in the freely moving state have the eyes, mouth, and dorsal feeler in their normal relation to each other. Under any circumstances the dorsal side may be determined by the opening of the cloaca there, or by the position of the median feeler always on the dorsal middle line.

This median feeler has up to the present time been overlooked in many genera; it has never yet been described in *Melicerta*, *Floscularia*, *Metopidia*, *Limnias*, or *Pterodina*. In these I am able to affirm its presence. Its existence has been already pointed out by others in *Rotifer*, *Salpina*, *Euchlanis*, *Hydatina*, and *Philodina*; but its constant position on the dorsal median line has, I believe, never been remarked.

But this dorsal feeler must be carefully distinguished from the lateral feelers of stationary Rotatoria, which are conspicuous in *Melicerta*, and have been known as long as that Rotifer itself. Lateral feelers are present also both in *Limnias* and *Floscularia*; and it is highly probable that they exist in all the stationary genera, though I have not as yet had an opportunity of observing other kinds than those named.

These lateral feelers are symmetrically placed on the sides of the creature's body, towards the ventral aspect, and close to the part which forms the upper end when the lobes are retracted. In *Melicerta* (Pl. XLVII. fig. 2) they are raised on stalks, and their anatomy has been well described by Professor Williamson and other observers. In *Limnias* (fig. 3) they have the same structure, but are placed on slight conical elevations, and so likewise in *Floscularia* (fig. 1); but in the last-named genus the organ is smaller in proportion to the bulk of the animal than in either of the other instances, and offers the additional peculiarity of having its setæ curved in the direction of the tail.

The setæ of the dorsal feeler are shorter and less conspicuous than those of the lateral, whilst the circular space on which they are set is larger in the dorsal. The three feelers of *Floscularia* have hitherto been entirely overlooked, as have those of *Limnias*.

In *Philodina* (fig. 4) and *Rotifer* the dorsal feeler is raised on a stalk, and much resembles a lateral feeler of *Melicerta*; but the true dorsal feeler of *Melicerta* (fig. 2), which has hitherto wholly escaped observation, is sessile on the back of the head, behind and between the eyes in the young, and on the same side of the body as the cloacal opening. It corresponds to the pedunculated dorsal feeler of *Philodina* in every particular of these relations, which fully suffice to establish a true homology between the two organs.

Hence, to properly compare these Rotifers, as done in a recent monograph, it will be

necessary to place them so that their pedunculated feelers point in opposite directions; any ganglion in the oral side of the neck of *Melicerta* will be on the side opposite that wherein the ganglion of *Philodina* is seated, whilst the cloacæ will open on corresponding sides.

The structure and disposition of the alimentary canal in Rotatoria have already been the subject of much attentive observation, and little can remain for further discovery, though a comparative examination of the gizzard-teeth of all the genera would produce interesting results. The approaches to the gizzard are more elaborate in the stationary genera, and reach their highest complexity in *Floscularia* (fig. 1). In this creature the part of the alimentary canal above the gizzard is divided by a highly irritable cilium-clothed sphincter of irregular outline (fig. 1 *c*) into two portions, one of which is the great bell-shaped orifice with its five-lobed seta-bearing rim, and the other a cavity whose walls are powerfully contractile. To this second or pharyngeal cavity immediately succeeds the true gizzard, containing the crushing-machine (fig. 1 *e*). The cavity of the gizzard in *Floscularia* is much more capacious than in any other Rotifer; and this becomes especially striking through the smallness of the dental apparatus, which is composed of small two-toothed nippers at the bottom of the cavity and towards the dorsal side. The prey, instead of being drifted down the throat by a cilium-current, is swallowed by a true act of deglutition; food is brought into the oral cup by that vortex which is created by the quick cilia that cover the faucial sphincter; after a few revolutions within the mouth it is presently passed into the pharyngeal cavity, the faucial sphincter closing behind and preventing return, whilst a sudden and almost convulsive contraction of the walls of the pharyngeal cavity forces the morsel into the gizzard or crop, through the narrow fissure-like opening which leads into it. It should here be remarked that with the edges of this opening a thin-walled, flattened, cilium-lined tube (fig. 1 *d*) is continuous, and depends freely in the cavity of the gizzard; the movement of the cilia within this freely suspended tube causes it to wave about in the gizzard, in the same way as the œsophagus of *Metopidia* is kept in constant agitation by its lining cilia. When the prey reaches the crop it is still alive, and often remains so for many minutes, making meanwhile violent efforts to escape, which would be likely to prove successful if it were not for the flattened tubular valve; this, whilst allowing, and aiding with its cilia, the entrance of prey forced in by the pharynx, is admirably suited to prevent any from finding or forcing its way back again: as it is only in *Floscularia* that prey is detained in the crop, so only in *Floscularia* is the tube valve required or developed.

This tube valve has often been seen by describers, but its nature has been entirely mistaken; it has been viewed as a "slit-like opening fringed with vibratile cilia"*, as "many plates or filaments"†, as two delicate membranes‡, and as a stream of water trickling into the gizzard. To inspect it a three-parts-grown specimen should be chosen, whose anatomy will not be obscured with those refracting grains which are developed in adults. If the tube be watched by daylight with a good microscope, its true nature will

* Dobie, Ann. Nat. Hist. 1849, No. 22, vol. iv.

† Dujardin, Hist. Nat. des Zoophytes, p. 611.

‡ Huxley, Trans. of Micr. Soc., new series, vol. i., 1853.

be made out; if such a specimen be gently compressed, so as to impede the wavy movement of the tube, the observation will be more certain; but absolute demonstration must depend on the occurrence of such an act as I have witnessed in three instances, in which the creature, by a quick convulsive effort, turned its anterior third inside out, everting the whole of the approaches to the gizzard, and then expelled the contents of the gizzard through the everted tube (fig. 1ª *d*). The whole proceeding looks much like self-destruction, but the animal in all the cases slowly withdrew the everted parts and reassumed its proper shape. Whilst the tube is everted and the ciliated inner side of it has become external, the cilia can be very plainly seen vibrating on its then exterior surface (fig. 1ª *d*). I have thus fully described this structure, as I believe the employment of a long, lax, ciliated tube as an intestinal valve is not on record. A more effective contrivance, and one more admirably suited to the wants of the creature, it would be hard to devise.

The construction and disposition of that portion of the alimentary system which is below the gizzard is very constant in all Rotatoria. It has already been well described. It is lined throughout with cilia, which, however, are far from constant in their activity. It is divided into two parts by a sphincter: of these the upper and larger, called stomach, is provided with two follicles, one on each side, which open into the upper part of it; the lower and smaller part of it, called intestine, opens either into the contractile vesicle, or into the cloaca, in common with that and the ovarian duct. In *Euchlanis dilatata*, where the observation is best made whilst the creature is turned upon its side, there is in the cloaca a sphincter, just below the region where these tubes open into it (fig. 7 *v*). I have seen this sphincter do the following service:—the intestine contained much fæcal matter, and its cilia were motionless, the sphincter of the cloaca closed, and then, by the systole of the contractile vesicle (fig. 7 *h*), the contents of the latter were thrown up into the intestine (fig. 7 *g*); the liquid could be seen to spread up between the mass of contents and the intestinal wall, waking the cilia into action: this act was repeated several times, and was soon followed by the extrusion of the fæcal matter. Whether the fluid was thrown up to wash out the remains of nutriment from the refuse of the food, or whether it was a natural enema, to ease the excretion off the sides of the bowel, I cannot say; but, believing the water-system to be excretory, I think the latter the most probable reason.

The so-called water-vascular system is one of the most striking and interesting features in the anatomy of the Rotatoria; yet, at the present time, it is the subject of what I cannot help calling a remarkable error regarding its ciliated appendages.

Its presence has been uniformly denied by all describers to the genera *Limnias* and *Floscularia*.

In both these I have had no difficulty in recognizing and carefully examining this system. In *Limnias* it offers nothing worthy of especial notice (fig. 3 *k*): but in *Floscularia* the tubes and ciliated funnels of the water-vascular system are very small in diameter when compared with the bulk of the creature's body; they are strictly symmetrical, and start below from a globular vesicle (fig. 1 *h*), which I could never see contract, though I have watched it for hours; this vesicle opens by a round orifice, situate in the dorsal middle line, at a little distance from the caudal end of the body;

the lips of the aperture may be commonly seen partially closing and opening. Starting, as stated, from this vesicle, the tubes (fig. 1 *i*), as usual, seek the mid-lateral region and approach the surface, where they acquire some fat-granules in their parietes; here the first cilium-funnel is situate (fig. 1 *k*): if the side of the *Floscularia* be towards the observer this will not be visible, as I shall presently explain. The tube continues to ascend in the side, as high as the neck, where there is another funnel (fig. 1 *k'*), situate just behind and below the lateral feeler; it then passes, still ascending, to the back of the neck, and crossing the middle line anastomoses with its fellow just behind the faucial sphincter; above the tube, near the middle line, and below and outside the dorsal median feeler, is a third funnel, lying horizontally (fig. 1 *k'''*); and above and outside this is a fourth (fig. 1 *k''*), hanging vertically. I have been unable to find more; but as the smallest number yet known in any Rotifer is five pairs, I have little doubt that the missing one, which should be in the side of the neck, will some day be observed. I have plainly seen the cilium-funnels in activity in the egg of *Floscularia*; they may also be seen in the eggs of *Philodina* (fig. 4ª *k*).

Of the peculiar circulatory apparatus described by Mr. Gosse* as compensating for the supposed absence of the water-vessels in *Floscularia*, I could never see any trace; but, in the contractions of the body of the animal, the granules alluded to by him move freely about in the perivisceral space.

Leydig, in his account of *Pterodina*†, states that he was unable to see any ciliated appendages to the water-vascular system of that Rotifer. These appendages I found to be five in number on each side; their positions are shown in the accompanying drawing of *Pterodina* (fig. 5 *k k*).

Now with regard to what I have here called cilium-funnels, a view at present prevails, according to which these are described as blind sacs enclosing a "long flickering cilium." The grounds on which I venture to differ from this view are, I think, conclusive. The Rotifer which is best suited for the observation is *Euchlanis dilatata*. It is common, and of good size. If a large specimen be chosen, and turned on its back (fig. 7ª), four pairs of funnels can be made out: but two pairs (fig. 7ª *k' k'''*) in the lateral ventral region are plainly visible to a low power; these are narrow in outline, and display, in a beautiful degree, the candle-flame-like appearance that is described as a flickering cilium. If the animal be now turned on its side (fig. 7), a feat which can be easily managed in a screw-compressorium, these two funnels will be so faintly marked as to be scarcely perceivable; whilst a third (fig. 7 *k''*), situate in the neck, which in the ventral view of the animal was barely visible, now shows itself as a flickering cilium. If now the observer search carefully, he will be able to discern each of those lateral-ventral tags which in the ventral view had the candle-flame-like appearance (fig. 7 *k' k'''*), but now in quite another shape —that of a broad triangle, with its lower margin well defined, and its surface clothed with short cilia in full activity—this not doubtfully or occasionally, but most evidently and constantly, so as fully to satisfy the observer's mind not only of the presence of the small cilia, but of the total absence of any large cilium. The tube (fig. 7 *i*) can be seen descending and opening into the triangle. Whether this is a triangular flattened ampulla,

* Popular Science Review, No. 2. † Siebold and Kölliker's Zeitschrift.

or whether the tube opens, and one side of its orifice is produced and expanded into the triangle, so that the latter is a single plane, I cannot make out; but I believe the cilia must be on two opposed surfaces; and it is to be remarked that an identical appearance of flickering cilia is produced by the same conditions in the tube-valve of the crop of *Floscularia*, described before in this paper, as also by the cilium-lined tubular œsophagus of *Metopidia* and many other Rotifers, which often wear the appearance of flickering cords. Any one making this observation will be quite sure that the tags or vibratile funnels are, as in Annelida, lined with short vibratile cilia, and that the long flickering cilium, which in some positions seems so surely present, is but an optical illusion, which arises when the observer looks along the level of the ciliated surface.

The position of direct observation should exclude argument; yet it is only fair to ask, in what manner a flabellum in a blind bag could produce a current? Again, cilia do not move in the flickering way here attributed to the imaginary single cilium; they have a lashing movement, upon their root as a centre of rotation: the flabella of certain Monads which wave about in an irregular serpentine way never look in the slightest degree like the candle-flame appearance in question; whereas it is very closely resembled by the narrow œsophagus of *Metopidia*, &c., and by the tube-valve of *Floscularia*, where we certainly have short cilia within a tube.

Lastly, the close analogy between these ciliated appendages and the open vibratile funnels on the water-vessels of Naids and their allies tends powerfully to support this conclusion. (Fig. 8 *k* represents one of the funnels of *Nais*, sp.) In these animals the cilia of the funnels not only line the interior of the appendages but extend over their border, and may be seen playing in the fluid, and agitating the corpuscles, of the perivisceral cavity.

EXPLANATION OF THE PLATE.

PLATE XLVII.

Fig. 1. *Floscularia*, adult.—The reproductive system and the granules in the perivisceral cavity are not represented.

Fig. 1ª. The same, a three-parts-grown specimen, with the oral and pharyngeal cavities and the tube-valve everted: *o*, the verge of the mouth; *c*, the faucal sphincter.

Fig. 1ᵇ. The same, three hours after hatching.

Fig. 2. *Melicerta ringens*.

Fig. 2ª. The same, emerging from its cell, showing its three feelers.

Fig. 3. Head of *Limnias Ceratophylli*, seen obliquely from below on its left ventral aspect.

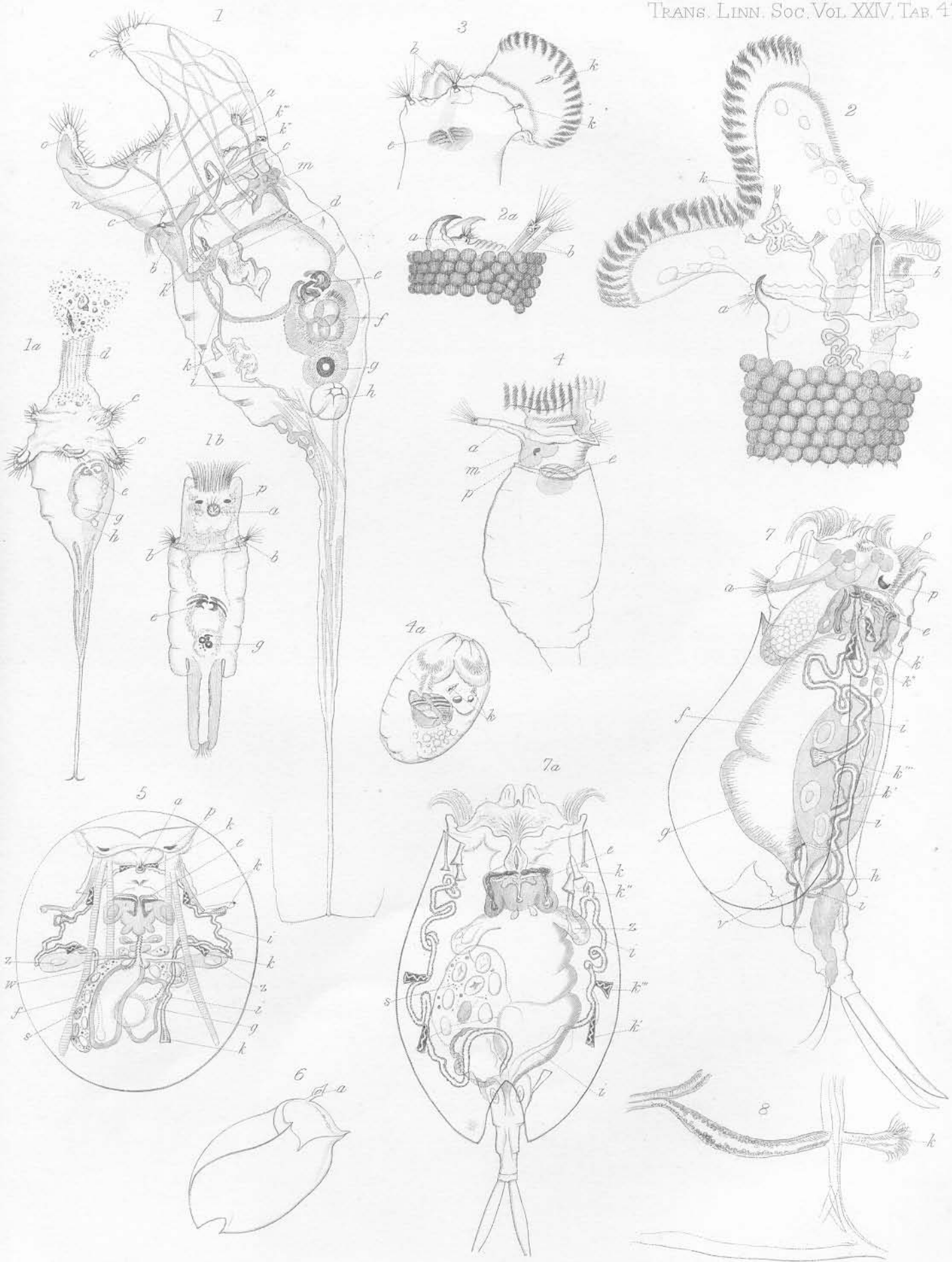
Fig. 4. Head of *Philodina*.

Fig. 4ª. Egg of *Philodina*: *k k*, tags of water-vascular system.

Fig. 5. *Pterodina*.

Fig. 6. Lorica of *Metopidia Lepadella*.
Fig. 7. *Euchlanis dilatata*, right side.
Fig. 7ª. The same, ventral view.
Fig. 8. Ciliated appendage of water-vessel of *Nais*, sp.

In all the figures *a* indicates, when present, the dorsal feeler.
b b, the lateral feelers.
c, the faucal sphincter.
d, the tube valve.
e, the gizzard-teeth.
f, the stomach.
g, the intestine.
h, contractile vesicle.
i, water-vessels.
k, ciliated appendages.
m, nervous ganglion.
n, muscular fibres.
o, lips of mouth.
p, eye.
s, ovary.
v, sphincter of cloaca.
z, pancreatic sacs.



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