PHILOSOPHICAL TRANSACTIONS.

XIX. *On the Structure, Functions, and Homologies of the Manducatory Organs in the Class* Rotifera. *By* Philip Henry Gosse, *Esq. Communicated by* Thomas Bell, *V.P.R.S., Pres. L.S.*

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1. An examination of the whole alimentary system in the class Rotifera would include—The buccal funnel; the manducatory apparatus, with its muscular bulb and the muscular bands by which it is retained *in situ*; the salivary glands; the œsophagus; the pancreatic glands; the stomach; the hepatic follicles; the cæca; the intestine; the rectum; and the cloaca. Of these, however, the manducatory organs will occupy my principal attention; and I shall endeavour to trace them throughout the class; and to show, that the various forms which they assume can all be reduced to a common type. I also propose to inquire, what are the real homologues of these organs in the other classes of animals; and what light we can gather, from their structure, on the question of the zoological rank of the Rotifera.

2. Considering the attractive appearance which the Wheel-animals present, and the facilities which are afforded for their investigation by their abundance—since they are found in great variety in almost every river, lake, pond, and ditch,—it is rather remarkable that they have been so little studied.

3. The foundation of our acquaintance with the organization of the Rotifera was broadly laid by Professor Ehrenberg, in the 'Transactions of the Berlin Academy,' as early as 1830; and in 1838 he published his 'Infusionsthierchen,' a work which, in spite of its mistakes and deficiencies, must be considered a magnificent monument of industry and scientific acumen. It is true, Leeuwenhoek, Baker, Joblot, and other early microscopists had figured a few species; and Rösel, Schäffer, and especially Müller, had attempted to resolve the internal anatomy of some; but all that had been accomplished amounted to little more than vague guessing, when Ehren-

BERG took them up. He penetrated into the minute organization of these animals; resolved and figured, with a precision and minuteness up to that time unattempted, the nutritive, circulatory, nervous, muscular and generative systems; and, though the details of some of the organs which he has described existed only in his imagination, and the functions of others which he clearly saw were quite misunderstood, it would be absurd to deny that his elaborate plates and descriptions are generally faithful representations of these minute creatures.

4. M. DUJARDIN, like his great predecessor, included the ROTIFERA, by the name of *Systolides*, among the INFUSORIA, in his work on the subject published in 1841. In many particulars his observations, which were largely polemical, have advanced our knowledge of the subject; but in some respects they are a retrogression. His personal acquaintance with species was greatly inferior to that of the Prussian zoologist, and insufficient for satisfactory generalisation.

5. Since then, I am not aware that any naturalist has attempted, *from personal observation*, a revision of the class, or even of any considerable number of species; and the science has advanced, chiefly, by isolated papers on individual species, and by critical examinations of the facts already accumulated. These memoirs I shall enumerate in chronological order.

6. In 1843, Dr. KÖLLIKER published a memoir * on *Megalotrocha*, confining himself to the segmentation of the egg, and the (so-called) seminal threads. Dr. OSKAR SCHMIDT, in 1846, gave a résumé of what was then known of the organization of the ROTIFERA generally †. In the same year, the late Dr. MANTELL, in his 'Thoughts on Animalcules,' though chiefly founded on EHRENBERG, added some information of interest and value on the development of the young in *Stephanoceros* and *Melicerta*. In the 'Annals of Natural History' for 1848, Dr. DOBIE described with minuteness two new species of *Floscularia*; and Mr. BRIGHTWELL recorded his important discovery of the diœcious character of a ROTIFERON which I have since named *Asplanchna*. The same species formed the subject of a valuable memoir by Mr. DALRYMPLE ‡, read before the Royal Society in February 1849. Meanwhile, however, some additional observations had appeared by Dr. LEYDIG §, on the egg-segmentation of *Notommata*, *Euchlanis*, and *Megalotrocha*; and in the same year (1848), Dr. FREY had published a work on the class generally ||, which I have not been able to see.

In 1850 I published several memoirs on ROTIFERA in the 'Transactions of the Microscopical Society' and the 'Annals of Natural History,' viz. "On the Habits of *Melicerta ringens* ¶" (January); "On the Anatomy of *Notommata aurita* ¶" (May); "On *Asplanchna priodonta* **" (July); and "On *Notommata parasita* ¶" (December).

* FRORIEP's Neue Not., No. 28. p. 17.

† WIEGMANN's Archiv, 1846, p. 68.

‡ Philosophical Transactions, 1849.

§ Isis, 1848, p. 170.

|| Ueber die Bedeckungen der wirbellosen Thiere. Göttingen, 1848. This work I know only by a citation in SIEBOLD and STANNIUS' 'Comparative Anatomy.'

¶ Trans. Micr. Soc. i. pp. 58, 93, 143.

** Ann. Nat. Hist. July 1850.

In 1851 I published a catalogue of 108 species that I had observed, including descriptions of five new genera and thirty-two new species*. In this latter year M. d'Udekem published in the 'Memoirs of the Brussels Academy' two papers†, the one on the circulatory system in *Lacinularia socialis,* the other on *Floscularia cornuta*; the latter as if a new species, but which had been described and figured by Dr. Dobie four years before.

The former of these animals, *Lacinularia socialis,* became the subject of two very valuable papers in the year 1852; the one by Mr. Huxley‡, and the other by Dr. Leydig §. In the following year appeared a "Memoir on the Anatomy of *Melicerta ringens,*" by Professor Williamson ||, closely followed by a second ¶ on the same species, by myself.

7. In this enumeration I believe I have included all that has been published on the subject of the Rotifera, *from original observation*: should anything, however, have been omitted, it is because it has eluded my most careful scrutiny.

8. What changes may have been produced on the state of our knowledge of the nervous, vascular, glandular, muscular and reproductive systems of the Rotifera, by these researches, it is not my province here to inquire. My present business is with the digestive system, and particularly with the organs of manducation; and of these, I think it is no more than the truth to say, our knowledge is almost exactly where Ehrenberg placed it five-and-twenty years ago.

9. This assertion seems strange after so many memoirs, of more or less value, by different observers, on various species; but the wonder is much lessened by a re-examination of their subjects. Of the thirteen monographs enumerated, two are on *Floscularia,* three on *Melicerta,* three on *Lacinularia,* three on *Asplanchna,* and two on *Notommata.* Now in *Melicerta* and *Lacinularia* the manducatory apparatus is of the same type, *and that an abnormal one*; in *Floscularia* and *Asplanchna* the types of structure differ widely from the former, and as greatly from each other. These three types are in fact unintelligible in themselves, and can be explained only by tracing the organs from their normal development, through their modifications and degenerations. Nothing then, in fact, has been attempted towards an explanation of the jaws, in the great families of *Hydatinæa, Euchlanidota,* and *Brachionæa*—the true types of Rotifera—except my own two memoirs on *Notommata* in 1850. And I freely confess, that, in spite of many and persevering efforts, I had not, at that time, been able to attain any satisfaction on the true structure of these organs.

10. Nothing is easier than to see the forms of the various parts, *in outline,* in some one aspect; to obtain, for example, a dorsal or ventral view of the jaws in *Brachio-*

* Ann. Nat. Hist. Sept. 1851. † Bull. de l'Acad. Belg. xviii. pp. 39, 43. ‡ Journ. Micr. Soc. i. (Trans.) p. 1.
§ Sieb. et Köll. Zeitschr., Feb. 1852. || Journ. Micr. Soc. i. (Comm.) p. 1.
¶ Ibid. p. 71. Note.—Since the presentation of this paper to the Royal Society, there has appeared in the 'Journal of Microscopical Science' an abstract of another memoir by Dr. Leydig, "On the Structure and systematic Position of the Rotifera." The original I have not yet had an opportunity of examining.—P. H. G.

nus, or a lateral one in *Furcularia*: but when we have done this, we have gone but a little way towards such an understanding of the whole form, and the relation of the complex parts to each other, as will enable us to project them, or to form an ideal model of the whole. A little more light is shed on the structure by crushing the animals between plates of glass, or under the graduated pressure of a compressorium: but the distortion of the parts is very great; and some of them, especially those which form the intermediate piece (*incus*), on which the greatest obscurity rests, are almost invariably broken into a multitude of separate fragments in the process of flattening; and thus the result merely tantalizes the expectation.

11. Little more seems to be yet known of the structure of the manducatory organs (I speak of the normal forms) than can be obtained by these modes, and the published descriptions of them are vague and unsatisfactory.

12. Thus Ehrenberg describes the general structure as follows:—"The normal intestinal canal in the Rotifera consists first of a globose muscular throat-bulb (*schlundkopf*), in which are fixed two toothed jaws, and the anterior opening of which is placed in the midst of the wheel-organ, somewhat towards the belly [side]*."—"In all the forms there is a moving manducatory organ (*kauorgan*), furnished, in forty-eight genera, with indubitable teeth, and evidently ministering to the alimentary canal †."

Again, in proposing a division of the class, according to the teeth, he groups the Rotifera as, i. Toothless (*Agomphia*); ii. Free-toothed (*Gymnogomphia*), where the teeth resemble the fingers of a hand fastened to the jaw-frame behind, but free in front; iii. Bound-toothed (*Desmogomphia*), where the teeth are fastened across upon the jaw, like an arrow upon a bow ‡.

The most laboured description of the normal structure the same zoologist has given under the genus *Hydatina*, which he professedly makes the vehicle for a *résumé* of his acquaintance with the typical forms of the class. "The nutritive system," he observes, "consists of a great buccal cavity, chiefly enclosed and formed by the rotatory organ, as an upper lip; in the bottom of which, near the ventral side, lies the spherical four-muscled throat-bulb, with two many-toothed jaws. In each jaw are held five conical teeth, resembling a hand, somewhat converging towards the bottom, diminishing in size inwardly. Sometimes a minute sixth tooth appears to be developed. The five teeth of each jaw, which are perceived, on crushing the body between glass plates, to be the only hard and solid parts, are jointed into a cartilaginous frame, which serves for the attachment of the muscles, and has the form of a shoulder-blade. This is the proper jaw, which is composed of several parts. Inwardly, both jaws are in connexion with a frame of cartilaginous throat-arches, which is very complicated, and seems more fitted for the support and attachment of the masticatory muscles than for proper activity §."

13. I shall presently show that these descriptions are both very imperfect and very

* Trans. Berl. Acad. 1830, p. 29. † Infusionsth. p. 385. ‡ Ibid. p. 386. § Ibid. p. 414.

incorrect; and the figures, with which they are illustrated, are but rude approximations to verisimilitude.

14. M. Dujardin sums up his observations on the same organs in the following words. After alluding to the Tardigrada, which he includes in his Systolides, the genus *Enteroplea*, which is said to be toothless, and the genera *Floscularia* and *Lindia*, which he describes (incorrectly) as lacking a ciliated mouth, he observes,—

"All the other Systolides, having jaws enclosed in a muscular pharyngeal bulb, which is moveable and protractile, at the bottom of a ciliated vestibule, may be distinguished according to the form of these jaws. Thus the *Rotifers* have their jaws in the form of a stirrup, opposed by the base, and bearing two or more small teeth, laid parallel, like arrows on a bow. The outer border, which is semicircular, furnishes a point of attachment for the muscles of the pharyngeal bulb; and, drawn by them, it is strongly elevated and depressed, to produce, during manducation, the movement of the jaws. Their inner border is composed of two transverse bars, a little arched outwardly. . . . . All the others . . . have jaws more resembling those of articulated animals, and composed of an assemblage of articulated pieces, which we may, up to a certain point, compare to the two pairs of mandibles and jaws, to the lips, to the tongue, and to the labial palpi of insects. In fact, in many of the Systolides we observe a central odd piece, on which are articulated two simple branches, which bear upon each other, or meet as by a hinge, in the midst of moveable and articulated pieces, supporting the jaws properly so called, and transmitting to them, thus, all the effort of the median muscular mass, to make them bite upon the prey, by furnishing to them a *point d'appui*, when the lateral muscles draw back the external branches which carry the jaws *."

15. The eminent French naturalist, in this description of the jaws, which appears to be drawn from the type found in such genera as *Diglena* and *Albertia*, has touched a key which might have unlocked the structure, not in a few genera only, but in the whole class of Rotifera. As it is, however, I cannot agree with Dr. Oskar Schmidt, that the arrangement and function of the teeth, and of the surrounding bulb, are so manifest as to need no further observation †.

16. It may not be out of place to describe the manner in which the following observations were made. The desideratum was to obtain views of *various aspects* of the same animal; particularly of the dorsal and ventral aspects, of the lateral, and of the vertical or frontal. But the minuteness of the objects, ranging from $\frac{1}{300}$ to $\frac{1}{50}$th of an inch, precluded the possibility of affixing them to a needle, or other machinery, by which they could be made to revolve while in the field of vision; and the more, since, being aquatic animals, they must be viewed immersed in water; a momentary removal causing the death of most species. The incessant activity of these little animals is also a great bar to accuracy of observation, if they be allowed freedom; and if we confine them by means of the compressorium, the form of their

* Infusoires, p. 583.

† Wiegmann's Archiv, 1846, p. 69.

bodies causes them to present almost invariably the same aspect to the observer, viz. that in which the greatest width is at right angles to the line of vision; so that we may examine specimen after specimen, till patience is exhausted, and acquire no new information, because we look each time at the same aspect.

17. In the course of experiments with various chemical reagents on these animals, I found that a solution of potash had the effect of instantly dissolving the flesh, and most of the viscera; leaving the general integument, the walls of the pharyngeal bulb, and all the solid parts of the manducatory apparatus uninjured*. In most cases, also, the last-named organs are expelled from the visceral cavity by the contraction of the integuments; so that they float at large, in brilliant clearness, undimmed by intervening tissues, and as patent to observation as when crushed between plates of glass; with the advantage of all the parts being unbroken, and retaining their relative positions. Now, by turning the screw of the compressorium, flattening or deepening the drop of water, waves were communicated to it, by means of which the floating bulb, being nearly globular, was made to revolve irregularly, and thus to present, in succession, various aspects to the eye.

18. The observations which I am about to record were made with one of Powell and Lealand's microscopes, with a power of 560 diameters; except those on *Stephanoceros* and *Diglena*, on which the powers employed were 220 and 300 diameters.

19. For the sake of precision in description, it may be well here to mention a few terms that I shall employ, and to define the sense in which they will be used. The symmetry of the Rotifera is truly bilateral, the genera *Stephanoceros* and *Floscularia* alone retaining a lingering remnant of radiism, in the arrangement of the frontal lobes; even in these, however, the whole of the anatomy besides, both external and internal, is bilateral. In most cases this arrangement is obvious; the motions of the animal, like those of the footed larvæ of insects, being performed on the belly, with the head foremost. Where this is not the case, as with those genera which, either with or without an enveloping tube, adhere to foreign substances by the tip of the foot, and elevate the body in an erect position, the *dorsal* aspect is always determinable by the eye or eyes being towards that surface, by the stomach and intestine passing down it, and by the cloaca being on that side of the foot. The *ventral* aspect has the manducatory apparatus, and the ovary. The *anterior* extremity carries the vibratile cilia; the *posterior* is terminated by the foot. In such species as are clothed with a lorica, I shall call the anterior termination of the dorsum, the *occipital* edge; and the anterior termination of the venter, the *mental* edge. Other terms will be defined in the process of description.

20. As the manducatory bulb, with its complex contents, is the principal subject of these observations, I shall commence with it; treating the other parts as accessory to it. In most Rotifera this organ forms a prominent object, conspicuous from its

* Dr. Leydig, I find, has used the same agent in examining the teeth in *Lacinularia*; but he does not appear to have employed it in the investigation of other Rotifera (Siebold and Köll. Zeitschr. 1852).

form and motions. By old observers the vigorous workings of its internal parts caused it to be mistaken for a heart; but it has long been recognized as an organ of mastication. Dr. Ehrenberg sometimes calls it *Kauorgan*, but more generally *Schlundkopf*, and its contents *Kau-apparat*. M. Dujardin speaks of it as *le bulbe pharyngien*. Von Siebold calls it a *pharynx*; and English zoologists have generally used the term *gizzard*. I hope to prove that it is neither a gizzard nor a pharynx, but a true *mouth*: in the mean time, however, whatever its homological value, it is doubtless a form of apparatus which has no parallel in other classes of animals, and therefore deserves a proper appellation. I propose then to appropriate to the sub-globose muscular bulb, which contains the manducatory organs in most Rotifera, the term *mastax*.

21. The *mastax*, with its contents, is found in the highest degree of development in the genera *Brachionus*, *Euchlanis*, and some of the *Hydatinæa*. It is usually more or less globose in form, composed of three lobes, which are confluent anteriorly, with a common rounded outline; but separated posteriorly, one lobe diverging towards the ventral side, the others laterally, and a little dorsally; so that a posterior aspect would assume the outline of a trefoil. The general form is sub-hemispheric in *Brachionus* and its allies; that of an oblate spheroid in *Euchlanis*; a prolate spheroid in *Notommata aurita*; cordate in *Notommata petromyzon*; sub-triquetrous in *Plagiognatha*; triglobular in *Notommata clavulata*; purse-like in *Mastigocerca*; irregularly oblique in *Synchæta* and *Polyarthra*; and wanting in *Floscularia*.

22. In substance it varies from a state in which its walls are thick and solid, composed of dense muscular fibre, with little cavity, as in *Brachionus*, to one in which it forms a capacious sac, with thin, apparently membranous, parietes, as in *Furcularia*.

23. The anterior side of the *mastax* is perforate, its walls here merging into the tube of the *buccal funnel*. It is perforate also on its dorsal aspect; whence the *œsophagus* issues to join the stomach.

24. Let us now examine in detail the *mastax*, in the modifications which it assumes in various species. In *Brachionus urceolaris* (Plate XVI. figs. 1 to 10), it is a dense, colourless, highly-refractive mass of muscles, sub-hemispherical, distinctly trilobate posteriorly, and cleft deeply on the ventral side of its anterior surface (fig. 1). Within it are placed two geniculate organs (*b*), which, from their resemblance in form and action to hammers working on an anvil, I have elsewhere named *mallei*; and a third (*f*), still more complex, which I call the *incus*. These three pieces are not arranged in the same plane; for the *mallei* approach each other a little dorsally, while the *incus* is placed on the ventral side of the centre, its stem pointing considerably towards the same side. Thus each of the three organs corresponds to, and occupies the centre of, one of the lobes of the *mastax*. This obliquity of the parts with respect to each other, and to the planes of the body, is one cause of the great difficulty which attends an endeavour to reconcile the various aspects of this organ in any intelligible manner.

25. Each *malleus* consists of two principal portions, articulated with each other by

a powerful joint, which seems to be ginglymate in its character, admitting of motion in one plane only. The two opposing surfaces appear to be united by elastic ligaments, while their irregularities lock into each other.

26. The inferior portion of the *malleus*, which I shall call the *manubrium* (*c*), is an irregularly-curved piece, shaped somewhat like the scapula of a mammal, knobbed at its head, and flattened at its lower or free end, where also it is twisted to one side. Ridges run down it, on both the interior and exterior surfaces. The head is obliquely truncate; and it is this oblique surface (*d*), that is jointed to the superior portion (*e*), which, from its prevalent form in other genera, rather than in this, I call the *uncus*.

27. The *uncus*, when at rest, is placed nearly at right angles to the *manubrium*, but is capable of considerable change of relative position by means of the joint. It consists of five or six *finger-like processes* (figs. 2, 3), set parallel to each other, and separated by narrow interspaces, which appear to be occupied by a thin membrane. These are not joints, moveable *inter se*, but resemble the teeth of a comb in their mode of origination. They are slender, rough, and enlarged at their tips; and the ultimate one of the series, next the dorsal side (fig. 3), is an offshoot from the penultimate. Their extremities are bent abruptly downward, approaching each other; and they are so arranged, that the whole *uncus* forms a segment, about one-third, of a cylinder, or a drum with incurving sides, with a broad truncate end (fig. 4).

28. The *incus* (*f*) also consists of distinct articulated portions. The principal are two stout *rami* (*g*), together vase-like in ventral aspect (fig. 1), resting on what appears to be a slender pedicel (*fulcrum*, *h*). But viewed laterally, the *fulcrum* is seen to be a thin plate (fig. 5), to one edge of which the *rami* are jointed, in such a manner, that they can open and close, like a pair of shears. Each *ramus* is a thick, somewhat trigonal piece, with the outer side rounded, the upper side hollowed, and the inner side flat, and in contact with the corresponding face of its fellow, in a state of repose. The *uncus* of each *malleus*, respectively, falls into the concavity of each *ramus*; and is fastened to it by a stout triangular muscle (*i*), which is seen passing from the hollow of the *ramus* to the under surface of the *uncus*.

29. Such are the firm parts; which, whatever their material, have great strength, solidity, and density. Their density, however, is not uniform; for, in some parts, they appear to merge insensibly into membrane, or into the muscular bands. They are perfectly transparent and colourless, and have a high refractive power. Their substance is not affected by a solution of potash, but is instantly dissolved, without effervescence, by hydrochloric, nitric, and acetic acid. Sulphuric acid also dissolves it, without any ebullition that appears to originate from the contact.

30. The special muscles which move these organs are numerous, and several of them massive. The walls of the *mastax* themselves are, as has been already said, muscular, and so thick as to leave the internal cavity but small. There are indications of muscles, which I have not been able satisfactorily to define; but the following are well made out. A thick muscle (*j*) embraces the upper and outer angle of the

articulation of the *malleus*, and is inserted in the wall of the *mastax* immediately over against it. A semi-crescentic band (*k*) is inserted, by its broad end, into the inferior and basal part of the *uncus*, and by its slender end into the middle of the inner side of the *manubrium*. The former of these (*j*) may be considered as an *extensor*, the latter (*k*) as a *flexor*. A broad and powerful band (*l*) is inserted along the whole inner side of the *manubrium*, and also apparently into the basal part of the *uncus*, and passes inwards towards the posterior or lobate wall of the *mastax*; into which it probably merges, as I have not been able to trace its inferior insertion.

31. The movements of these organs are very complex. The most conspicuous is an alternate approach and recession of the two *unci*, by a perpendicular motion on the hinge-joint. The opposing faces come into successive contact, and bruise down the particles of food in the manner of mullers. But a moment's observation shows that there are other movements besides this. The *manubria* move also at the same time; their free extremities are made to approach each other, as the *unci* mutually recede; and that with a peculiar twist, which greatly alters the apparent figure of these organs. [See figs. 6 to 8; of which 6 represents the right *manubrium* when the *unci* have receded, 8 the same when the *unci* approach, and 7 an intermediate condition.] The *incus* also has considerable motion. Sometimes the *fulcrum* is elevated and the *rami* depressed, so that the former is invisible: the *rami* open and shut with the working of the *mallei*, being fastened to them by the strong triangular muscle above-mentioned; but it is also evident that they have a motion of separating and closing independent of the *mallei*, though this is comparatively limited in extent, and not very often exercised. Again, when substances are brought into contact with the jaws, which, for any reason, are not acceptable, they are thrown up through the *buccal funnel*, by a peculiar scoop-like action of the *unci*, which is very curious to witness.

32. I have seen this action many times; but, in particular, on one occasion, in which much intelligence seemed to be displayed. I was watching a *Brachionus pala* in water, in which a number of that beautiful, mulberry-like animalcule, *Syncrypta volvox*, were revolving. One or two of these had been devoured, and were very visible in the intestinal canal of the *Brachionus*, which appeared excited by the enjoyment to unusual efforts. The mode in which it directed its ciliated flaps towards the spot where a *Syncrypta* was whirling, or suddenly stretched forward to the extent of the long foot, as if it would seize the prey, seemed to indicate a perception of its presence; as did, still more, the manner in which it depressed the lip-like lobe of the rotatory organ on one side, when the prey was in the vortex on that side, and the eager haste with which it shrank down into the lorica, the instant the animalcula dropped at length into the *buccal funnel*. Now, however, arose a difficulty; the black, millstone-like *unci* opened and stretched forward to grasp the little victim; they touched the globular investing case, but could not embrace it. The *Brachionus* redoubled his efforts; the jaws gaped vigorously, but could only scrape the sides of the little globe, which at every touch slipped away, the expanse of the *unci* being not

quite sufficient to grasp it. At length the animal appeared indignant; the jaws no more endeavoured to grasp, but, with a very distinct and sudden upward jerk, threw out the prey, which until then had been retained and pressed downwards by the contraction of the sides of the *buccal funnel.* Several times I saw this scene occur, with the same violent efforts, and the same ill success. A smaller *Syncrypta*, however, was bruised down by the jaws, while under my eye, and passed quickly into the stomach.

33. This incident I have described with some minuteness, not only as illustrating the particular movement in question, but also because of its bearing upon the general functions of the organs under review—the prehension and manducation of food. And it may be well, before I notice the modifications of the *mastax* in other forms, to say a few words on the structure and functions of the *buccal funnel*, and of some other contiguous organs.

34. The broad vibratile disk of *Brachionus* is deeply cleft at its mental edge, the incision reaching down to the summit of the *mastax*. The sides of the cleft can be brought into contact; and hence the structure is visible only at certain times, as when food is taken in. But the interior is a wide infundibuliform cavity, narrowing to a slender tube at its lower extremity, where its sides merge into the parietes of the *mastax*. This is the cavity which I have called the *buccal funnel*.

35. In *Brachionus amphiceros* the strong setiform cilia of the disk-lobes overarch the incision; and its upper edges, for a short distance downward, are irregularly jagged or crenated. In other species, as *B. Bakeri* and *B. dorcas*, the margins are smooth. In every case, however, the interior surface of the *funnel* is set with fine cilia, and currents, or ciliary waves, may constantly be seen pouring down the tube.

36. The sides of the *funnel*, in all cases, are formed of irregular bulbous masses of transparent flesh, which may be presumed to be muscular. Those masses which encircle the rim are usually large, and more regular. The parts are very flexible and mobile. The tube can be quite closed by the contact of its walls, even while the upper part of the *funnel* remains expanded: in *B. Bakeri* I have seen a globose mass occasionally pushed up from behind the tube to a considerable distance up the *funnel*, and presently retracted. It may be that some function analogous to taste is exercised by this organ.

37. Attached to the tube of the *funnel*, resting on the summit of the *mastax*, are seated a pair of large, clear, vesicular organs (see fig. 9, *n*), which, from their appearance and their situation, may be assumed to be *salivary glands*. In *Brachionus* they are of great size, and are generally two- or three-lobed. In *Asplanchna* (fig. 56), also, they are very large, and kidney-shaped. In the genera *Euchlanis* (fig. 12) and *Anuræa*, similar, and probably homologous vesicles are seated on the *œsophagus*, just below its exit from the *mastax*.

38. The tube of the *buccal funnel* (*m*) invariably opens upon the spot where the *unci* meet. The particles of food, or the minute animalcules, which form the prey of

the ROTIFERA, are drawn by the discal vortices into the *funnel*, and lodged at this point, within the *mastax*. The *unci*, and the *rami* of the *incus*, conjointly work on them; and they are speedily dismissed to the tips of the *rami*, immediately below which, on the dorsal side of the *mastax*, the *œsophagus* opens (*p*); a membranous tube, capable of great expansion and contraction, but varying much in length and diameter in different genera. A current of water appears to be almost constantly setting through the *funnel*, along the *rami*, in a direction towards their extremities, and thence through the *œsophagus* into the stomach.

39. In general, the ciliary vortices are sufficient to bring the prey within the *funnel*; but in several genera of the family *Euchlanidota*, as *Metopidia*, *Colurus*, *Monura*, and *Stephanops*, there is a curious accessory organ, which aids in the capture of prey; at least, I am sure it is so employed in several species of *Metopidia*.

40. Thus, in *M. acuminata* (fig. 11), the frontal region is formed by an arched fleshy process occipitally, which is approached by a small one at the mental side; and between these is the wide entrance of the *buccal funnel*. The occipital process is protected by a horny crystalline plate, forming a segment of a sphere, and when viewed laterally taking the appearance of a curved horn. It can be partially protruded and retracted, and also bent down to meet the mental lobe.

41. This apparatus, when the animal is taking food, is kept in vigorous action. A strong vortex is produced by the ciliary wheels; and as the floating atoms whirl by, the moveable plate is thrown forward with a grasping motion, the fleshy head being, at the same time, protruded; and, when the lobes are in contact, retracted. This is repeated almost every instant, with manifest eagerness and discrimination, the manducatory apparatus working vigorously all the while.

42. The same curious organ is frequently employed in another way. It is bent considerably downward; and, as the animal crawls deliberately up and down the stems of aquatic plants, it is used to rake and grub among the floccose deposits, the minute *Diatomaceæ*, &c., that adhere to them. (See fig. 11.)

43. Taking the structure described in *Brachionus* as the standard, I now proceed to examine how it is modified in other genera. In *Euchlanis deflexa* (figs. 12 to 15), the *fulcrum* of the *incus* (*h*) is thinned off ventrally to a blade-like edge, which is minutely jagged, and dilated laterally at the foot. The *rami* are very large (*g*), expanding at the sides in a triangular, pointed form; and arching across the *mastax* towards the *dorsum*, where each terminates in an elongated, curved, descending spine. The two points approach each other in a forcipate manner.

44. The *rami* are crossed at right angles by the four-fingered *unci* of the *mallei*, which by their motions evidently open the *rami*; though these latter do not appear, as usual, to be separable to the *fulcrum*, but to be united into one piece, with an ovate excavation between them (fig. 14), that does not reach to the *fulcrum*.

45. The *manubria* are more developed than in *Brachionus*. Instead of the thickened knob, to which the *uncus* is articulated, the upper portion of the *manubrium*

forms a broad laminar dilatation, down which run several carinæ, or ridges, of solid material; the interspaces, apparently, being filled with membrane, or softer and more fleshy substance (*c*). The ridges enclose three *areas*, of which the central one extends through the whole length of the *manubrium*, and the two external ones are smaller, and compose the dilatation. This structure is worthy of notice, since it is highly characteristic; and, as we shall presently find, will help us to identify this organ under very modified forms.

46. The parietes of the *mastax* are much thinner than in *Brachionus*. A stout muscle (*j*) embraces the articulation of the *malleus*, including a portion of the *manubrium*, and of the *uncus*. In *E. hipposideros*, a fan-shaped muscular band spreads along the interior side of both these parts, filling the angle, and stretching from one to the other: it is evidently a powerful *flexor*.

47. In this genus we see a structure of the *incus*, which prevails extensively in the class: each *ramus* is produced into an angular projection on either side of the *fulcrum*. To this projection, which I shall call *alula* (*o*), a muscular band is fastened, which passes down, and is inserted into the fundus of the *mastax*. Another more slender band or ligament connects the projection with the foot of the *fulcrum*.

48. The tube of the *buccal funnel* (*m*) is very wide. The *œsophagus* (*p*) is also wide, and short. On the latter duct are seated two globose clear *salivary glands* (*n*), each of which encloses a spherical nucleated nucleus. These must not be confounded with the *pancreatic glands*, which are much larger, and seated on the stomach, below the entrance of the *œsophagus*.

49. In *Notommata aurita* (figs. 16 to 21), while there is much resemblance to *Euchlanis*, the structure is in some respects peculiar. The form of the *mastax* is prolate, the longitudinal diameter exceeding the transverse,—a figure which is dependent on the fact, that the *fulcrum* of the *incus*, and the *manubria* of the *mallei*, are greatly produced in length, and are all extended nearly in the same direction; viz. that of the longitudinal axis of the body (see figs. 16 & 17).

50. The *manubrium*, as in *Euchlanis*, is three-looped, and dilated at the summit, unsymmetrically (see fig. 20). The *uncus* is broad, composed of five fingers, which are somewhat divergent, and is arched transversely as well as longitudinally. It is furnished, on that side which is next to the *dorsum*, with a peculiar, semicrescentic process (*q*), strengthened by a carina: the points of these two processes are opposed to each other at their tips, beyond the tips of the *rami* of the *incus*.

51. The *fulcrum* of the *incus*, when viewed ventrally, might be mistaken for a straight slender rod, with a round, dilated foot (fig. 16). It really consists of two slender curved rods, united by a thin lamina: the exterior of these, which is dilated laterally at the foot, is more curved than the interior, whose extremity it receives in the hollow of its own (fig. 17), as the chord of a bow joins the extremity of the arc. The summit of the *fulcrum* is obliquely truncate, and to this oblique surface are articulated, by a hinge-joint, the two *rami*.

52. The *rami* here take the form of moveable blades or jaws (figs. 16, 21), which arch across the vault of the *mastax* towards the *dorsum*, and receive, on their convex surfaces, the *unci*, which are tied to them near their extremities. The *rami* are capable of being widely opened (fig. 21), when several jagged teeth are seen on their opposing edges, which lock into each other when closed. In the act of expansion, an obtusely pointed *lamina* is seen below their arch (fig. 21, *r*), which is capable of being slightly protruded or contracted, independently of the motion of the *rami* or *unci*. The *rami* themselves, though opened and closed with the *mallei*, are not dependent on the action of the latter, for they evidently possess a powerful spontaneous motion in opening and closing. This movement is doubtless produced by the muscular bands which (as we saw in *Euchlanis*) connect the lateral processes (*alulæ*) of the *rami*, which are greatly developed, with the fundus of the *mastax*, and with the foot of the *fulcrum* (*t* and *u*).

53. The muscles of the *malleus* differ from those which we have seen in *Brachionus* and *Euchlanis*. A long band passes from the summit of the *manubrium* to the fundus of the *mastax*; another ties its lower extremity to the paries, immediately below it; while a third passes upward from the inner face of the same piece, probably to the inferior surface of the *uncus* (fig. 16).

54. The entrance of the *buccal funnel* into the *mastax* is, in this species, protected by a vault of many complex pieces, which appear solid (fig. 16, *v*), though of such tenuity and fragility that I have not been able to resolve them satisfactorily.

55. *Notommata clavulata* (figs. 22 to 26), a species of large size and of peculiar beauty, is remarkable for the great development of the *mallei*. The *buccal funnel* is here shallow, but richly ciliated; its short tube merges insensibly into the *mastax* (fig. 23), which consists of three lobes, more than usually marked, and nearly spherical. Each *manubrium* is, as usual, dilated above, where the lateral loops are trigonal, and attenuated below. A broad trapezoidal *uncus* (figs. 25, 26) is articulated to it, of eight fingers, of which the second and third are branches of the first. The fingers are arched both transversely and longitudinally, and their extremities are connected by a web (fig. 26). A transverse process crosses their inferior surface, doubtless a point of attachment to the ligament, which fastens them to the *ramus* of the *incus*, and which corresponds to the triangular ligament (*i*) described in *Brachionus* (§ 28). The elasticity of this ligament is well shown in the working of the jaws; for the *uncus* is elevated to a considerable distance above the level of the *incus* (see fig. 24), when the appearance and action of the pair are exactly those of curved dentate mandibles, opening and snapping across the tube of the *buccal funnel*. The *incus* is placed nearly horizontally, or at right angles with the plane of the *manubria*; but, during the vigorous working of these organs, they are alternately depressed and elevated to so great a degree, that the *fulcrum* appears now above, now below their level.

56. The *fulcrum* is rather short, much compressed, and thickened at its free extremity; its direction scarcely deviates from that of the *rami*,—in this respect contrast-

ing widely with *Not. aurita.* The *rami*, when closed, assume a pyriform or lozenge-like outline, but are cleft to their base; and as the *unci* are attached to the terminal half of their length, they open widely (fig. 24).

57. The whole manducatory apparatus in *Anuræa acuminata* bears a resemblance, singularly exact, to this of *Not. clavulata*, notwithstanding the external diversity of the two animals. The similarity extends even to the manner in which the *unci*, which are seven-fingered, are protruded into the *funnel*, and fiercely snapped.

58. *Notommata petromyzon* (Plate XVII. figs. 27 to 31) is remarkable for the extreme simplicity of the parts under review; a circumstance which makes it peculiarly valuable as a study. It is one of those species in which the ciliated facial disk is very oblique, being nearly on the plane of the *venter*. Hence the *buccal funnel* is short at all times, and can be quite obliterated, the entrance of the *mastax* opening on the facial surface. This organ is a delicate sac with membranous walls, of obcordate form (fig. 31), deeply trilobate at the fundus.

59. The *fulcrum* of the *incus* (fig. 31) is thin and blade-like; straight, except that its free extremity is slightly incurved, very deep, and truncate at its articulate extremity. The *rami* (fig. 29), when united, form an isosceles triangle, cleft to the *fulcrum* and arching downwards.

60. The *mallei* are equally simple. The *manubrium* (figs. 28, 31) is a slender rod, with a projecting process near its articulation. The *uncus* (fig. 28) consists of two fingers, membranous in texture, and at times evanescent, which work on the *ramus* near its extremity; and two muscular threads are seen connecting the former with the latter.

61. Notwithstanding the simplicity of the organs in this instance, a comparison with *Not. aurita* will show that the structure is essentially the same in the two species.

62. In *Notommata lacinulata* (figs. 32 to 34) the *mastax* is very large, subtrihedral, with the orifice at the surface of the disk or protruding from it; so that there is no *buccal funnel*. The *incus*, though somewhat simple, is very large; and the *rami*, when closed, form a hemispherical *dome* of thin texture; so as to resemble, when viewed obliquely from above (fig. 33), a globe of glass standing on a pedestal (the *fulcrum*). The similitude is enhanced by lines passing in different directions over the vault, like the astronomical circles. The *mallei* (fig. 34) are slender rods, hooked at the bottom; and soldered at the upper part across the dome, where they become very much attenuated, without any distinct division into *manubrium* and *uncus*.

63. The *rami* of the *incus* are divided to their base; in use, they are protruded considerably, and are distinctly organs of prehension; their edges being employed vigorously, in nibbling at the floccose matter that accumulates on aquatic plants, as the little animal crawls, by means of its two-toed foot, up and down the stalks.

64. M. Dujardin has constituted a genus (*Plagiognatha*) for this species and *Not. felis* of Ehrenberg; mainly, however, because they have "mâchoires à branches parallèles tournées du même côté, et recourbées vers le bord cilié, avec une tige cen-

trale (*fulcrum*) droite, très-longue, élargie à sa base *." This description is so vague, that it might embrace a multitude of widely remote species and genera; while it does not at all indicate the true peculiarity of the organs it professes to define.

65. *Furcularia gibba* (figs. 35 to 37) comes, in the form of its jaws, very near to *Not. lacinulata*; but most of the species of this genus, as described by Professor Ehrenberg (*not by M. Dujardin*, who includes in it a number of dissimilar species, already well defined and separated by his Prussian predecessor), are distinguished by the *manubria* being dilated laterally at their free extremity, so as to resemble the foot of a towel-horse. These expansions are doubtless for the attachment of muscles (which, however, I have not been able to define); and as the simple *uncus* is affixed to the edge of the *ramus* only by its point (fig. 36), a greater play is probably afforded it by such muscles, in the combined action of the jaws upon the prey.

66. The *rami* are broad, glassy, vaulted, cleft throughout, capable of widely opening (fig. 36), and produced into long decurved points (fig. 37). Their lower edges are thickened, so as to form a marginal band.

67. *Furcularia marina* has its manducatory organs formed on another type, approaching that of *Diglena*; as I shall presently notice.

68. *Notommata gibba* (figs. 38 to 40) prepares us for the remarkable modification of these organs which we find in *Synchæta* and *Polyarthra*. It is a minute species, having much of the appearance and habits of *Not. lacinulata*; but remarkable for the length and lozenge-form outline of the *mastax*, owing to the great posterior development of the ventral lobe, which is itself dependent on the great elongation of the *fulcrum*. The *manubria* (fig. 39) are long and incurved at their free extremities; the *unci* are single-toothed, and soldered to the *rami*. The latter are curved, glassy blades; along the middle of each runs a line, which is difficult to understand: after much study, I think it to be the angle of depression of the surface, as represented ideally at fig. 40.

69. In *Synchæta* and *Polyarthra*, the *mastax* and its included organs attain their maximum of development as regards dimensions, though not as regards complexity. In some species of the former genus fully one-third of the entire bulk is occupied by these organs. Owing, however, to the extreme delicacy of the parts, particularly of the *mallei*, and the unequal refraction produced by the prismatic form of the animals, the structure is unusually difficult to resolve. Ehrenberg evidently did not understand it: the points of the *unci* he appears to have seen, in *S. pectinata*, but no more; and the frontal styles he mistook for accessory jaws †. In *Polyarthra*, he merely says that "there are two single-toothed jaws ‡." His figures give little or no light on the true structure in either genus.

70. Dujardin knows nothing of *Synchæta*, no species of which he seems to have seen; but concludes, most groundlessly, that it is not distinct from *Hydatina*. Of *Polyarthra* he merely says, "Mâchoires unidentées §;" and though he figures a spe-

* Infusoires, p. 651. † Infusionsthier. p. 437. ‡ Ibid. p. 440. § Infus. p. 641.

cies*, he gives no details of the internal structure, but represents two projecting articulated setæ, which he calls "appendices de la bouche." Of the latter, however, I must confess, after the examination of dozens of specimens, I can discern no trace, with a power of 560 diameters.

71. In 1850 I had discovered, in a species of *Synchæta*, what seemed to me a most anomalous condition of the manducatory organs. As the species appeared new, I described it†, in 1851, by the name of *S. mordax*. The peculiarity consisted in two pairs of hooked jaws, exactly resembling the mandibles and maxillæ of a beetle, now and then projected from the front, and opened with a sudden snapping motion, and instantly withdrawn. Each pair moved independently of the other, but in evident connexion with two pairs of bulbous muscles, seated deep in the breast. They could scarcely be discerned, when withdrawn beneath a sort of membranous lip that formed the frontal outline; and no trace of them could be recognized after the animal had been subjected to the compressorium.

72. Until recently, this structure completely baffled my endeavours to solve it. It was totally unlike anything that I was acquainted with in the whole class; and yet I was quite sure of the exactitude of the observation, having witnessed the phenomena on many occasions. Very lately, however, I have succeeded, by means of the solution of potash, in defining the whole structure of the solid parts, and can demonstrate them at pleasure. I found, with surprise, that there is in them no deviation from the normal type, while the function and homology of the organs are greatly illustrated by their action.

73. The *mastax*, as before stated, is of large size, ventricose, globose, or subcubical in figure, with both the *incus* and the *mallei* so much bent, as to form, when viewed laterally (fig. 43), each two sides of a quadrangle. The *fulcrum* is a slender, compressed rod, slightly arcuate. The *rami* are thin, elastic blades, nearly straight when viewed laterally (fig. 43), but arched in a forcipate manner; the internal edges not in contact, but approaching at the points, which are somewhat twisted. The *mallei* are slender; the *manubrium* much bent; the *uncus* a single, pointed finger, connected with the *ramus* by a delicate membrane, cut into teeth,—at least in *S. tremula* (fig. 42). The points of the *unci* form the anterior, as the points of the *rami* form the posterior, pair of snapping teeth.

74. The vigorous action of these jaws would lead us to expect powerful muscles, and we find them peculiarly thick and bulbose. The great convergent pair with clubbed summits, that form a conspicuous V-shaped object in the midst of the animal, are muscles, which envelope the *mallei* (fig. 41), and are seen, during the momentary protrusion of their tips, like thick gums around the bases of the teeth. A thick, clavate muscle also proceeds from the articulation of the *uncus*, and lines the globosity of each lateral lobe of the *mastax* (fig. 41). In *S. mordax* a pair of muscular bulbs are placed, one on each side of the foot of the *fulcrum*: these are probably

* Infus. pl. 21. fig. 6, A. B.

† Ann. Nat. Hist., Sept. 1851.

the extremities of fasciæ, that extend to the *rami*; as the motions of the latter are synchronous with twitchings in these bulbs.

75. There is a subtile clear membrane stretched over the whole apparatus, but not in contact with it; for it has a slight power of independent contraction and protrusion. It is of considerable breadth, with a blunt point in the centre, which is simple in *S. mordax*, bifid in *S. tremula* (fig. 41). As there is no *buccal funnel*, this must be the occipital (or rather frontal) margin of the *mastax*, the teeth being evidently extruded from beneath it; there must also be a mental, or inferior, margin, but I have not defined it.

76. *Polyarthra* differs little from *Synchæta* in the form of its jaws. The *mastax* is more oblique (fig. 47), its central lobe being much produced, and pointing towards the venter. The muscles of the upper portion are so dense (fig. 44) as to shut out all sight of the interior, until they are dissolved away by potash (fig. 46).

77. The *rami* are very broad, somewhat square at the base, flat, but much arched longitudinally (fig. 47). They open and shut vigorously, with a snapping action, but are not protruded from the front: their whole interior edges come into contact.

78. The *mallei* are simple, slender, bent rods, apparently without distinct articulation (fig. 48). During life they are thick, and irregular in outline (fig. 46), owing, doubtless, to their being invested with muscle, as in *Synchæta*.

79. There is a clear vaulted membrane, spreading like a dome over the jaws, when viewed vertically (*i. e.* from the front), which is certainly the paries of the *mastax*: it has an advancing and receding margin (fig. 49), which is placed considerably towards the mental aspect, where the *mastax* opens at the bottom of a shallow *funnel*.

80. From these forms, especially that of *Synchæta*, the transition is easy to *Diglena*, *Eosphora*, *Albertia*, and *Furcularia marina*. Thus, in *Diglena forcipata* (figs. 50, 51), the *incus* is a true forceps; the *rami* projecting in nearly the same plane as the *fulcrum*, and the hooked points coming into contact. The edges have a peculiar structure, being delicately ridged transversely; while from the terminal points of the ridges spring slender setæ in a double row, which project so as to oppose those of the other *ramus*. This curious structure I find also in *Diglena grandis*. The *fulcrum* is compressed.

81. The *mallei* have nearly straight *manubria*, slightly enlarged at the free extremity, and clubbed towards the joint, where they are invested with thick muscle. The *uncus* is a simple curved piece, so far as its point of attachment to the *ramus*; but at this point there is articulated to it a stout curved acute *spine*, which, when the *rami* are closed, crosses its fellow of the opposite *uncus*, and plays over the setæ of the *ramus* (fig. 50). In *Diglena grandis* there are *two* spines on each *uncus*, the one much shorter than the other; as there are also in *Eosphora aurita*. In the latter species these tooth-like spines are projectile, as a formidable pair of jaws; and I doubt not that such is their function in *Diglena* also, though I have not seen them so used; especially as, in both genera, the ciliated disk is prolonged on the prone surface

nearly in the longitudinal plane of the venter; so that the aperture of the *mastax* is brought to the surface, without the intervention of any appreciable *funnel*.

82. Scarcely differing from this structure is that of the curious little *Albertia vermiculus*, first found by M. Dujardin, living entozoically in *Lumbricus* and *Limax*, and which I have found in the intestine of *Nais proboscidea* (figs. 52, 53). Whether the *uncus* has an accessory tooth, or not, I cannot certainly say, owing to the minuteness of the parts; the animal being only $\frac{1}{100}$th of an inch in length, and the dental apparatus being unusually minute in proportion. It is, however, frequently protruded, to the extent of fully half of the apparatus, from the front, and vigorously snapped.

83. *Furcularia marina* (figs. 54, 55) is another species, in which these organs are greatly protrusile; the whole of the long *mallei* being sometimes exterior to the frontal disk (fig. 54). The *incus* (fig. 55) seems to me a simple, much-arcuated forceps; and the *mallei* to be without *unci*, the *manubria* (simple incurved rods) being articulated to the bases of the *rami*. M. Dujardin describes and figures them differently*, but I believe he is mistaken.

84. We are now prepared to understand the form of dental apparatus, which has hitherto appeared perfectly anomalous in this class,—that of *Asplanchna*, as described and figured by Mr. Brightwell and Mr. Dalrymple, in the case of *A. Brightwellii*, and by myself in that of *A. priodonta*. To these must be added *Notommata myrmeleo*, and *N. syrinx*, of Ehrenberg; referrible doubtless to the same genus. A moment's comparison of the jaws of *A. priodonta* (Plate XVIII. figs. 56 to 59) with those of *Synchæta tremula*, or of *Diglena forcipata* (Plate XVII. figs. 41, 50) either opened or closed, will show that the former constitute an *incus*, with the *fulcrum* much diminished; the very row of teeth that runs, like the edge of a saw, along the interior of the *ramus* (figs. 58, 59), having its counterpart in the ridges and setæ of *Diglena*; as also in the teeth of these organs in *Notommata aurita*.

85. The *mallei*, at first sight, seem wholly wanting in *Asplanchna*; but they are really present, though in a state of extreme attenuation and degeneration. Mr. Dalrymple thought he saw an occasional glimpse of an accessory curved point, outside the tip of each jaw, in *A. Brightwellii*; and I have invariably observed the same in both that species and *A. priodonta* (figs. 58, 59). It is a curved pointed rod, which, at its lower end, that ordinarily would be free, is attached to a process, which is itself attached, I believe, by a transverse ligament, to the *ramus*, near its articulation. It is most evanescent; yet it is not dissolved by treatment with potash, and I have no doubt that it represents the *malleus*.

86. The *fulcrum*, though short and thin, is very deep; the depth in fact exceeding the length (fig. 59); and it affords a clear insight into the nature of the articulation of the *rami*—a ginglymus of the simplest kind; the articulating parts having straight parallel edges, united by an interposed membrane.

87. Another peculiarity in this genus is the absence of the *mastax*; at least in its

* Infus. p. 649; and pl. 22. figs. 4, c, d, e.

ordinary form of a chamber inclosing the trophi. The *fulcrum* is attached to a reniform muscular *cushion* (fig. 56); with the *rami* projecting freely into the *buccal funnel*; and, under graduated pressure, protruded from the front, when they snap vigorously. But when we consider that the normal form of the *mastax* is that of three lobes, of which one belongs to the *incus*, and two to the *mallei*, it is natural to expect that the evanescence of the *mallei* would be accompanied by the evanescence of their muscular lobes. And this I conclude is the true state of the case: the *cushion* is the lobe of the *incus*, and therefore the sole representative of the *mastax*; the lateral lobes having become obsolete.

88. I was unwilling to interrupt the regular gradation, through which we have traced the degeneration of the *mallei* to evanescence; but I now retrace my course a little, to notice how the same organs degenerate in other modes. In a beautiful and common species, well known to most microscopists, *Mastigocerca carinata* (figs. 60 to 62), the dental apparatus occurs under an unusual form. The *mastax* is a somewhat slender sac, much produced in length, and with the component lobes greatly and irregularly developed. The *incus* has a *fulcrum* of great length and slenderness, a straight rod with a dilated foot (fig. 62, *h*). The *rami* are small, forcipate, and resembling those I have lately described; but with the *alulæ* greatly produced (*o*). The *mallei* have long, slender, incurved *manubria*, and simple *unci*.

89. But the remarkable circumstance is the non-symmetrical character of the apparatus. The left side is much more developed than the right. The left *alula* of the *incus* (*o*) descends to a greater distance than the right (*o'*); and its extremity is dilated into an expansion, with several irregular angles, to which muscular threads are attached. The *ramus* also of the same side is larger than its fellow. So with the *mallei*. The *manubrium* of the right (*c'*) is comparatively short, very slender, and of uniform thickness; with a long, slender, rod-like *uncus* (*e'*), doubly bent in the middle. The left is much longer, irregularly swollen, clubbed at the articulation, and bearing a thick, curved, knobbed *uncus*, which terminates at a point not precisely opposite the tip of its fellow (*e*)*.

90. In *Monocerca* (fig. 63),—from which *Mastigocerca* can scarcely be said to differ generically, though Professor Ehrenberg places it in another family,—the right *malleus* entirely disappears, not a vestige of it remaining; though the left (*b*) is long, and well developed. The *incus* is a straight rod, with a high *carina* (*f*), with the *rami* almost obliterated: the *alulæ*, however, are rather large, but unequal.

91. This want of symmetry is a remarkable character of the genus, and is displayed in other particulars. For example, in *Monocerca bicornis*, the little projecting tubular organ, which Ehrenberg has called the respiratory tube, but which I consider a rudimentary *antenna*, is double; but the two are unequal. In the same species, and also in *M. porcellus*, the lorica terminates frontally in two *spines*, of

* In *Notommata parasita* there is a similar want of symmetry, the right *manubrium* being much shorter than the left (see my memoir in Trans. Micr. Soc. iii. p. 143).

which, again, the left is considerably larger than the right. The lorica, in *Mon. rattus*, and much more prominently in *Mast. carinata*, is furnished with a *dorsal carina*, running along the median line; the elevation of this ridge is not perpendicular, but leans considerably over to the right side. Even the single *foot-spine*, which is so characteristic of the genus, must be considered either as representing the ordinary pair soldered together, or as single through the obsolescence of the other. That the latter is the true solution is the more probable, since, in *Mastigocerca*, there is, at the base of the foot-spine, another spine, very minute, but distinctly jointed to the foot-bulb. This unsymmetrical development is not without parallel in higher animals; of which it will be sufficient to allude to a single example, in the case of the projecting tooth of the Narwhal.

92. The figure of the *incus-fulcrum* in *Monocerca porcellus*, and the obsolescence of its *rami*, make an approach to the structure which we find in a very curious form, *Scaridium longicaudum* (Plate XVII. figs. 64, 65). The whole organization of the manducatory apparatus is here so abnormal, that I shall describe it in detail; especially as Dujardin has not noticed the genus at all, and Ehrenberg confines himself to the vague remark, that "the *Schlundkopf* (Pharynx) is oblique, with unequal, pincer-toothed (one-toothed) jaws."

93. The *mastax* is somewhat obconic, or shaped like the heart of a mammal; a muscular sac, on the parietes of which transverse *rugæ* appear (β). The eye (x), a large flattened capsule, with the crimson pigment not quite filling it, is attached to its occipital surface; apparently not connected, as usual, with the large occipital ganglionic sac (y); which, however, presses upon it from above and behind. The summit of the *mastax* projects into a point, which, though within the level of the ciliated ridges of the front (fig. 64), seems to be in contact with the surrounding water, without the intervention of a *buccal funnel*. This point is cleft deeply; the incision being transverse, from right to left, but obliquely upwards (fig. 65). The occipital division separates widely from the mental one, with a gaping or snapping action, very frequently performed; but with so great a rapidity and suddenness, that it needed long-continued observation to enable me to understand the parts. The structure is as follows.

94. Behind the occipital division, and from its point, spring several arched setæ; and an apparatus of hooked teeth is visible within its concavity. The mental division (δ) is slightly bifid, with rounded points; between which, at the moment of gaping, several hooked setæ are projected, and instantly retracted (ε). These setæ, or teeth, are connected, by prolongations of their bases, which are doubly geniculate and appear jointed, with the summit of the *fulcrum* (g); and must therefore be the representatives of the *rami*. The *fulcrum* itself is a straight rod, with a strongly developed *carina* (h), arcuated somewhat in the same way as that of *Notommata aurita* (see fig. 17).

95. The *mallei* consist each of a thin *uncus* (e), working on the *ramus*, and of a

manubrium (*c*), singularly looped, but of such extreme tenuity, as to require the most delicate adjustment of focus to resolve it. Indeed, I have never been able to see more than one in a lateral view; but infer the existence of the other, from the symmetrical appearance of the apparatus, in a dorsal aspect. Singular as the form of this organ is, I think we can recognise in it the three loops which constitute the solid framework of the *manubrium* in *Euchlanis*, &c. (§ 45).

96. We have now traced the same common organs of manducation, through various phases, from what I ventured to call their normal development in *Brachionus* and *Euchlanis*. Viewed generally, these modifications may be considered as successive degenerations of the *mallei*, and augmentations of the *incus*. I shall now return to the same starting-point, and trace a chain of modifications in another direction; a chain of fewer links, it is true, but all tending to the same point, the degeneration and final obsolescence of the *incus*, and (in the final stage) of the *mallei* also.

97. Though the types of structure, in the manducatory organs of the species which we have now to consider, are few, being not more than three or four, the species and genera are numerous; and they may all be distinguished, by a remarkable peculiarity, from those with which we have been hitherto engaged. They no longer assume a prone position when at rest, with the venter towards the support, but take an erect posture, the body elevated in the same line as the foot, the tip of which is the point of attachment. Many of the members of one of the great groups, and all of another, inhabit cylindrical cases, made of gelatinous matter, thrown off from their own bodies, absurdly called "loricæ" by Ehrenberg, for the purpose of giving a semblance of unity to his artificial arrangement, but really having not the slightest analogy with the stiff integument of *Brachionus*, *Euchlanis*, &c., which is an organic part of the animal.

98. The genera *Pterodina* and *Triarthra* may seem exceptions to this generalization; for the former has a distinct lorica, as has also the allied genus which I have named *Pompholyx*; and *Triarthra* has a posterior stylet, which, with the anterior pair, has been compared with the pinnæ of *Polyarthra*; while yet all these display modifications of the manducatory apparatus, belonging to the type which I am about to describe.

99. I am not in this place occupied with the principles of a new arrangement of the Rotifera, and shall therefore merely say, that the above exceptions are apparent rather than actual; though they may be considered as osculant groups.

100. Dismissing these, I come to examine the manducatory organs as they appear in the genera *Triarthra*, *Pompholyx*, *Pterodina*, *Œcistes*, *Limnias*, *Melicerta*, *Conochilus*, *Megalotrocha*, *Lacinularia*, and *Tubicolaria*. So far as my examinations reach (which include eight of these ten genera), there is no appreciable variation in the structure of these organs in them all; and in one of the two, which I have never been so fortunate as to meet with, the deficiency has been well supplied; since it is the species (*Lacinularia socialis*) which forms the subject of the admirable memoirs of Mr. Huxley and Dr. Leydig, already referred to (§ 6).

101. Professor EHRENBERG had simply described the apparatus as consisting of teeth, which, like the arrow on a bow, are fastened across the jaw*; and M. DUJARDIN does little more than repeat the description. He says, "all these animals present a pair of jaws, almost in form of a stirrup, composed of an arch traversed by a bar, on which lean, by the free extremity, three parallel teeth springing from the bow of the stirrup, which is engaged in the fleshy bulb†."

102. Dr. LEYDIG, who complains of the inaccuracy of EHRENBERG's figures, describes the apparatus as consisting of "two bent quadrangular plates, across which several lines are stretched; the three foremost, which are stouter than the rest, jutting out as three teeth." He says that the two plates have a shears-like figure; and notices at their union "an apophysis (the *fulcrum*), which seems to enter into the circular mass of the gizzard‡."

103. Mr. HUXLEY, on the other hand, saw the analogy of this type with that which I have already considered; but not with the stirrup-like form which is found in *Philodina*, &c. He thus describes it: "The armature of the pharyngeal bulb is composed of four separate pieces. Two of these (which form the *incus* of Mr. GOSSE) are elongated triangular prisms, applied together by their flat inner faces§: the upper faces are rather concave, while the outer faces are convex; and upon these the two other pieces (the *mallei* of Mr. GOSSE) are articulated. The last are elongated—concave internally, convex externally—and present two clear spaces in their interior; from their inner surface a thin curved plate projects inwards. At its anterior extremity this plate is brownish, and divided into five or six hard teeth, with slightly enlarged extremities. Posteriorly the divisions become less and less distinct, and the plate takes quite the appearance of the rest of the piece.

"This is essentially the same structure as that of the teeth of *Notommata* [=*Asplanchna*], described by Mr. DALRYMPLE, and by Mr. GOSSE (on the anatomy of *Notommata aurita*); and *very different from the true 'stirrup-shaped' armature.*"

104. Professor WILLIAMSON describes the apparatus with elaborate care as he finds it in *Melicerta*. His remarks are too long to quote, but they agree mainly with what was already known. He notices "two broad elongated plates," which he calls "*crushers*," from which "proceed laterally numerous parallel bars, somewhat thickened at their inner extremities, where they are attached to the plates; whilst at their opposite ends they are united with others of the same side by a curved connecting bar, from the outer sides of which are given off various loops and processes. . . . From the upper extremities of the two crushers there project, upwards and backwards, two slender prolongations, united by a kind of double hinge-joint near their apex, where they not only play upon each other, but also on a third small central fixed point,

* Infusionsth. p. 386. † Ibid. p. 615. ‡ SIEB. and KÖLL. Zeitsch. 1852, p. 463.

§ Mr. HUXLEY says, these are "not described by LEYDIG;" but they are his "bent quadrangular plates," *ut supra*.

lodged in a little conglobate cellular mass *." Professor Williamson denies that the transverse teeth move on the plates, as affirmed by Ehrenberg, since they are firmly united with them. He further states, that "the conglobate organ in which the apparatus is imbedded [*i. e.* the *mastax*] is composed of numerous large cells, each of which contains a beautiful nucleus with its nucleolus;" and supposes that muscular threads penetrate it to reach the dental apparatus †. The statement of the cellular character of the *mastax*, and the presumption of penetrating muscles, are alike negatived by my observations, not only of this species, but of the whole range of the Rotifera. The able and learned Professor has probably been misled, in the former conclusion, by some overlying tissues, perhaps similar to the salivary glands in *Euchlanis* (see § 48).

105. My own observations on the same species, published in the same journal, did not succeed in dispelling the obscurity which still rested on the structure; and I shall therefore here merely allude to them, as a part of the bibliography of the subject. It appears, however, that though more attention has been bestowed on this type than on any other in the class, it still needs solution. I shall therefore attempt to give it in detail, as it appears in *Limnias ceratophylli* (Plate XVIII. figs. 66 to 71).

106. The *mastax* consists (fig. 66, *a*) of three subglobose lobes, as usual (not *four*, as stated by Leydig, and by Ehrenberg before him); one on each side appropriated to each *malleus* (*b*), and the third descending towards the ventral aspect, which envelopes the *incus* (*f*). The *mallei* are more intimately united to the *rami* of the *incus* than in the former type; each *uncus* forming, with its *ramus*, a well-defined mass of muscle, enclosing the solid parts, and in form approaching the quadrature of a globe (ζ); two flat faces opposing and working on each other (fig. 66). Across the upper surface of the mass the *uncus* is stretched (fig. 71, *e*), as three long parallel fingers, arched in their common direction, and imbedded in the muscular substance; their points just reaching the opposing face of the *ramus*, and meeting the points of the opposite *uncus*, when closed. The *manubrium* (*c*) is much disguised, by being greatly dilated transversely, forming three bow-like loops of little solidity, to the chord of which the fingers are soldered, *not articulated*. The surface of the dense muscular mass displays *striæ* parallel to the fingers, and, as it were, continuing their number towards the dorsal extremity, becoming fainter till they are imperceptible. These *striæ* do not disappear when the muscular parts are dissolved by potash; and hence I infer the existence of a delicate investiture of solid substance, similar to that of the teeth, &c., enclosing the muscular mass.

107. The *incus*, which cannot be separated from the *mallei*, thus consists of two portions (*g*), corresponding to the *rami* in *Brachionus*, &c., each of which forms the

* These two prolongations are, as I conceive, but the lateral outlines of the *fulcrum*; and the joint is not at the point where they unite, as Professor Williamson supposes, but at the point of their widest separation, whence the *rami* diverge.

† Journ. Micr. Sci. i. (Comm.) p. 4.

lower part of the quadrantic mass above described. At the ventral extremity they are articulated to a slender *fulcrum* (*h*), which is a little bent downward. The solid framework of each *ramus* sends off, from its inferior surface, a slender curved process (*o*), which is connected with the extremity of the *fulcrum*, and is probably the analogue of the *alula*.

108. The action of this apparatus is as follows:—The ciliary vortices, produced by the waves of the coronal disk, pass together through the upper sinus, and are hurled in one stream along the centre of the face, nearly to the projecting chin. Here is placed the orifice of the *buccal funnel*, a perpendicularly descending tube of considerable width (fig. 66), slightly funnel-shaped at the top, the interior surface of which is strongly ciliated. It descends straight upon the *mastax*, over the part where the *unci* unite. But just above this point there are two valves projecting from the walls of the tube, also well ciliated. These can be brought into contact, or separated in various degrees, at will; and being very sensitive, they regulate the force of the inflowing current, and doubtless exclude hurtful or useless substances. The current now flows along the two *rami* of the *incus*, as already described; and, passing between their separated points, descends into the *œsophagus*, a slender duct opening beneath them (*p*), and leading into the digesting stomach.

109. As this current passes, the manducatory apparatus acts upon the particles of food which it brings in its course. The quadrantic masses approach each other and recede, with a rapid rolling movement, in the direction of the curvature of the *mallei*; while, at the same time, the *rami* of the *incus* open and close their points, rise and sink, and occasionally perform a kind of shoveling action. The points of the fingers of the *unci*, meeting each other, doubtless pierce and tear the *Infusoria* swallowed, and the striated faces of the quadrantic masses bruise, squeeze, and grind them down.

110. When the muscular investiture is dissolved away by potash, the essential identity of the whole structure with that of the type already described becomes abundantly evident. A comparison with *Notommata clavulata*, for example (compare fig. 71 with figs. 25 and 26), will show this. Even the *mallei*, which in some aspects present difficulty (figs. 67 and 69), when viewed vertically are but little changed: the fingers are parallel, instead of divergent, and the ansate character of the *manubrium* is lost; but three areas, enclosed by loops or carinæ of solid substance (fig. 71), reveal their true nature.

111. Another well-marked and easily recognized family, in this group, is that which Ehrenberg has named *Philodinæa*, the first forms of Wheel-animals which attracted the notice of microscopists. The *buccal funnel* is here rather long and slender, and always permanent; the manducatory apparatus having no power of materially altering its relative position in the body, and never being brought into contact with the exterior.

112. The *mastax* in *Rotifer macrurus* (figs. 72 to 78), which may be considered as

a typical species, consists of the usual three globose lobes, of which the two lateral are somewhat produced above, to embrace the termination of the *funnel*. The dental apparatus differs very little from the type which we have seen in *Limnias* and its fellows. The *mallei* and the *incus* are soldered together, into two sub-quadranti-globular masses (ζ), which appear to be muscular, but invested with a solid integument. These contain the *rami* of the *incus*, and are crossed by two strong teeth, which rise from below the exterior edge of the mass, and descend upon its interior face.

113. The *manubria* are more obsolescent than in *Limnias*; but they may still be recognized, in a vertical aspect (fig. 74), as three loops, of which the central one is chiefly developed (*c*); and in a dorsal aspect (fig. 72), as a translucent, reniform lobe, descending on the exterior of each quadrant. Numerous delicate striæ cross the quadrantic masses, on *each* side of the principal teeth, and these are permanent (fig. 74) after potash-treatment. A very minute and rudimentary *fulcrum* (fig. 75, *h*) is seen in the lateral aspect.

114. The structure and action of an apparatus of this type may be made more clear by a homely illustration. Suppose an apple to be divided longitudinally, leaving the stalk attached to one half. Let this now be again split longitudinally, so far as the stalk, but not actually separating either portion from it. Draw the two portions slightly apart, and lay them down on their rounded surfaces (fig. 76). They now represent the quadrantic masses in repose, the stalk being the *fulcrum*, and the upper surfaces being crossed by the teeth. By the contraction of the muscles of which they are composed, the two segments are made to turn on their long axes, until the points of the teeth are brought into contact, and the toothed surfaces rise and approach each other (fig. 77). The lower edges, however, do not separate, as the upper edges approach, but the form of the masses alters, becoming more lenticular; so that when the toothed surfaces are brought into their closest approximation (fig. 78), the outline has a subcircular figure. It is on account of this change of form, that I presume the masses themselves to be partially composed of muscle.

115. In *Philodina* (e. g. *P. roseola* and *P. megalotrocha*) the quadrants are connected by an elastic ligament, which crosses from the interior face of one to the other, just below the points of the teeth. I find no trace of this in *Rotifer*. The teeth are generally but two; in *P. aculeata*, however, I find, as Ehrenberg does, *three*, and he indicates the same number in *P. macrostyla* and *Monolabis conica*, species which I have not met with.

116. It has been usual to call the divisions of the dental apparatus, in this family, "stirrup-shaped;" but this comparison is grounded on a misapprehension of their true form, which I have proved, by numberless examinations, to be that of the quadrature of a sphere, as above explained.

117. It is no less evident that Mr. Huxley's remark, above cited, that the jaws in *Lacinularia* (=*Limnias*) are "very different from the true stirrup-shaped armature" (so-called), is founded on error; the two forms bearing the very closest analogy, as

will appear by a comparison of the figures 66 and 72, while I have already proved the essential identity of the former with the structure in *Brachionus*, &c.

118. We are now arrived at the most aberrant forms of the ROTIFERA, the genera *Floscularia* and *Stephanoceros*. In the former (figs. 79 to 82), the position of the dental apparatus is even more abnormal than its structure. The teeth appear to be enclosed in no *mastax*, and are placed far down in the abdominal cavity; nearer to the cloaca, in fact, than to the flower-like disk. I will endeavour to explain this.

119. The whole of the upper part of this elegant animal's body is lined with a very sensitive, contractile, partially-opake membrane, which, a little below the disk, recedes from the walls of the body, and forms a *diaphragm* with a highly contractile, and versatile central orifice. At some distance lower down another *diaphragm* occurs, and the ample chamber thus enclosed forms a kind of *crop*, or receptacle for the captured prey. Below the second *diaphragm* is another capacious chamber, which we must consider as a stomach, since digestion evidently commences in it, and it opens into the intestine.

120. The *mastax*, as I have above stated, is wholly wanting; the dental apparatus, which is very small, evidently springing from the common paries of the stomach, just below the second *diaphragm*. That this absence of the *mastax* is real, and not illusive, is proved by the facts, that the *Infusoria* swallowed pass into the stomach, where they accumulate in its wide cavity; that the jaws are seen to act on one and another, according as they come within reach; and that, after such action, they pass off again into the same cavity, to undergo another mastication, when chance again brings them within reach of the teeth.

121. From the ventral side of the ample *crop* that precedes the stomach, there springs, in *F. ornata*, a perpendicular membrane, or *veil* (fig. 79), extending partly across the cavity*. This is free, except at the vertical edge, by which it is attached to the side of the chamber; and being ample, and of great delicacy, it continually floats and waves from side to side. At the bottom of this *veil*, but on the dorsal side, are placed the jaws, consisting of a pair of curved, unjointed, but free *mallei*, with a membranous process beneath each.

122. Each *malleus* (fig. 80) is an *uncus* of two slender, arched, divergent fingers, united by a subtile web†: the back of each curves downwards, where, expanding and becoming membranous, it is connected with some delicate but definite processes (figs. 80, 81) with rounded outlines, which I should have supposed to be muscular bulbs, but that they remain after treatment with potash. They are probably analogous to the loops in *Limnias* and *Rotifer*, representing the *manubrium*.

* Dr. DOBIE considers this waving *veil*, in his *Floscularia cornuta*, to be a slit in the *diaphragm*, fringed with vibratile cilia, the motion of which, as he thinks, gives rise to the peculiar serpentine movement always observed at this point. (Ann. Nat. Hist. 1848.)

† M. D'UDEKEM describes the jaw as "a simple plate, armed with one sole tooth." (Bull. de l'Acad. Roy. de Belg. xviii. 43.)

123. Across the *uncus*, about midway between the bifurcation and the tip, on the inferior surface, a membrane originates, which projects transversely and perpendicularly downwards to some distance, curving at the bottom towards its fellow of the opposite *malleus* (fig. 80). I incline to think this the vanishing representative of the quadrantic mass in *Limnias* and *Rotifer* = the *ramus* of the *incus*.

124. The whole apparatus is very minute, and in some specimens can, either not at all, or with much difficulty, be detected; so that we may consider the dental apparatus of the Rotifera degraded to its lowest point in this genus.

125. *Stephanoceros*, the most elegant of Rotifera, affords peculiar facilities for observation; since it is by far the largest animal in the Class, reaching to one-fifteenth of an inch in height*. There are two capacious *crops* (each bounded by a *diaphragm*), of which the lower seems to answer to that of *Floscularia*. The jaws are placed in the latter, not in the stomach, which is distinctly separated from it. They are evidently imbedded in its dorsal paries, working freely in the cavity, without an enclosing *mastax* †.

126. Ehrenberg's figures of the apparatus seem more than usually incorrect; it is but fair to say, however, that he admits his observation to be susceptible of doubt. Each *malleus* is an *uncus*, of three curved divergent fingers (figs. 84, 85), whose extremities are united by an indented membrane, like the foot of a water-fowl. There is no distinct *manubrium*, but the posterior part of the *uncus* forms a knob, which is enclosed in a large muscular bulb.

127. The *incus* consists of two very mobile and widely separable *rami*, somewhat quadranti-globular, but much flattened, and each furnished with a lengthened process, which unites with its fellow to form the hinge, without a *fulcrum* (fig. 83). The *uncus* is connected with the *ramus* by an elastic ligament, by which means the latter is stretched open vigorously, while the teeth of the *malleus* act on the prey imprisoned in the *crop*.

128. Thus I have shown that the masticatory apparatus in the whole class of Rotifera is modeled on one common plan. The organs, indeed, are considerably modified, and sometimes so much disguised as to be unrecognizable, on cursory examination: but a careful scrutiny proves that every modification (for I have omitted none, that I am acquainted with, in which there is any variation of importance) is, without any violence, referrible to the common type.

129. This form of the trophi, alone, isolates the Rotifera from other animals, and proves, in concurrence with other points of organization, that this class is a very natural and well-marked group; since we find one type of structure running through the whole, which is yet widely different from that of any other class of animals.

130. As no group of animals, however, nor any set of organs, is so isolated as to

* Ehrenberg can only have seen small specimens, since he mentions one-third of a line as the dimensions of the species. I have, however, seen several of the size mentioned in the text.

† Ehrenberg figures one, indeed, of the usual three-lobed form, but I fear it is imaginary.

have no relations of affinity with others, it is a subject of interest to inquire, What is the homological value of the complex apparatus we have been considering? or, What organ or set of organs do they represent in other classes?

131. It has been usual to compare the jaws of the ROTIFERA with the gastric teeth in the higher CRUSTACEA, but I do not think there is in them any homology with these appendages. It is true that the great subcartilaginous crop in *Asplanchna* (fig. 56), a structure unparalleled by any other genus in the whole class, presents a curious similarity, in form and appearance, to the stomach of some of the Decapods, particularly that of *Cancer pagurus*; but the resemblance diminishes on examination; and the bruising teeth of the Crab have no more analogy with the expanding jaws of the *Asplanchna*, than with the complex apparatus of the more normal ROTIFERA. The resemblance lies in the circumstance that, in each case, the viscus consists of membranous walls, stretched, as it were, over a subcartilaginous framework, of a somewhat cubical shape. But the positions of the afferent and efferent orifices differ importantly, in the two viscera, in relation to the angles of the framework, *in situ* as well as *inter se*; the pyloric orifice in the stomach of the Crab being situate at the extremity most remote from the cardiac, while, in the crop of the *Asplanchna*, the efferent orifice is placed close to the afferent, at the ventro-anterior angle.

132. But again; this viscus in the CRUSTACEA is a true digestive stomach; whereas the crop of *Asplanchna* is merely a temporary receptacle, separated from the stomach by a long *œsophagus*: as there is thus no homology between the viscera themselves, there can be none between their respective appendages.

133. If the manducatory organs of the ROTIFERA were really represented by the gastric teeth of the CRUSTACEA, the small central piece of the latter would, of course, be the *incus* of the former: but this cannot be, since the central piece of the latter is affixed to the dorsal wall of the viscus; whereas, in ROTIFERA, the *incus* springs from the ventral or inferior side, its muscles forming the ventral lobe of the bulb.

134. Once more; the gastric teeth are simple masses of calcareous matter, deposited, in the form of tubercles, on the interior of the parietes of the stomach, to grind the food as it passes through the pylorus; whereas, the jaws of the ROTIFERA are complex organs, distinctly articulated, tied by ligaments, moved by their own proper muscles; and their function is, often, to seize prey without the mouth, and always to bruise or lacerate it before it enters the stomach at all.

135. Homology cannot consist with such diversities as these; and, therefore, the gastric teeth of the CRUSTACEA have no true analogy with the jaws of the ROTIFERA.

136. If it should be objected that, in *Floscularia*, &c., we find the jaws affixed to the walls of the digesting stomach, I reply, that these are the most aberrant forms of their class; and that we must not ground our deductions of analogy upon the condition of organs that are just vanishing, or merging into a remotely diverse type; especially when the comparison would tend to unite opposite ends of a series; as, in the present instance, the *Floscularidæ* are undoubtedly the lowest forms of ROTIFERA,

looking towards the POLYZOA; whereas, it is in the highest forms that we must expect to find affinities with the ARTHROPODA.

137. To the ARTHROPODA I am convinced that the ROTIFERA belong—the humblest members of that great group; though, as my present business is with one system of organs alone, I am precluded, at this time, from adducing the various reasons derived from other parts of their economy, which have guided me to this conviction. I think that they lead, however, to the INSECTA rather than to the CRUSTACEA.

138. The dental organs in ROTIFERA are true *mandibulæ* and *maxillæ*, and the *mastax* is a *mouth*. This is a startling proposition, if we look only at *Floscularia*, where it is situated in the midst of the abdominal cavity, or at the *Philodinadæ*, and the *Brachionidæ*, where it is enclosed in the breast. But I have shown that the apparatus is identical, in these families, with that of *Diglena*, *Furcularia*, and *Synchæta*, in which it is terminal and protrusile. And this latter is the normal condition. I have myself witnessed the protrusion of the jaws from the surface of the body, in the following genera:—*Furcularia*, *Pleurotrocha*, *Taphrocampa*, *Notommata clavulata*, *N. aurita*, *N. petromyzon*, *N. parasita* (all of which represent different genera), *Plagiognatha*, *Scaridium*, *Synchæta*, *Polyarthra*, *Diglena*, *Asplanchna*, *Mastigocerca*, *Monocerca*, *Salpina*, *Monostyla*, and *Anuræa*.

139. The integument in the ROTIFERA is very flexible, and, especially in the frontal regions, is extremely invertible. In those genera in which the buccal apparatus can be brought into contact with the external water, it is ordinarily, to a greater or less degree, retracted within the body, by the inversion of the surrounding parts of the exterior; while, in those genera in which it is permanently enclosed, analogy requires us to consider this condition as induced by a similar inversion, but of permanent duration. If we imagine the head of a soft-bodied Insect-larva retracted to a great degree (as is done partially by many Dipterous larvæ), the skin of the thoracic segments would meet together in front, around a purse-like opening, which would be the orifice of such a buccal funnel as exists in most ROTIFERA. In the latter, it is the normal condition; in the former, it is merely accidental.

140. The delicacy and transparency of the *mastax* are, indeed, unlike the corneous and opaque mouths of Insects, and of most larvæ; but its walls are composed of the same solid materials as the teeth themselves; since they are left after treatment with potash, which dissolves away the muscles*.

141. There is, then, no difficulty, I think, in identifying the *mallei* with the mandibles, and the *rami* of the *incus* with the maxillæ, of Insects. Perhaps the *unci* of the former more strictly represent the mandibles themselves, and the *manubria* the

* "In many Dipterous insects the head is covered with the same flexible membranous skin with the rest of the body, from which it is often scarcely to be distinguished. In these, except that it contains the organs of manducation, it wears no more the appearance of a head than any other segment of the body. The head of these larvæ is also remarkable for another peculiarity; that it is capable of being extended or contracted, and of assuming different forms at the will of the insect" (KIRBY and SPENCE, Int. to Ent. iii. 113).

cheeks, into which they are articulated. As in Insects, their usual form is curved, with the convexity outwards, and the extremity variously notched or dentated. Their motion, as in that great Class, is chiefly a shears-like opening and shutting, in the horizontal plane; combined with a kind of rotatory action, which, according to Mr. KIRBY, the mandibles of some insects possess*. The same excellent entomologist enumerates several instances, in which the mandibles of Insects are not symmetrical, the one being developed more than the other; or, at least, differing from it in form †:—a circumstance in which these organs curiously agree with the unsymmetrical *mallei* in *Mastigocerca*, &c. (§ 89 to 91).

142. A glance at the trophi of *Diglena*, *Albertia*, or *Synchæta*, is sufficient to show that the *incus* with its *rami* is the homologue of the maxillæ, since they are placed, in these genera, nearly in the same plane as the *mallei* (= mandibulæ), and within them. There are not wanting, however, numerous instances, among Insects‡, in which the direction of the maxillæ is not parallel to that of the mandibles, but inclined to it; as is more generally the case in the ROTIFERA§.

143. The maxillæ are much more constantly present, in Insects, than the mandibles; the latter being either greatly deteriorated or entirely wanting in important groups, as in *Lepidoptera*, *Aphaniptera*, and some *Diptera*; and this agrees with the evanescence of the *mallei* in many ROTIFERA, while the *incus* is almost invariably present.

144. The *rami* of the *incus*, then, form the maxillæ proper; but whether the *fulcrum* answers to the two *cardines* (KIRBY), soldered together, or to the *labium*, I am not prepared to decide. I incline, however, to the former hypothesis; since, in *Scaridium*, as we have seen (§ 93), there appears to be a lower lip, though the *fulcrum* is large and distinct.

145. In *Diglena*, and its allies, the manducatory apparatus approaches most nearly to that of a predaceous insect; the *rami*, in particular, being almost the counterparts of the maxillæ of a carnivorous beetle. The series of bristles, with which the inner surface is fringed (§ 80), aids the resemblance. *Asplanchna* also presents an instructive example of resemblance in these organs. Here the extremity is two-lobed (fig. 59), as in many beetles; while the interior edge is, in *A. priodonta*, cut into numerous teeth.

146. The lips (*labrum* and *labium*) seem to be lost in all the species which have the *mastax* permanently inclosed; but in such as can protrude the jaws, the upper and lower margins of the *mastax* form distinct edges, more or less moveable by retractation and protrusion. In some instances I have been able to see these margins (which I must regard as representing the lips), or at least one of them; as in *Synchæta* (§ 75), *Polyarthra* (§ 79), and *Notommata aurita* (§ 52); but, in *Scaridium*,

* KIRBY and SPENCE, Int. to Ent. iii. 431. † Ibid. iii. 432. ‡ Ibid. iii. 439.

§ "The mandibles of the larvæ of Tipulæ, which are transverse and unguiform, do not act against each other, but against two other fixed, internally-concave, and externally-convex, and dentated pieces" (KIRBY and SPENCE, iii. 122).

both are very distinct; the labrum being furnished with stiff arched setæ, the labium plain, but bifid (§ 94).

147. I am not aware that any trace exists, in the ROTIFERA, of any organs, or processes, answering to *palpi*, either labial or maxillary. I was at first disposed to consider the processes at the bases of the *rami*, which I have called *alulæ* (§ 47), as maxillary palpi; but, as muscle-bands, in many cases, are inserted into their points, it is manifest that they will not bear this character.

148. To sum up these observations—we may consider a perfect mouth in the ROTIFERA as consisting of seven elements; viz. a *labrum*, a pair of *mallei*, a pair of *incus-rami*, a *fulcrum*, and a *labium*; corresponding homologically to the *labrum*, the *mandibles*, the *maxillæ* (with their *cardines*), and the *labium*, of Insects.

149. But, if this parallel be truly drawn, it is interesting to trace the same organs to their extreme point of degradation, and to mark where they disappear. Their minimum of development is attained in *Floscularia*, and *Stephanoceros*, which (notwithstanding the opinion of Mr. HUXLEY* to the contrary) do certainly lead to the POLYZOA. The latter, therefore, present the point where the two great divisions of the Animal Kingdom, the MOLLUSCA and the ARTICULATA, unite, in their course towards the true Polypes.

150. Now, in one genus of POLYZOA, there is a structure, which we may compare with the apparatus in ROTIFERA. The oval muscular bulbs in *Bowerbankia densa*, which approach and recede in their action on food, as described by Dr. ARTHUR FARRE, in his admirable memoir on the Ciliobrachiate Polypi†, appear to me to represent the quadranti-globular masses of *Limnias*, *Rotifer*, and *Stephanoceros*, reduced to a lower condition of structure, and deprived of *mallei*.

151. I do not see that this conclusion in the least involves (as Mr. HUXLEY supposes) the denial of either the Molluscous affinities of the POLYZOA, or the relationship of the ROTIFERA with the VERMES; the latter being clearly approached by another road, through the ANNELIDA. It would be easy to show (were this the suitable occasion for it) that the ROTIFERA link with the latter, through *Taphrocampa* and *Chætonotus*; as they do with the ENTOZOA, through *Albertia*.

* Journ. Mic. Sci. i. (Trans.) p. 16.

† Philosophical Transactions, 1837, p. 392.

Explanation of the Plates.

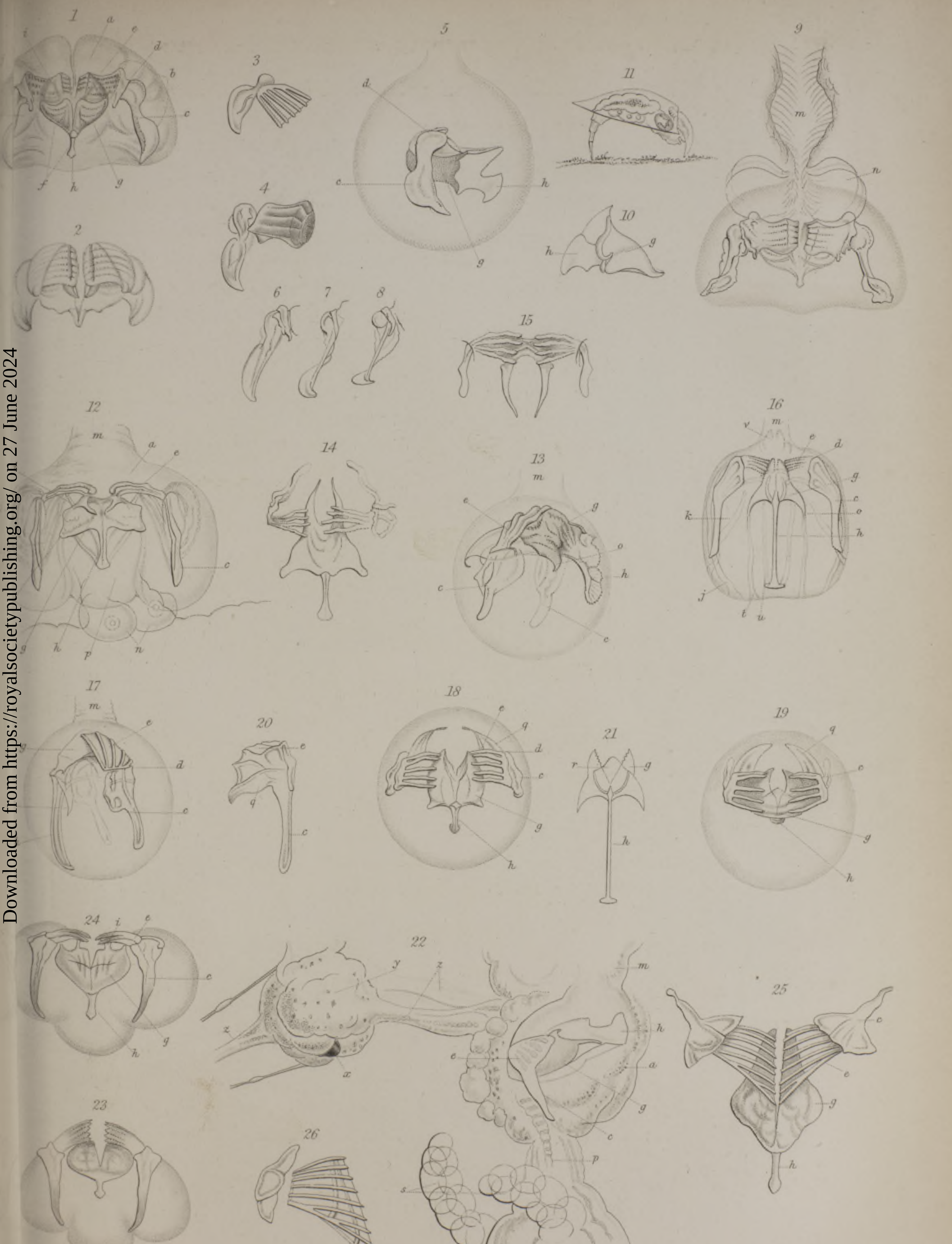
PLATES XVI., XVII., XVIII.

The figures of considerable portions of animals, are magnified 220 diameters; those of the details were taken with a power of 560 diameters, but are not drawn to scale.

The following letters of reference indicate the same organs, or their representatives, in all the figures in which they occur:—

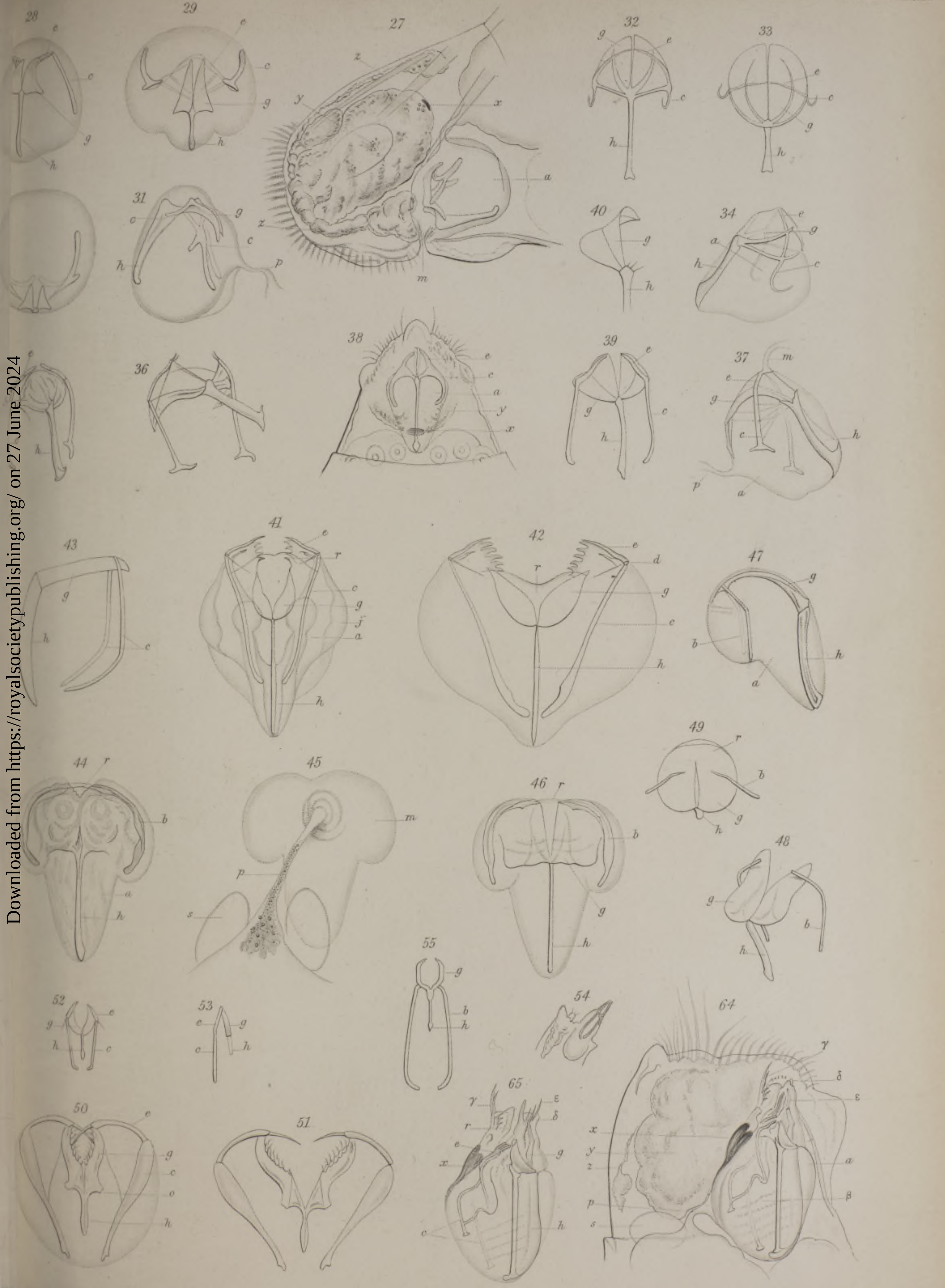
a. Mastax.
b. Malleus.
c. Manubrium.
d. Articulation.
e. Uncus.
f. Incus.
g. Ramus.
h. Fulcrum.
i. Muscle, connecting the uncus with the ramus.
j. Muscle for extending the malleus.
k. Muscle for bending the malleus.
l. Muscle for throwing-in the manubrium.
m. Buccal funnel.
n. Salivary glands.
o. Alula.
p. Œsophagus.
q. Dorsal process of uncus.
r. Labrum.
s. Pancreatic glands.
t. *u.* Muscular bands proceeding from the alulæ, helping to open the rami.
v. Domular structure in funnel.
x. Eye.
y. Ganglion.
z. Nervous chords.

Fig. 1. *Brachionus urceolaris*: mastax and dental apparatus; ventral aspect.
Fig. 2. *Brachionus urceolaris*: jaws; viewed nearly from above.
Fig. 3. *Brachionus urceolaris*: malleus, flattened by pressure.
Fig. 4. *Brachionus urceolaris*: the same; as it appears during life.
Fig. 5. *Brachionus urceolaris*: mastax and dental apparatus; lateral aspect.
Figs. 6, 7, 8. *Brachionus urceolaris*: manubrium; illustrating its changes of position during action.
Fig. 9. *Brachionus urceolaris*: buccal funnel, salivary glands, mastax, and dental apparatus; dorsal aspect.
Fig. 10. *Brachionus rubens*: incus; lateral aspect.
Fig. 11. *Metopidia acuminata*: showing the frontal plate.
Fig. 12. *Euchlanis deflexa*: buccal funnel, mastax, dental apparatus, œsophagus, and salivary glands; dorsal aspect.
Fig. 13. *Euchlanis deflexa*: mastax and dental apparatus, after potash-treatment; lateral aspect.
Fig. 14. *Euchlanis deflexa*: the same; frontal aspect.
Fig. 15. *Euchlanis deflexa*: the same; viewed dorsally, and nearly frontally.

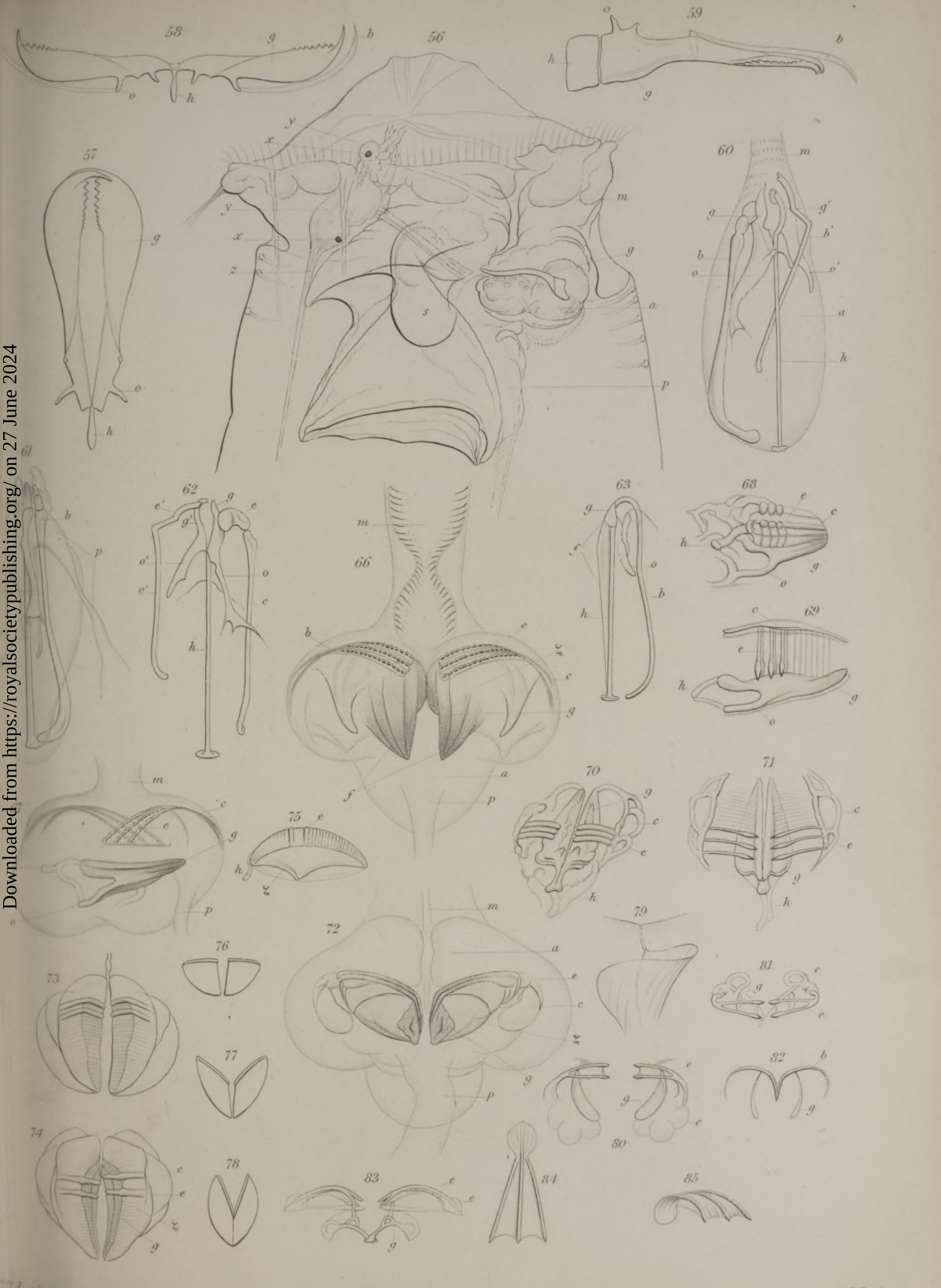


del. ad viv.

J. Basire. sc.



viv. del. J. Basire sc.



... ad nat.   J. Basire, sc.

Fig. 16. *Notommata aurita*: mastax, &c.; ventral aspect.
Fig. 17. *Notommata aurita*: the same; lateral aspect.
Fig. 18. *Notommata aurita*: the same; fronto-ventral aspect.
Fig. 19. *Notommata aurita*: the same; frontal aspect.
Fig. 20. *Notommata aurita*: malleus.
Fig. 21. *Notommata aurita*: incus, opened; with labrum.
Fig. 22. *Notommata clavulata*: ganglion, with its eye and nervous chords, mastax, jaws, œsophagus, pancreatic glands, and commencement of stomach; lateral aspect.
Fig. 23. *Notommata clavulata*: mastax, &c.; ventral aspect.
Fig. 24. *Notommata clavulata*: the same, opened.
Fig. 25. *Notommata clavulata*: mallei and incus, after potash-treatment; viewed frontally.
Fig. 26. *Notommata clavulata*: right malleus.
Fig. 27. *Notommata petromyzon*: the head, with the ganglion, mastax, jaws, œsophagus, stomach, and various muscles.
Fig. 28. *Notommata petromyzon*: mastax; ventral aspect.
Fig. 29. *Notommata petromyzon*: the same; fronto-ventral aspect.
Fig. 30. *Notommata petromyzon*: the same; frontal aspect.
Fig. 31. *Notommata petromyzon*: the same; lateral aspect.
Fig. 32. *Notommata lacinulata*: jaws; ventral aspect.
Fig. 33. *Notommata lacinulata*: the same; fronto-ventral aspect.
Fig. 34. *Notommata lacinulata*: mastax, &c.; lateral aspect.
Fig. 35. *Furcularia gibba*: jaws, closed; latero-ventral aspect.
Fig. 36. *Furcularia gibba*: the same, opened.
Fig. 37. *Furcularia gibba*: mastax, &c.; lateral aspect.
Fig. 38. *Notommata gibba*: the head; dorsal aspect.
Fig. 39. *Notommata gibba*: jaws; nearly a ventral aspect.
Fig. 40. *Notommata gibba*: one ramus; designed from study of various aspects.
Fig. 41. *Synchæta tremula*: mastax and jaws; ventral aspect.
Fig. 42. *Synchæta tremula*: the same, after potash-treatment; expanded under pressure.
Fig. 43. *Synchæta tremula*: jaws; lateral aspect.
Fig. 44. *Polyarthra platyptera*: mastax; ventral aspect.
Fig. 45. *Polyarthra platyptera*: the same; dorsal aspect; with the œsophagus, pancreatic glands, and stomach.
Fig. 46. *Polyarthra platyptera*: mastax and jaws; ventral aspect.
Fig. 47. *Polyarthra platyptera*: the same, after potash-treatment; lateral aspect.
Fig. 48. *Polyarthra platyptera*: jaws; viewed obliquely.
Fig. 49. *Polyarthra platyptera*: the same; frontal aspect.
Fig. 50. *Diglena forcipata*: jaws, closed; ventral aspect.

Fig. 51. *Diglena forcipata*: the same, opened.
Fig. 52. *Albertia vermiculus*: jaws; ventral aspect.
Fig. 53. *Albertia vermiculus*: the same; lateral aspect.
Fig. 54. *Furcularia marina*: head, with the jaws protruded.
Fig. 55. *Furcularia marina*: jaws.
Fig. 56. *Asplanchna priodonta*: the anterior third of the animal.
Fig. 57. *Asplanchna priodonta*: jaws, closed; frontal aspect.
Fig. 58. *Asplanchna priodonta*: the same, opened.
Fig. 59. *Asplanchna priodonta*: right jaw, interior surface; lateral aspect.
Fig. 60. *Mastigocerca carinata*: mastax, &c.; dorsal aspect.
Fig. 61. *Mastigocerca carinata*: the same; lateral aspect.
Fig. 62. *Mastigocerca carinata*: jaws, after potash-treatment; ventral aspect.
Fig. 63. *Monocerca porcellus*: jaws; ventral aspect.
Fig. 64. *Scaridium longicaudum*: the head; showing the large ganglion, with the eye pressing on the mastax; lateral aspect.
Fig. 65. *Scaridium longicaudum*: the lips opened, and the rami protruded.

β. Rugæ on mastax.
γ. Setæ of labrum.
δ. Bifid labium.
ε. Projectile setæ of ramus.

Fig. 66. *Limnias ceratophylli*: mastax and jaws; with the termination of the buccal funnel; and the commencement of the œsophagus; dorsal aspect.
Fig. 67. *Limnias ceratophylli*: the same; lateral aspect.
Fig. 68. *Limnias ceratophylli*: jaws, after potash-treatment; lateral aspect.
Fig. 69. *Limnias ceratophylli*: the same; showing the elevation of the mallei.
Fig. 70. *Limnias ceratophylli*: the same; obliquely-ventral aspect.
Fig. 71. *Limnias ceratophylli*: the same; frontal aspect.
Fig. 72. *Rotifer macrurus*: mastax, &c.; dorsal aspect.
Fig. 73. *Rotifer macrurus*: jaws, after potash-treatment; fronto-dorsal aspect.
Fig. 74. *Rotifer macrurus*: the same; frontal aspect.
Fig. 75. *Rotifer macrurus*: the same; lateral aspect.
Figs. 76, 77, 78. *Rotifer macrurus*: diagrams, to illustrate the changes of form in the quadrantic jaws. ζ. Quadrantic masses.
Fig. 79. *Floscularia ornata*: veil, or septum, in crop.
Fig. 80. *Floscularia ornata*: jaws; dorsal aspect.
Fig. 81. *Floscularia ornata*: the same; frontal aspect.
Fig. 82. *Floscularia ornata*: the same, closed.
Fig. 83. *Stephanoceros Eichhornii*: jaws; dorsal aspect.
Fig. 84. *Stephanoceros Eichhornii*: uncus; frontal aspect.
Fig. 85. *Stephanoceros Eichhornii*: the same; oblique aspect.