XIV. *On the Diœcious Character of the Rotifera.* *By* Philip Henry Gosse.

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1. When Dr. Ehrenberg, in 1838, published his 'Infusionsthierchen,' containing his matured conclusions respecting the Rotifera, he defined the Class as consisting of animals all the individuals of which are hermaphrodite, oviparous, and ovipositing. The hermaphroditism, or "dualism of the sexual system," he described as consisting of "an ovary, simultaneously developing a few great eggs; two thread-like male sexual glands, thicker and club-shaped in front, and a contractile bladder, placed near the cloacal orifice, uniting the hermaphrodite organs for self-impregnation."

2. These conclusions remained unchallenged till 1848, when Mr. Brightwell announced his important discovery of separate sexes in a Rotiferous animal, since named *Asplanchna*. The presence of the tortuous threads in both sexes, and of the contractile bladder in the female, at once negatived the conclusions of Ehrenberg, that these were male impregnating organs, though their functions were still undetermined.

3. This single example, however, was by no means sufficient to overthrow the presumed hermaphroditism of the Class as a whole; though it naturally threw doubt on statements as yet unhesitatingly received. The case might have been one of those solitary exceptions, which occasionally mock our generalizations; like the exception to the law of metamorphosis in *Gecarcinus* and *Astacus*; or to that of immediate relation of impregnation to birth, in *Aphis* and *Daphnia*.

4. In the "Annals and Magazine of Natural History" for July 1850, I published some observations on a second species of *Asplanchna* (*A. priodonta*), in which I described and figured the male. Soon afterwards I had the pleasure of repeating and verifying those of Mr. Brightwell and Mr. Dalrymple on *A. Brightwellii*.

5. The diœcious character was thus extended from a species to a genus. Since then, I believe, no advance has been made in our knowledge of the sexual relations of the Rotifera, from actual observation, save the discovery of a third species of the same genus. Dr. Franz Leydig, in a recent able memoir* on this Class of animals, announces that *Notommata Sieboldii* has distinct sexes; and that the male, while exhibiting some curious peculiarities of external form, agrees with that figured by Mr. Dalrymple, in all essential points. He appears not to have been aware of my observations on *A. priodonta*.

* "Ueber den Bau, und die systematische Stellung, der *Räderthiere*" (Siebold and Kölliker's Zeitschrift, July 1854).

It is manifest, however, that the animal which the German zoologist describes as a *Notommata* must be referred to my genus *Asplanchna*; and that its alliance with *A. Brightwellii* is still more intimate than is that of *A. priodonta*. Thus we have still no absolute proof that the diœcious character is not confined to a single genus.

6. Dr. LEYDIG, however, conjectures, and supports his suggestion with many plausible reasons, that several animals, described and figured by EHRENBERG as distinct species, may be really the males of other recognized forms. Thus *Enteroplea hydatina* he ventures to assign as the male of *Hydatina senta*, grounding his conclusions on the descriptions and figures of EHRENBERG and DUJARDIN. The close resemblance of *Enteroplea* to *Hydatina*, its smaller dimensions, and the absence of a manducatory apparatus, had been noticed by EHRENBERG, who found the eggs which produced the animal, among those from which were evolved *Hydatinæ*. What EHRENBERG described as an undeveloped ovary, Dr. LEYDIG considers to have been analogous to the sperm-bag of Mr. DALRYMPLE; in other words, a true testicle. This last interpretation is further confirmed by the figure given by DUJARDIN; in which, moreover, additional evidence is found, in the absence of a true alimentary canal, in the presence of certain "*touffes des granules pédicellées*" in the posterior part of the body (which Dr. LEYDIG interprets as "masses of spermatozoids"), and of "un organ cilié entre les muscles de la queue," which Dr. LEYDIG supposes to have been the excretory duct of the testicle, *i. e.* the penis.

7. To these conclusions I entirely assent (perhaps with the exception of his interpretation of DUJARDIN'S "*touffes pédicellées*"); and they are still further confirmed by the observations which I have presently to offer.

8. For reasons of a similar character, Dr. LEYDIG presumes *Notommata granularis* of EHRENBERG to be the male of *N. Brachionus*, and *Diglena granularis* of WEISSE to be the male of *D. catellina*.

9. The first occasion on which I saw a male of this Class was on the 9th of August, 1849, when, however, I was too inexperienced in the study of the ROTIFERA to be aware of the true character of the animal which I was observing. Among many specimens of *Brachionus pala*, which I had just obtained from a pond near London, was one with seven or eight eggs excluded and attached to the posterior extremity of the lorica. One of these eggs was discharged from the ovary in my sight, so that I was sure of their origin. When extruded, the ovum displayed a substance slightly granular, and almost colourless, except that a slight tinge of smoky black pervaded the whole. In an hour or two this pellucid interior became turbid, and soon after was marked with indistinct corrugations, which gradually acquired more definiteness. The waves of the frontal cilia were next seen at one extremity of the egg, sometimes moving transversely, sometimes longitudinally, but conveying, in either case, no accurate idea of the organs which produced them. The vacant space occupied by these waves became larger, and presently the eye became visible, as an undefined pale red spot, near the middle of the egg. About the same time two or three amorphous masses of opake substance were seen near the posterior extremity. See Plate XV. fig. 1.

10. After about five hours from extrusion the motions of the enclosed embryo become very vigorous: the folds of the body are continually changing their places, and the working of the cilia is strong and rapid. Presently the regularly elliptical form of the egg undergoes a slight alteration, becoming more elongated, then slightly constricted in the middle, apparently by the pushing outwards of the two extremities of the body, and by the inflation of the fore-parts. At this moment the anterior half of the egg-shell is pushed off; the cilia are instantly seen expanded and rotating for a second or two; the little new-born *Brachionus* (see fig. 2) sits in the hinder half of the shell, as in a nest, and then glides away.

11. The infant *Brachionus* swims rather feebly at first; but, acquiring vigour as it goes, presently darts along with amazing swiftness, so that the eye can scarcely follow it. When several of the young were hatched, they whirled and shot round and round the live-box in which they were enclosed, in the most headlong manner, and were every instant coming into contact with the parent, when, almost invariably, the course of the little creature would be arrested, and it would play around the body of the mother, or grasp with its pincer-like toes her cilia. As I have already said, I had at that time no notion of these being males, having seen no offspring but these produced from this species. I had, however, seen the birth of several young of *Brachionus urceolaris*, which were exactly like the parent, whereas these were very dissimilar; a circumstance which excited my curiosity, as did also the fact that both eggs and young were notably smaller than those of *B. urceolaris*, in proportion to the adult. The actual dimensions of the eggs in question were $\frac{1}{360}$th of an inch in the longer diameter; of the new-born male, $\frac{1}{290}$th; of the parent, $\frac{1}{100}$th, exclusive of the foot.

12. I shall not here describe the structure of the male, because I shall presently have occasion to recur to the species again, in recording observations made with the advantage of more experience.

13. In April 1850 I first saw eggs of two different dimensions, attached to the same species. This was *Brachionus rubens*, several specimens of which carried each seven or eight small eggs (fig. 3), measuring $\frac{1}{350}$th of an inch in length, while others carried few eggs (two or three at most), nearly twice as large, viz. $\frac{1}{190}$th of an inch in length. One of the latter, under slight pressure, freed prematurely a young one, enveloped in a spined lorica, agreeing in all respects with the parent. I then crushed several of the smaller eggs. From such as were nearly mature, numbers of spermatozoa were expressed: these had a round body, and a short tail which was vibrated in a serpentine manner. They measured about $\frac{1}{3500}$th of an inch in the diameter of the body, and the length of the tail was about the same (fig. 4). These were sufficiently numerous to make it appear as if the eggs had been entirely filled with them. The less mature eggs yielded spermatozoa also, but without motion, with the tail undeveloped, adhering together, and somewhat resembling blood-disks.

14. Others of the smaller eggs produced the young by natural maturation. These were quite diverse from the parent, having no perceptible lorica, nor any spines; no

mastax or jaws; no alimentary canal; nor any distinct organization within, except a large red eye near the middle of the body. The whole interior, with this exception, appeared to be filled with a granular mass, in the midst of which, near the posterior region, were two or three amorphous lumps of opake substance. The foot was short; the frontal cilia very large and strong, and the little animal shot to and fro with great swiftness (fig. 5).

15. My next observations were made on *Brachionus amphiceros*. Here again I met with large and small eggs in individuals of the same species; the former $\frac{1}{170}$th of an inch in length, the latter $\frac{1}{317}$th. As before, the larger eggs (fig. 7) produced young exactly like their parent; the smaller (fig. 6) yielded animals quite dissimilar, but agreeing in all essentials with the small young of *B. pala* and *B. rubens*.

16. One of these latter was hatched under my eye. The little animal (figs. 8, 9, 10) was several seconds in escaping, after the broad ciliated head was outside the egg-shell. Then it swam swiftly away, and remained traversing the live-box with indefatigable perseverance all the time I looked at it. It was totally different from the other young of the same species, and from the parent: it had no lorica, no jaws, no mastax, no stomach, nor any viscera, except a large mass of opake matter, apparently surrounded by traces of a vesicle near the hinder part. It had a red eye placed near the middle of the body, and an ample rotatory organ, of which the central cilia were sometimes made to converge, as in the parent (fig. 9). The body was wide, nearly cylindrical, gibbous at the posterior part, where it was abruptly attenuated to a stout cylindrical foot (fig. 8). But this organ exhibited a remarkable peculiarity; for, from behind the foot, proceeded a stout cylindrical organ, truncated and ciliated at its extremity, whence a blunt point was sometimes protruded: this organ, from its direction and size, might easily be mistaken for the foot itself, for the latter was much shorter and smaller, and projected almost like the thumb of a mitten, but it was readily known by its two little soft toes (fig. 10). The body seemed to be hollow, with thick walls, but a great number of bubbles hindered the transparency. Pressure did not reveal the slightest trace of jaws. The colour of the fore-parts was buff, like that of the parent; but the rest was colourless, except the opake mass and the red eye. I put this specimen and a newly-born female together, and watched them for an hour; but though, in their devious wanderings, they once or twice touched each other, no apparently voluntary communication took place. I left them together all night, and in the morning the female was dead. The male, however, was still active, and lived till the middle of the day.

17. About the same time *B. pala* occurred again to my notice, and this time with both male and female eggs. The observations now made may perhaps be most distinctly given in the words of my journal.

$12^h\,45^m$ P.M. I isolated a specimen with five small eggs attached, in two of which the embryos were vibrating the cilia (fig. 1). There was in the ovary, nearly ready for exclusion, another egg, similar in size and appearance to the least advanced of the five attached.

$1^h\,5^m$. The egg last named was extruded under my eye, but took its place with the

other five, not differing from them. The small egg, when deposited (and for some time before), is pellucid and colourless, except that many yellow oil-globules are contained in it, which are aggregated into two (or three) masses. The pellucid interior has a delicately granular appearance, which after a while begins more distinctly to form cells, and becomes more turbid.

$3^h\ 30^m$. A male was hatched from the most advanced of the small eggs. It is almost indistinguishable from that of *amphiceros*; but the toes are rather more developed (fig. 2).

The opake masses in the posterior region are aggregated together, and very conspicuous. This aggregate mass seems to be contained in a central irregular bladder, which is connected with the protrusile organ. I distinctly saw, many times in succession, the penis behind the foot everted and protruded beyond the toes, when the tip was seen to be ciliated: a sort of thick (two-lobed?) piston (probably the thickened retractor muscles) was thrust rapidly down when it was protruded. It is frequently retracted with the foot into the abdomen.

18. I put it, almost as soon as born, into a live-box, with a half-grown female, and managed to enclose them together, by means of cotton fibres, in a cell sufficiently small to be contained in the field. I watched them long: the male was very wild, trying to escape: several times, in darting round, he stopped near the hinder part of the female, and momentarily protruded the penis, and turned it towards her, and once, as I thought, actually introduced it into the cloaca, but only for an instant. The female appeared conscious of excitement while the male was near, whisking about the foot and feeling him with it.

19. The next day I collected about a dozen females, half-grown and adult (which I could easily take up with a tube from the numbers in the water), and placed with them two lively males that had been hatched during the night. I directed my attention principally to one of these, as I could not watch them both. It soon came near some of the females, when it seemed to become animated by a sort of frenzy; describing, with excessive rapidity, a circle, of which its head formed the circumference, and its foot the centre: the extremities were incurved in the direction of its circular movement. After a while it left off and began to play about the body of a female, moving over and round the lorica, while she whisked about the foot, as if to lay hold of him; at length she drew in her foot, and that of the male appeared to adhere to it, and I distinctly saw the thick penis presented to the cloaca, and for a moment inserted about half its own length; then it was instantly drawn out, and the male began his frenzied gyrations again. Two or three times I saw similar play between him and females, but could not see any actual intromission again. Sometimes he moved his body in quick waves, the foot being the fixed point.

20. Next I examined the little new species that I have named *B. angularis*, which was swarming in a bottle of water dipped from a pond near Tottenham. Many carried two eggs each, measuring $\frac{1}{290}$th of an inch in length, others several, which measured only $\frac{1}{350}$th. One of the latter produced a little male (figs. 13, 14), which appeared

covered with a tortoise-like lorica. Its length, exclusive of the foot, was $\frac{1}{290}$th of an inch. A constriction indicates the distinction between the head and the body. The foot has a thick penis united to it behind (fig. 14), the tip of which is protrusile and ciliated. No internal organs are visible, except a red eye near the middle of the back, and a mass of opake matter at the hinder part. The interior is occupied with a vast number of minute granules or globules irregularly clustered. Its movements were very rapid; it darted incessantly about the live-box, so that it was impossible to keep it for more than a moment in the field; several females were enclosed with it, some of which were without eggs, while others carried them. By means of a small microscope I watched them awhile, and had the satisfaction of seeing what I had no doubt was a sexual conjunction, though it was but momentary, with one of the females without eggs.

21. All the observations I have mentioned (except the first) were made in April and May 1850. Leaving what I have to say of other genera for the present, I shall go on with *Brachionus*, detailing all I have learned of the males of this genus together.

In August of the same year I examined many specimens of *B. Bakeri*. One of these had two eggs attached to its body, which, from their size and appearance, I judged to be male eggs (fig. 11): they measured $\frac{1}{350}$th × $\frac{1}{540}$th of an inch. After a while, one of these began to show the ciliary action; then the eye became visible; and at length the well-defined fœtus moved vigorously in its transparent prison (fig. 11 *c*). Meanwhile, the egg that had been developing was at length extruded, and took its place beneath its two fellows (fig. 11 *b*). The evolution of the fœtus from these eggs being delayed considerably beyond the usual period, I endeavoured to promote it by artificial pressure, and in one case succeeded in cracking the egg, so that the animal was enabled to escape (fig. 12). It was very inert and feeble, did not swim rapidly away as usual, but remained in the same place. It resembled other male *Brachioni*; there was manifestly a simple enveloping lorica, cup-like, without points. On killing it by pressure, the viscera were forced out in the form of globose vesicles of various sizes; the eye was resolved into three or four atoms of pigment, and the opake white spots that are so characteristic of males *seemed* composed of an immense number of moving atoms, excessively minute, which, when they were freed from the body, continued for a moment or two to move spontaneously. These were probably spermatozoa; but, from subsequent observations, I have reason to think I was mistaken in supposing them to have proceeded from the opake masses.

22. About the same time I procured from Walthamstow a very fine and elegant species, described by myself under the name of *B. Dorcas*. One specimen carried a *female* egg nearly matured, in the ovisac, and the empty shell of another (fig. 15) attached to its lorica. Another had three *male* eggs attached, and one maturing: the dimensions of male eggs were $\frac{1}{290}$th × $\frac{1}{310}$th of an inch: fig. 16 represents one of these, with the fœtus nearly ready for exclusion; the thick penis-foot is seen turned up to one side.

23. The female is represented at fig. 17, an hour after birth. I had the pleasure of seeing this hatched. The egg is of a bluish-grey hue, and shows the large mastax with

the jaws, long before hatching. I was surprised at the great size of the newly-born young, not only in proportion to the parent, but even to the egg from which it was just escaped. For, when I delineated it an hour afterwards (during which I did not perceive any manifest increase), its length, from the tip of the frontal antlers to the posterior tubercles, was $\frac{1}{98}$th of an inch. The dimensions of the empty shell (fig. 15), which still retained its form, were $\frac{1}{175}$th $\times \frac{1}{220}$th of an inch: this continued attached to the parent for hours afterwards. This increase I suppose to be effected by the expansion of the lorica (at first flexible and membranous), which in the egg had lain in many folds, and by the imbibition of water into the cavity of the body.

24. Soon afterwards I had a young male of the same species hatched. I selected a specimen with two small eggs attached, and isolated it in the live-box, examining it at intervals. At length I perceived the young male whirling rapidly about the box, and on looking at the adult, saw that one of the eggs was but an empty shell. By the aid of cotton filaments and the compressorium, I was enabled to keep it steady, and to examine and draw it with care (see figs. 18, 19). It is of the usual shape, with a well-marked neck, up to which a flexible lorica appears to reach. The head is broad, truncate, or sub-conical, with vibrating bristles set on the cone, and rotating bristly cilia around the margin. A head-mass, of irregular, rounded, or sacculated lobes, bears a lozenge-shaped red eye on its dorso-posterior angle (fig. 19). From each side of the head a chain of irregular masses runs down to the posterior part of the body, probably answering to the tortuous glands of the female. A large mass, similar in appearance to the head, but distinct from it, occupies the middle of the body, extending down into the penis-foot. This great mass is continually moved by quick contractions up and down, but it does not appear to be tubular and hollow. The common white, opake, granular masses are enveloped in it, near the hind part of the body.

25. From this time I made no further investigation into the subject until the autumn of the present year (1855), when I had an opportunity of examining the beautiful and interesting marine species *B. Mülleri*, and of seeing, with satisfaction, that in the point of its œconomy, which is the subject of this memoir, it differs not from its congeners of fresh water. The males, however, displayed an internal organization more developed than in any species that I had yet seen, with the exception of the *Asplanchnæ*.

26. In July last, my kind friend Mr. BRIGHTWELL of Norwich sent me a small phial of sea-water much filled with this species. I immediately divided the contents among my Aquaria, where they increased rapidly. Many of the females have two or three male eggs attached, which are $\frac{1}{290}$th of an inch in length, and others carry one or two female eggs $\frac{1}{212}$th of an inch long. The male young (fig. 20) is $\frac{1}{220}$th of an inch long, exclusive of the foot, and about $\frac{1}{300}$th of an inch wide, with a distinct, but very flexible lorica, of which the anterior edges seem to become membranous. There is a great conical head (fig. 20 *a*), set with large setiform cilia all over the front, and behind descending into a rounded mass of several lobes, with a red eye (*b*) on the truncate apex of the posterior lobe. Several muscle-threads (*c*) pass longitudinally from this head-

mass to the hinder mass (*d*), which is connected with the foot (*g*) and the great protrusile penis. In the midst of this latter mass is situated the group of opake white granules (*f*), which are always so conspicuous in male ROTIFERA. The central part of the body is occupied by the spermatic sac (*e*),—a great pyriform vesicle, connected by a bottle-like neck with the head-mass, and apparently terminating posteriorly in a round form, where, however, a distinct corrugation probably marks an orifice closed by a sphincter, which leads to the discharging duct. On pressure, this sac is seen to be filled with bodies having a vermicular motion, and, on the pressure being continued, it bursts, giving issue to a number (about thirty) of spermatozoa (fig. 22). These spermatozoa are comparatively of great size, being $\frac{1}{300}$th of an inch long; they consist of a slender, nearly cylindrical body, merging into a long whip-like tail, which keeps up a quivering undulatory motion for several minutes after exclusion. With these are also extruded many spicula-like bodies (fig. 23), much more minute, somewhat fusiform, slightly curved, and motionless.

The penis (fig. 21) is, as usual, thick, and united to the foot, terminating in a short truncate tube, which I could not see to be ciliated. A few crimson pigment-cells, exactly agreeing with those of the eye, are usually seen in some part or other of the body, apparently in contact with the inner surface of the integument.

27. In the middle of the summer of 1850 I discovered the males of two or three other genera. The first of these was the curious form which I have named *Sacculus viridis** (fig. 24). I have had no opportunity of seeing the birth of females of this species, all the specimens that came under my observation (that bore eggs at all) carrying either one or two eggs of like size and appearance. From one of these eggs (fig. 25), which, before maturity, are much clouded and spotted with granules and globules, a young was produced in my live-box, which was, I doubt not, a male (fig. 26). I could not detect any eye (though this organ is conspicuous in the parent), nor any internal organization; nothing but a confused assemblage of granules and globules; even the ordinary opake masses were not present. The form somewhat resembled that of an amphora with a short wide neck; the frontal cilia were very large, but the motion was not rapid, nor was the animal wild, as male ROTIFERA usually are.

28. *Polyarthra platyptera* is another form, which, from its habit of carrying its deposited eggs, affords facilities for investigations regarding its sexuality. Finding it numerous in July, with eggs attached, I discovered that these presented the same diversity that I have mentioned above (§ 13, &c.). I isolated one with six small eggs attached, measuring $\frac{1}{700}$th × $\frac{1}{875}$th of an inch. Presently afterwards I found another, with a single egg attached, measuring $\frac{1}{292}$nd × $\frac{1}{437}$th of an inch. This egg was truly oval, being sharper at one end than at the other. Several of the smaller eggs were hatched together, about twenty-four hours after isolation. They

* From the description and figure of Dr. LEYDIG, I have no doubt this is identical with the genus *Ascomorpha* of PERTY. I had, however, characterized and named it in the 'Annals and Magazine of Natural History' for September 1851, a year before M. PERTY's work was published.

each produced a little animalcule (figs. 27, 28, 29), which, in its form, brightness, and motions, greatly resembled a free *Vorticella*. Its length was $\frac{1}{580}$th of an inch. The head (fig. 27) is very large, and the body tapers quickly to the posterior part, but both extremities are truncate. The front bears two warts, between which the rotatory cilia are placed, but the cilia are longer (perhaps *setæ*) on the warts. The hinder part is bifid (figs. 28, 29), the smaller division being the caudal extremity or toeless foot, and the larger a protrusile truncate penis, ciliated at the tip. No internal organization is discoverable. In one there was a globule in the midst of the great head, but under sunlight it reflected no colour, and it was wanting in another. Towards the posterior dorsal parts, a few irregular dark specks were visible, but generally the whole animal was clear, colourless, highly refracting, and showing an indistinct granulation. Its motions were swift and impatient, gliding about the field with headlong speed, occasionally remaining in one place for a few minutes, but not in stillness, for it was rapidly oscillating to and fro, and quivering.

29. The last observation that I have to offer is on *Synchæta tremula*. This genus does not carry about its eggs after their escape from the ovary, and as I did not see the hatching of the male I am about to describe, I cannot identify it with positive certainty.

30. In a phial of water obtained near Leamington, this *Synchæta* was very numerous, but I am not aware that any other Rotiferous animal was present. Among the hundreds which congregated, in their playful gyrations, just above the sediment, I found a specimen (figs. 30, 31) which was certainly a male, and, from its form, was probably of this genus. It was about $\frac{1}{220}$th of an inch long, obconical, with a rounded front, set with many long cilia, and surrounded by a prominent ring, also set with long cilia. The body was capable of taking a swollen or round form, when the separate foot was more distinct (fig. 31). The organization differed not from that of males of other species. A red eye sharply defined, a central granular viscus, contained in a longitudinal cavity, in the bottom of which lay a large, irregular, opake white mass, was all that could be traced internally. The foot seemed to carry a great protrusile penis, and to terminate in two minute toes. No spermatozoa were visible within, nor were expressed by the compressorium. The animal was active and swift. A constriction behind the wreath of cilia formed a well-marked neck.

31. From the following observations which I published in the 'Journal of Microscopical Science' for January 1853, I think I am justified in concluding that *Melicerta ringens* also produces separate male and female young:—

"Opening one or two cases [of *Melicerta*], I freed one and another very curious egg-like bodies, not symmetrical in shape, being much more gibbous on one side than on the opposite, and measuring $\frac{1}{150}$th $\times$ $\frac{1}{260}$th of an inch. Each was encircled by five or six raised ribs, running parallel to each other longitudinally, somewhat like the varices of a wentle-trap. Viewed perpendicularly to the ribs, the form is symmetrical—a long narrow oval. The whole surface between the ribs appeared punctured or granulate, and the colour was a dull brownish-yellow. Under pressure it was ruptured, and discharged an

infinity of atoms of an excessive minuteness, but every one of which, for a few seconds, displayed spontaneous motion. Their whole appearance, and the manner in which they presently changed to motionless disks, were exactly the same as of the spermatozoa which the male eggs of other ROTIFERA contain, except that these were so minute.

"From another I extracted an egg of the ordinary form and appearance. It was very long, measuring $\frac{1}{145}$th × $\frac{1}{390}$th of an inch. The contained embryo was well-advanced; two red eyes were plainly seen by reflected and by transmitted light: the gizzard was transverse, very large in proportion, and the jaws worked vigorously: a little opake body, white under sunlight, was in the posterior part. This embryo died without hatching."

32. Thus there is evidence of the dicœcious character in the following genera and species of ROTIFERA:—

Asplanchna Brightwellii.	*Brachionus amphiceros.*
Asplanchna priodonta.	*Brachionus angularis.*
Asplanchna Sieboldii.	*Brachionus Bakeri.*
? *Synchæta tremula.*	*Brachionus Dorcas.*
Polyarthra platyptera.	*Brachionus Mülleri.*
Brachionus Pala.	*Sacculus viridis.*
Brachionus rubens.	*Melicerta ringens.*

And it is presumed, with a high degree of probability, to mark also the following:—

Hydatina senta.	*Diglena catellina*.*

33. It must be borne in mind, too, that there is no direct evidence on the other side; for no species has, I believe, been actually proved to be hermaphrodite. Hence, I think, we may reasonably conclude a distinction of sex to be the normal condition of the Class, or at least of that great group which is most typical, viz. such as have articulated *mallei* working upon a separate articulated *incus*. Whether the same rule prevails so generally in those which have the *mallei* and *incus* fused together into quadrantic masses, and in those in which these organs exist in a rudimentary condition, is a question yet to be determined. As these are certainly the lowest forms of their Class, it is possible that hermaphroditism *may* be found in them—in the *Philodinadæ* for instance.

34. In summing up the results of the herein-recorded, as well as of former observations, the most prominent thing that strikes us is the absolute and universal atrophy (so far) of the digestive system in male ROTIFERA. It was first observed with admiration in *Asplanchna Brightwellii*, and has been found to belong, without exception, to every male since observed. Mr. DALRYMPLE, indeed, remarked a little isolated congeries of vesicles in the cavity of the male of the species just named, and I have seen it also. Possibly this may be the lingering rudiment of a stomach, but it is scarcely likely; and

* Since this memoir was read, I have been enabled to add to the above list *Notommata Brachionus*. The male of this species much resembles those of the *Brachioni*, equalling in its organization the male of *B. Mülleri*. Its form, however, is as conical as that of *Synchæta*.

whatever it be, no semblance of such viscera is to be traced in *A. priodonta*, or in any other male that has come under my observation.

35. Another curious peculiarity is the dissimilarity that always subsists between the sexes. In *Asplanchna* and *Hydatina* the resemblance is at its highest point: in every other instance observed, the sexes are so unlike, that they would be taken for widely remote genera. The male is always inferior in size, and also in organization, to the female.

36. Whether certain individuals produce only male, and others only female young, or whether separate impregnations are required for the production of the separate sexes, I do not know; but from all my observations, I gather that the development of the one sex never takes place coetaneously with that of the other; for male and female eggs are never seen attached to the same parent, and the immature eggs in the ovary invariably develope themselves into the same sex as those which are already extruded.

37. The duration of life in the male is always very brief. I have never been able to preserve one alive for twenty-four hours. Their one business is to impregnate the females, which is the work of a few minutes, probably, in a state of freedom; and for this momentary occupation no supply of loss by assimilation of food is wanted; and hence we can understand the lack of the nutritive organism.

38. *Some* organs are found, with greater or less distinctness, in all. The (presumed) male of *Hydatina senta* received its names of *Enteroplea* and *Organ-fisch* from EHRENBERG, on account of the copiousness of its internal organization. A muscular system is well-developed there, and in the males of *Asplanchna* and of *Brachionus Mülleri*; and, from the varied movements of all, its existence may be inferred where it is not detected. The frontal cilia are, in almost all cases, much more developed than in the females; the result of which endowment is seen in the excessive rapidity with which the male shoots in all directions through the water. The great head-mass of granular substance is generally distinct; and in several cases (as in the *Asplanchnæ* and in *Br. Dorcas* and *Mülleri*) the great occipital ganglion is well-defined, with the red eye seated on it as in the other sex. Even where the ganglion is not apparent, the eye is conspicuous, with the exception of *Sacculus* and *Polyarthra*; and in this last instance the small size of the animal must be borne in mind, and the density of the anterior parts.

39. In the (presumed) male of *Hydatina*, in those of all the *Asplanchnæ*, and of *Brach. Dorcas*, there are organs answering to the lateral convoluted threads of the female; and, in *Aspl. Brightwellii*, at least, these are accompanied by tremulous tags, and by a contractile bladder.

40. A large mass of substance, which, being perfectly opake, appears black by transmitted light, but is white when the rays are reflected, is so generally found in male ROTIFERA, as to be characteristic, though it is not universally present. I do not find it in the *Asplanchnæ*, nor in *Sacculus*. On the other hand, I have observed it in the young of *Stephanoceros*, *Floscularia complanata*, and *F. cornuta*; and EHRENBERG mentions it in *F. ornata* and *Lacinularia*. In *Stephanoceros*, it was certainly associated with well-developed jaws; and hence I presume it is not exclusively an indication of the male sex.

The mass is sometimes broken up into fragments of irregular size and shape, and sometimes apparently pulverulent. In general, it appears to lie loosely in the midst of the granular amorphous matter that occupies the posterior region of the body-cavity; but in *Brach. Pala*, and especially in *B. amphiceros*, I have fancied that I discerned traces of a vesicle, within which the white substance seems to be contained.

41. On the nature of this substance I have no light from personal research. Dr. LEYDIG, however, considers it to be a urinary concretion (*Harnconcremente*), analogous to the chalky fluid which is discharged by many insects, immediately after their evolution from pupa.

42. In the male of *Asplanchna Brightwellii*, there is, as its discoverer observes, "a conspicuous round sperm-vessel, or testis, in which ..... spermatozoa in active vibratile motion may be seen*." Mr. DALRYMPLE, and subsequently myself, also saw these, both within the sac and discharged by pressure. Each spermatozoon, according to my own observation, consists of an oblong body, $\frac{1}{1750}$th of an inch long, and an abrupt, slender, vibratile tail, of equal length. In the sperm-sac of *A. Sieboldii*, Dr. LEYDIG finds various seminal elements, viz. round cells; pyriform cells, drawn out to a fine point, and adhering to each other by their rounded ends, in a stellate manner; oblong bodies, with one side dilated into a free, undulating, membranous border; and slender, stiff, rod-like bodies, with a central swelling; all containing nucleated nuclei†. On the male of *A. priodonta*, my observations were too limited to determine more than the existence of the globular sperm-sac.

43. In *Brachionus rubens* and *B. Mülleri* I found spermatozoa, which I have above described (§§ 13 and 26). In the latter, the sperm-bag is of great size, and contains, besides the spermatozoa of unusual development, slender spiculiform bodies (fig. 23), which may be the equivalents of the little rods described by Dr. LEYDIG in *Aspl. Sieboldii*. The sperm-bag (in *Br. Mülleri*) is closed posteriorly, as it is also in *Aspl. Brightwellii*, by what appears to be a true sphincter (fig. 20); and such I conjecture to be the explanation of those diverging lines which M. DUJARDIN saw in *Enteroplea* (so-called), which he considered to be pedicels of his "*touffes de granules*," while the "*touffes*" themselves I take to have been the masses of urinary concrement. Dr. LEYDIG, however, considers the whole to have been masses of spermatozoids.

44. The outlet of the sperm-bag is, in all cases, by a thick protrusile and retractile penis. Wherever a foot exists, this intromittent organ is continuously united to its dorsal side, and is often so greatly developed that the foot itself appears as an appendage. The protrusion of the organ, at least in most of the examples that I have noticed, is by the eversion of the integuments. When these are evolved to the utmost, the organ is seen to be a thick column, conical or nearly cylindrical, with the extremity truncate, and surrounded by a wreath of vibratile cilia. It was, doubtless, the extremity of the penis that M. DUJARDIN saw, as "*un organ cilié entre les muscles de la queue*," in the (so-called) *Enteroplea*. The male of *Sacculus viridis* (fig. 26), a species which is footless in

* BRIGHTWELL in 'Ann. Nat. Hist.,' Sept. 1848.

† *Op. cit.* p. 32.

both the sexes, is the only example in which I have not seen the penis; but the organ is probably wholly retractile within the body, and my observations, on the only individual of this sex that I saw, were insufficient to determine anything concerning it.

45. For a parallel to the curious facts thus established we must look only to the CRUSTACEA. The economy of the *Hectocotylus* of certain Cephalopod MOLLUSCA, though perhaps even still more abnormal, is only remotely analogous. Nor is the parallelism very close of those ENTOZOA in which the males are organically united to the females, as the genera *Heteroura* and *Syngamus*, described by Professor OWEN*.

46. In the Class CRUSTACEA, however, many examples occur of a sexual difference, which may instructively be compared with the one before us. Thus, among the *Isopoda*, we find the parasitic genera *Bopyrus*, *Phryxus*, and *Ione*, in which the males are notably smaller than the females, very diverse in form, and in some respects inferior in structure. In the *Siphonostoma* "the males are extremely small, and do not in the least resemble the females†," though those of different genera bear a strong resemblance *inter se*, even when the females are very dissimilar. So low is their grade of organization, that BURMEISTER has attempted to prove these minute creatures to be embryonic or larval forms. And, finally, in the CIRRIPEDIA, Mr. DARWIN has proved the existence of males in the genera *Ibla* and *Scalpellum*, which are very minute as compared with their females, excessively abnormal in form, and in some respects in an embryonic condition, though unquestionably mature, as shown by the spermatozoa‡. And, what is still more interesting, the same accurate zoologist observes,—"After the most careful dissection of very many specimens ..... I can venture positively to assert that there is no vestige of a mouth, or masticatory organs, or stomach§." Again, he describes the internal structure as "a pulpy mass with numerous oil-globules," and the sperm-vesicle as "a pear-shaped bag at the very bottom of the sack-formed animal, containing either pulpy matter, or a great mass of spermatozoa‖,"—terms which might have been employed in describing some of the male *Brachioni* (§ 26, &c.).

47. In all these analogies I conceive we may find additional reasons, to those that have been before adduced, for assigning to the ROTIFERA a zoological position among the ARTICULATA.

EXPLANATION OF THE PLATE.

PLATE XV.

Fig. 1. *Brachionus Pala*; male egg, nearly mature.
Fig. 2. *Brachionus Pala*; male, newly born.
Fig. 3. *B. rubens*; male egg, nearly mature.
Fig. 4. *B. rubens*; spermatozoa from the same egg.
Fig. 5. *B. rubens*; male, newly born.

* Cycl. of Anat. and Physiol. p. 142.
† BAIRD's 'Entomostraca,' 325.
‡ Monograph of Lepadidæ, 198.
§ Ibid. 235.
‖ Ibid. 236.

Fig. 6. *B. amphiceros*; male egg, just laid.
Fig. 7. *B. amphiceros*; female egg, nearly mature.
Figs. 8, 9, 10. *B. amphiceros*; males.
Fig. 11. *B. Bakeri*; hinder part of an adult female. *a*, male egg in the ovisac; *b*, egg just laid; *c*, egg nearly mature; *d*, empty egg-shell.
Fig. 12. *B. Bakeri*; male.
Figs. 13, 14. *B. angularis*; males.
Fig. 15. *B. Dorcas*; empty shell of female egg.
Fig. 16. *B. Dorcas*; male egg, mature.
Fig. 17. *B. Dorcas*; female, newly born.
Figs. 18, 19. *B. Dorcas*; males, newly born.
Fig. 20. *B. Mülleri*; male. *a*, head-mass; *b*, eye; *c*, muscles; *d*, posterior mass; *e*, sperm-sac; *f*, urinary concretion; *g*, foot.
Fig. 21. *B. Mülleri*; penis and foot.
Fig. 22. *B. Mülleri*; spermatozoa.
Fig. 23. *B. Mülleri*; spiculiform bodies.
Fig. 24. *Sacculus viridis*; adult female, carrying male eggs.
Fig. 25. *Sacculus viridis*; male egg, just laid.
Fig. 26. *Sacculus viridis*; male, newly born.
Figs. 27, 28, 29. *Polyarthra platyptera*; males.
Figs. 30, 31. *Synchœta tremula* (presumed); male.

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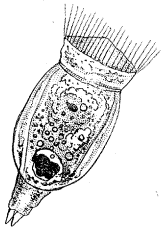

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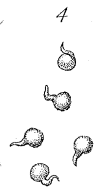

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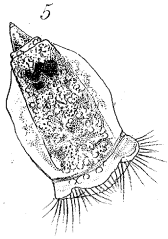

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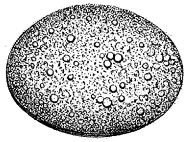

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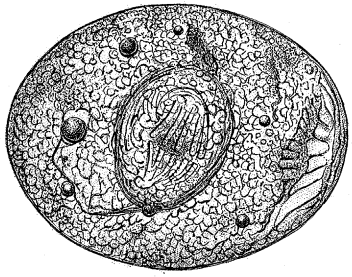

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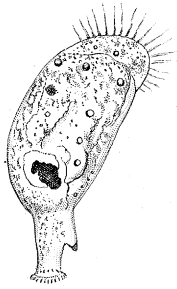

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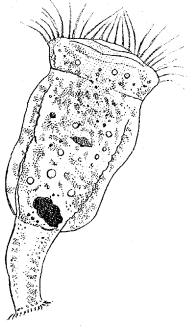

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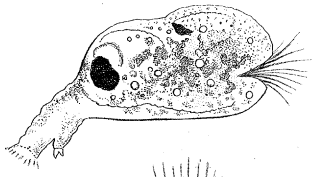

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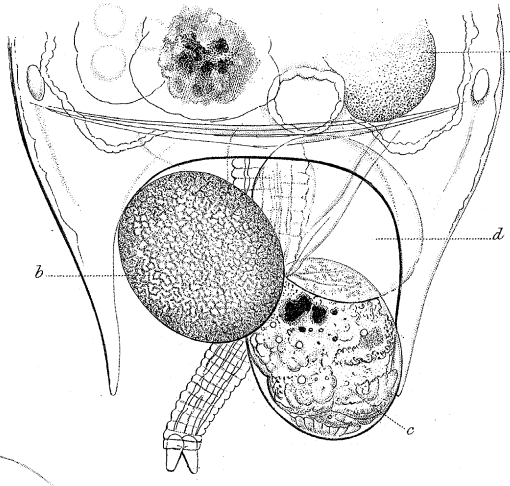

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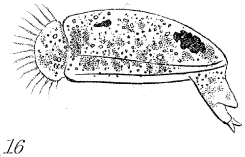

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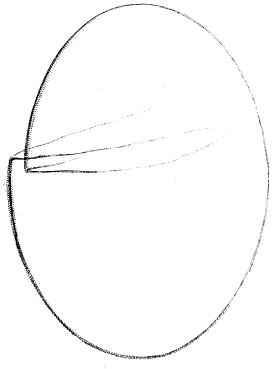

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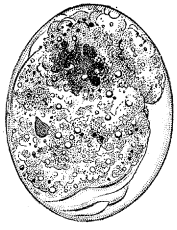

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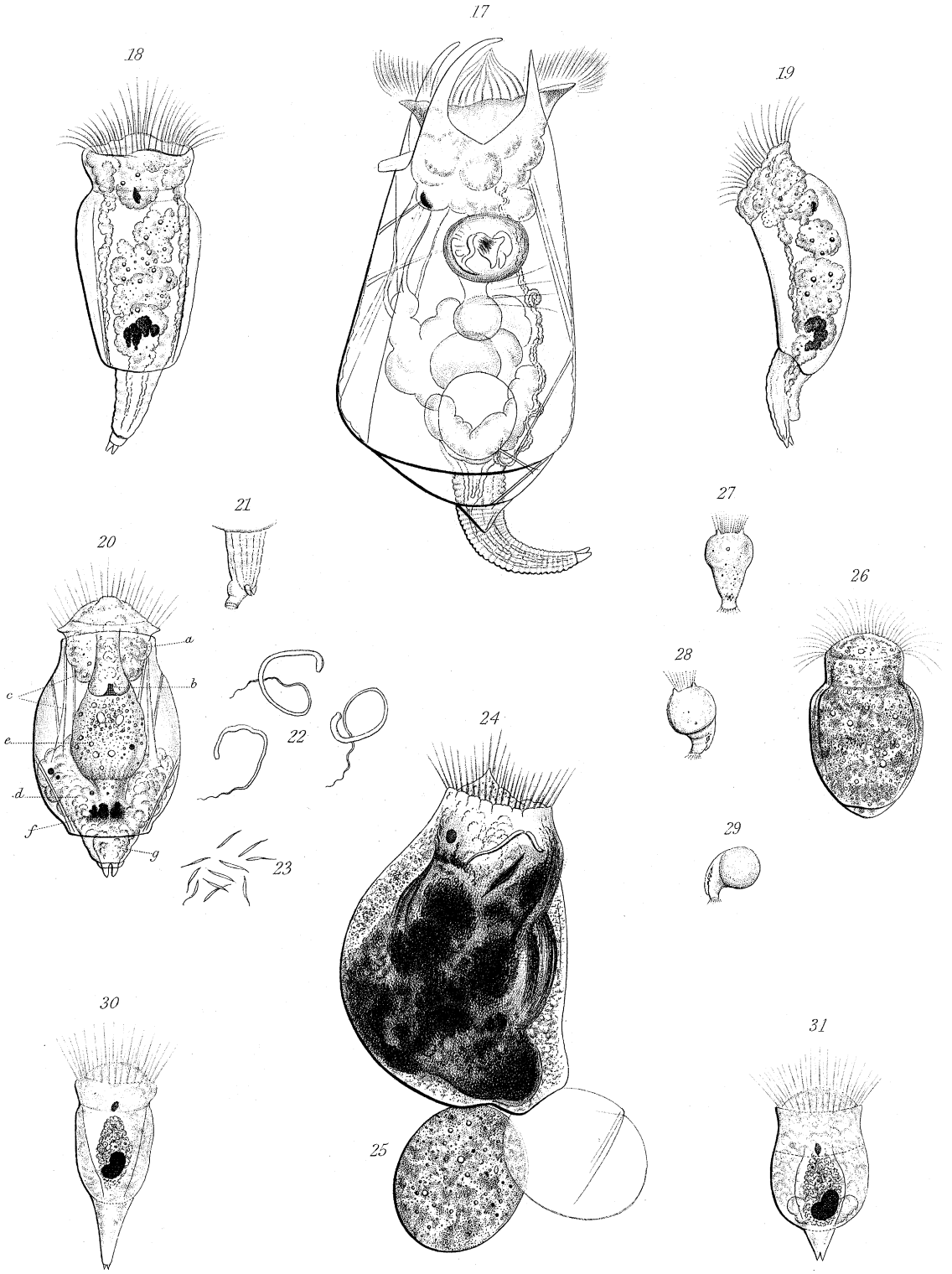
P.H.Gosse, ad viv. del.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