CONTRIBUTIONS TO THE BIOLOGY OF THE GREAT LAKES.

ROTATORIA OF THE UNITED STATES.

II. A MONOGRAPH OF THE RATTULIDÆ.

By H. S. JENNINGS,

Assistant Professor of Zoology in the University of Michigan.

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INTRODUCTION.

There is perhaps no need so great in American zoology as to have the different groups of invertebrates thoroughly described and set in order, so that the worker in ecology, physiology, variation, or morphology can determine them without becoming a professional systematist. As matters stand at the present time, most of our aquatic invertebrates can not be determined without the study of much scattered literature, ancient and modern, and much wearisome and unprofitable sifting of synonymy.

Happily there is at present a strong movement toward remedying this state of affairs. What is needed is a set of studies comprising monographic treatments of the various groups—each account of a group complete in itself, so far as the American species are concerned, so that any species of the group can be determined without reference to other literature. This can be accomplished if different investigators select circumscribed groups of not too great extent, perhaps a single genus, and set this thoroughly in order, describing and figuring all species likely to occur in America, and bringing the names into consonance with recognized rules of nomenclature. It is such a study of one of the families of the Rotatoria that is herewith presented.

The *Rattulidæ* are a family of free-swimming Rotatoria, containing altogether about 40 to 45 species. Their chief general interest lies in their peculiar unsymmetrical structure, most of them having the organs so disposed as to give the impression that the body has been twisted, while the primitive bilateral symmetry is still further disturbed by a number of the organs becoming rudimentary on one side. They are found as a rule amid aquatic plants in the quiet parts of lakes, ponds, and streams. Only one of them (*Rattulus capucinus* Wierz. & Zach.) can be said to be limnetic—that is, commonly found free-swimming at a distance from the vegetation of the shores and bottoms. A few occur in swamps; but clear water, amid actively growing vegetation, is the place where the *Rattulidæ* abound. In such regions they are often among the most abundant of the Rotifera.

The classification of the *Rattulidæ* has fallen into great confusion. This statement could be made of almost any of the larger groups of Rotatoria, but it is perhaps more strikingly true of this family than of any other. Many species have been described under several different specific and generic names, while in other cases several different species have been described under a single name. The twisted, unsymmetrical structure has always been more or less of a puzzle to systematists, making it difficult to determine even what were properly to be considered dorsal and ventral surfaces, and the great difference in appearance between contracted and extended animals has further tended to favor confusion. It has seemed to the writer that there is no group of the Rotatoria so much in need of a thorough revision as this one. For this reason it has been taken up first.

In the following paper I attempt to give an account of the structure and movements of these animals, paying especial attention to the asymmetry and its biological significance, and to furnish as far as possible full descriptions and figures of all known species. A large majority of the known species I have myself been able to study, and in these cases the descriptions and figures are based on my own observations. I have attempted to make these so detailed that further mistakes in the identification of these species will hardly be possible. In the case of species which I have not been able to examine myself I give the figures and descriptions which have been published by other authors. Many of these descriptions are very unsatisfactory, as comparison with a large number of species is necessary for bringing out the important characteristics, and such comparison has, in the absence of preserved material, been almost wholly lacking until very recent times.

In the preparation of this paper I have been especially indebted for assistance of the most essential character to Mr. Charles F. Rousselet, of London, England, and to Mr. F. R. Dixon-Nuttall, of Eccleston Park, North Prescot, England. Mr. Rousselet placed at my disposal his valuable mounted collection of the *Rattulidæ*, including a number of species which I did not have in my collection, and has assisted me throughout the work with valuable notes and suggestions. Mr. Dixon-Nuttall sent me his notes and drawings of a considerable number of species of *Diurella*, which he had long been studying, and gave me permission to make use of some of his excellent figures, a number of which are given on plates IV and XIII. The continued cooperation of these two careful investigators has added much to the completeness and accuracy of this paper, and has made it possible, by comparison of specimens, to be certain that my determinations of doubtful species agree with those of the best European authorities.

I am indebted also for specimens of *Rattulidæ* from Lake Bologoe in Russia to the kindness of Dr. Romuald Minkiewicz, of the University of Kasan, Russia; to Herr Max Voigt, of Plön, I am under obligations for specimens of his new species, *Diurella rousseleti*. For notes and other assistance I am indebted to Herr Oberförster L. Bilfinger, of Stuttgart, Germany; to Prof. Dr. Otto Zacharias, director of the Freshwater Biological Station at Plön, Germany, and to Prof. Dr. Karl Eckstein, Eberswalde, Germany. It is a pleasure to express here my thanks to these gentlemen.

METHODS.

The use of preserved mounted specimens has been the basis for the present work. It is only through the methods devised within the last decade by Mr. Charles F. Rousselet, of London, England, that the use of such preserved material has become possible in the study of the Rotatoria. Hence the complete lack hitherto of type or reference specimens among these animals. This has been one of the prime causes of the great confusion in the classification of the Rotatoria. A few of the genera have been worked over in the last few years with the use of preserved specimens by Mr. Rousselet and his collaborators in England. It is not too much to say that it will be necessary to go over the entire group of Rotatoria in the same manner before order can be brought out of the present confusion.

Killing and preservation.—The collections of preserved material on which the following paper is based were made as follows: The Rotifera were taken in various ways—by towing with the tow net in water free from vegetation, by washing aquatic plants in jars of water, by bringing into the laboratory quantities of aquatic plants together with some of the water about them, etc. Most of the Rotatoria come after a time to the lighted side of the vessel in which the material collected is placed. These are transferred in large numbers to a watch glass and placed beneath a simple microscope or low power of the compound microscope, where the movements of the organisms can be observed.

Now a considerable quantity of Rousselet's narcotizing fluid is mixed with the water in the watch glass. One-fourth as much narcotizing fluid as there is water, or a larger or smaller proportion, may be used, as seems desirable from observation of the movements of the animals. Rousselet's narcotizing fluid consists of 2 per cent solution of hydrochlorate of cocaine, 3 parts; methyl alcohol, 1 part; water, 6 parts. This causes the animals to swim slowly and gradually to settle to the bottom; they will soon die, and if allowed to die unfixed will be quite worthless for study, destructive changes taking place in the tissues at the moment of death or perhaps even before. As soon, therefore, as most of the rotifers have sunk to the bottom, as much of the water as possible is drawn off from above them with a pipette. Then a small amount of 0.25 per cent osmic acid is introduced, which kills and fixes the rotifers at once. Now remove the osmic acid as quickly as this can be done without taking up too many of the rotifers (within a minute or two if possible), and wash several times in distilled water. In thus fixing the rotifers in large numbers at once, it is usually impossible to draw off the osmic acid as soon as would be best, so that the animals become much blackened. But the blackening may be removed later with hydrogen peroxide. If the osmic acid has been used at the right time usually a majority, or at least many, of the rotifers will be found to be fixed well extended. But as the time required for narcotization varies with different species as well as with different individuals of the same species, many of the animals will be found contracted or with the structure partly obscured by degenerative changes. With practice, however, it will become possible to secure a sufficiently large percentage killed in good condition to make the collection very valuable.

For study of the loricate Rotifera it is advisable to kill some part of every collection directly by means of osmic acid, without previous narcotization, for in the loricate rotifers some of the most important distinctive characters can best be seen in contracted specimens.

After several washings the collections are preserved in 3 to 6 per cent formalin (3 to 6 parts commercial formalin to 100 parts water). They can not be preserved in alcohol without causing extensive shrinkage, rendering them useless for further study.

These collections may later be examined under a lens in order to study the rotifers belonging to any family, genus, or species, and the specimens desired picked out by means of a pipette drawn to a capillary point. The different species are sorted into different watch glasses, and the blackening due to the osmic acid is removed by drawing off most of the formalin and adding a few drops of hydrogen peroxide for a few minutes. As soon as the desired degree of bleaching is reached the hydrogen peroxide is replaced by formalin. The formalin should be changed several times and allowed to stand several hours before mounting the specimens, otherwise bubbles of oxygen may appear under the cover glass after it is sealed.

Specimens which have not been in osmic acid long enough to require bleaching are better in some respects than those that have been bleached by the hydrogen peroxide, as the latter removes the pigment from the eye, as well as the blackening due to the osmic acid.

The specimens are then mounted in hollow-ground slides. The slides should be thin and the concavities shallow, so that it will be possible to use high powers of the microscope. The specimens are transferred to the concavities along with some of the formalin, and covered with a circular cover glass. It is best not to leave any bubbles of air beneath the cover. The superfluous fluid is withdrawn from the edge of the cover with a bit of filter paper, and the cover is then sealed.

It is, of course, necessary to use some sealing material that will not allow water to evaporate through it. Mr. Rousselet, the originator of this method of mounting rotifers, recommends the following for sealing the mounts: After fixing the cover with a ring composed of a mixture of two-thirds gum damar with one-third gold size, there are added two coats of pure shellac, followed by three or four coats of gold size, allowing twenty-four hours for each coat to dry.

The following account of the *Rattulidæ* is based on the study of 101 collections, made as above, and representing about half as many different stations. These collections were mostly made about the shores of Lake Erie, during the summers of 1898, 1899 and 1901, while the writer was connected with the biological work on the Great Lakes carried on by the United States Fish Commission. The following regions were examined with special thoroughness:

1. The region about the islands in the western part of Lake Erie.
2. The south or Ohio shore of Lake Erie, in the region known as East Harbor, some distance from Sandusky, Ohio.
3. The lake shore and river at Huron, Ohio.
4. The region about Erie Harbor, Pennsylvania, including the swamps and ponds on Presque Isle.
5. Long Point, on the Canadian shore of Lake Erie.
6. Many collections have also been made about Ann Arbor, Mich., in the Huron River, and in a number of small streams and ponds in the neighborhood.

These collections have been supplemented by specimens and notes furnished by a number of investigators in Europe, as mentioned in the introduction.

STRUCTURE OF THE RATTULIDÆ.

The *Rattulidæ* are Rotatoria, usually of small size, in which the cuticle of the body has become stiffened to form a sort of shell, called a lorica. At the anterior end is a ciliated area or corona, by means of which the animal swims; this may be retracted within the lorica. At the posterior end is a small separate joint, known as the foot (*f*, figs. 1, 27, 46, etc.). To the foot are attached one or two bristle-like structures, which are called the toes. The internal organs comprise an alimentary canal, nervous, muscular, excretory, and reproductive systems, and certain mucus glands. In the following account these sets of organs will be taken up in order.

I. EXTERNAL FEATURES.

(1) *General form.*—The more usual form of the body in the *Rattulidæ* is that of a cylinder, or long oval, frequently curved. In some cases the body is much elongated, as in *Rattulus elongatus* Gosse (pl. XII, fig. 102), or *Diurella insignis* Herrick (pl. II, fig. 15); in other cases it is short and plump, as in *Diurella porcellus* Gosse (pl. II, figs. 19–21). In a few cases (*Rattulus latus* Jennings, pl. VII, figs. 65, 66; *R. multicrinis* Kellicott, pl. VI, figs. 55–57) the body is broad and ovoid in form.

A striking feature of the animals is their tendency to asymmetry in shape. This shows itself in many ways. The body with the toes usually forms a curve, concave to the right, convex to the left (figs. 1, 8, 16, 28, 46, 95, 99, 102, etc.). The curve is often not simple, but is of such a nature that the body forms a segment of a spiral. This is perhaps best seen in fig. 1, of *Diurella tigris* Müller; it is a characteristic which is difficult to represent in a drawing, although often very noticeable in the animal itself. As will be seen later, the asymmetry shows itself in the form and arrangement of many organs.

(2) *Lorica.*—The body is covered with a hardened cuticula, known as the lorica. The lorica covers the body completely, being without openings at the sides, but it is open anteriorly for the projection of the corona, and posteriorly for the protrusion of the foot. The lorica is not so stiff and unyielding in the *Rattulidæ* as in many of the Rotifera, usually permitting considerable change of form. Compare, for example, the extended form of *Rattulus longiseta* Schrank (pl. VIII, fig. 67) with the contracted form in the same species (pl. VIII, fig. 70). In some species the lorica is stiffer, not permitting such marked changes in shape.

Head-sheath.—The anterior part of the lorica is usually set off from the remainder of the body by a slight constriction. This anterior portion, covering the head, may be known as the head-sheath (*h. s.*, figs. 1, 3, 8, etc.). It presents a number of interesting characteristics, and some that are very important in classification. Only in *Rattulus latus* Jennings is it impossible to distinguish a head-sheath from the remainder of the lorica.

The head-sheath frequently has longitudinal plaits, if they may be so designated, which serve for permitting the folding of the head-sheath when the head is retracted within the lorica. These are well seen in figs. 3, 4, 58, 59, and 62. These plaits seem to be due to alternate longitudinal strips of hard, stiff material, and of soft, yielding cuticula. On the inner surface of the head-sheath are many fine transverse muscle fibers (shown especially in figs. 58 and 59, pl. VI). When the head is drawn within the lorica, these longitudinal folds are brought together by the yielding of the

soft strips between them, and partly slip over one another, so that the size of the head-sheath is greatly reduced and the anterior opening nearly or quite closed. It is possible to withdraw the head, at least partly, in most species without causing the complete folding of the head-sheath; evidently a supplementary contraction of the fine transverse muscle fibers is necessary to bring this about.

In some species (notably *Diurella tigris* Müller, pl. I, figs. 3, 4; *Diurella rousseleti* Voigt, pl. IV, fig. 37; *Rattulus multicrinis* Kellicott, pl. VI, fig. 58; *Rattulus capucinus* Wierz. & Zach., fig. 59, and *Rattulus cylindricus* Imhof, pl. VII, fig. 62) the head-sheath falls when contracted into very regular folds. In *D. tigris* Müller, *D. rousseleti* Voigt, and *D. intermedia* Stenroos, and perhaps in other species, the number of these folds is nine. In some other species, as, for example, in *Rattulus gracilis* Tessin, pl. V, fig. 48, the folds are very irregular. In still other species no such folds are present, and the lorica may remain widely open when the head is retracted. This is the case, for example, in *Rattulus scipio* Gosse, pl. V, fig. 52.

On the anterior dorsal margin of the head-sheath there are in certain species of the *Rattulidæ* a number of teeth. In *Diurella rousseleti* Voigt there are nine well-marked teeth; in other species there are but one or two. Leaving out of consideration for the present the case of *Diurella rousseleti*, we may classify the teeth in other species into two categories:

(*a*) In *Rattulus multicrinis* Kellicott (pl. VI, figs. 55 and 58), *Rattulus capucinus* Wierz. & Zach. (pl. VI, figs. 59–61), and *Rattulus cylindricus* Imhof (pl. VII, fig. 62), there is a single nearly median projection of the dorsal lorica edge, extending over the head. In *Rattulus cylindricus* Imhof this is prolonged into a long hook, curved downward over the anterior opening of the lorica. In these cases the tooth seems to be nearly or quite in the middle line.

(*b*) In a number of other species there is either one tooth (*Rattulus gracilis* Tessin, figs. 45–48; *Rattulus scipio* Gosse, figs. 50–52; *Diurella tigris* Müller, figs. 1, 3, 4; *Diurella tenuior* Gosse, figs. 7, 8; *Diurella weberi*, figs. 12–14 and 116–117; *Diurella intermedia* Stenroos, figs. 108, 109)—or two teeth (*Rattulus longiseta* Schrank, figs. 67–70; *Diurella insignis* Herrick, figs. 15, 16; *Diurella porcellus* Gosse, figs. 19, 20; *Diurella stylata* Eyferth, figs. 27–30), which seem of a different character. These lie distinctly to the right of the dorsal middle line (so far as that can be defined), and form prolongations of one or both edges of the "striated area" of the lorica, hereafter described. When there are two of these teeth they are usually unequal in size, the right one being longer. (Only in *Diurella stylata* Eyferth are they nearly or quite equal in length.) In most species they are merely short teeth, but in *Rattulus longiseta* Schrank and *Diurella stylata* Eyferth they are long spines. The position of these teeth on the right side is one of the markedly unsymmetrical characters of the *Rattulidæ*. A further account of these teeth may best be deferred until the "striated area" has been described.

Many of the species have no teeth at the anterior edge of the lorica. The anterior opening of the lorica is usually oval, with a slight notch near the ventral middle line. In some few cases the edge of the head-sheath projects farther on the left side of the opening than on the right. This is notably the case in *Diurella weberi* n. sp. (pl. XIII, figs. 116–117); it is slightly so in *Diurella tenuior* Gosse and *Diurella brachyura* Gosse, and perhaps in other species.

In some cases three or four or more teeth have been described by different authors at the anterior edge of the lorica. In many cases this is due to the optical

effect of the longitudinal folds in the head-sheath above described or to the slight rounded projections of certain parts of the head-sheath mentioned in the last paragraph. Sometimes the folds of the head-sheath project as sharp teeth. An example of this condition is found in *Diurella rousseleti* Voigt, where there are nine of these teeth. These, however, are of different character from the one or two teeth which I have described above. These latter are structures to a certain extent *sui generis*, and I shall, as a rule, restrict the use of the term *teeth* in this connection to them.

Stenroos (1898) has described a new species, *Mastigocerca* (*Rattulus*) *rosea*, which is said to have two long teeth or spines, like those of *Rattulus longiseta* Schrank, at the *ventral* margin of the lorica. In other respects the animal resembles *Rattulus longiseta* Schrank. As this peculiar position of the teeth is unknown in any other of the *Rattulidæ*, and is entirely out of harmony with the structure and behavior of the *Rattulidæ* in other respects (as will appear later), it seems possible that there was an error of observation in this case.

Striated area, Ridge.—One of the most peculiar characteristics of the *Rattulidæ* is the presence on the lorica of a dorsal longitudinal area, striated transversely, which extends from the anterior edge some distance backward on the body. This area shows the most varied differentiations in different species—in some appearing as a single high ridge, in others as two ridges, in others as a depression, while in still other cases there is no change in the surface of the lorica at this region except the transverse striations. This peculiar area is so characteristic for the *Rattulidæ*, and plays such a part in determining their forms, that it must be treated in full.

The area is unsymmetrical in position, usually beginning at the anterior margin of the lorica, to the right of the mid-dorsal line, and passing obliquely backward and toward the left side. Its sides are, as a rule, rather sharply defined, frequently appearing as thickenings or ridges. This area shows in *Rattulus elongatus* Gosse a condition which will serve as a useful point of departure for an understanding of the various differentiations which it undergoes in other species. In *R. elongatus* Gosse (pl. XII, fig. 102) the area begins at the anterior edge as a broad, shallow furrow, with well-marked sides. This furrow lies a little to the right of the position of the eye, as seen from above. From the sides of the furrow transverse striations pass toward its middle (and a little forward). The striations are not continuous from one side to the other, but meet in the middle of the furrow in a sort of rhaphe.

The furrow proper extends backward for a distance only somewhat greater than the diameter of the lorica. Near its posterior end, in its middle line, is situated the dorsal antenna. Though the furrow or depression below the general surface ceases at the point above indicated (shown at *x*, figs. 102 and 105), the striated area continues, with well-defined edges, for about one-third the length of the lorica.

In *Rattulus longiseta* Schrank (pl. VIII, fig. 67) the striated area is of very nearly the same character as in *Rattulus elongatus* Gosse, save that it exists as a depression throughout its entire length, reaching to the middle of the lorica. In this species we have another characteristic feature added—the relation of the striated area to the two anterior teeth or spines. *The two teeth are continuations of the thickened edges of the striated furrow.* This appears to be true in all species where the teeth exist. The tooth or spine which forms the continuation of the right edge is much longer than the left one.

What is the function of this striated area and what are the transverse striations which mark it? The striated furrow, as we find it in *Rattulus longiseta* Schrank,

bears much resemblance to one of the longitudinal folds in the head-sheath of such species as *Rattulus capucinus* Wierz. & Zach. and *Rattulus multicrinis* Kellicott (pl. VI, figs. 58 and 59); and these folds are cross-striated, just as in the case of the furrow. The striations in the folds of the head-sheath are evidently fine muscular bands, which have the office of bringing the folds together when the head is withdrawn.

In the case of the dorsal striated area, it seems beyond question that the striations are of the same nature—that they are muscular bands. They are clearly not surface markings, but are internal bands. This is seen with especial ease in such forms as *Rattulus carinatus* Lamarck and *Rattulus bicristatus* Gosse, in which the striated area rises in the form of one or two ridges. Moreover, the two edges of the furrow may be closely approximated, when the animal is strongly retracted, as in pl. VIII, fig. 70. When the head is extended the bases of the two teeth (on the opposite sides of the furrow) are a considerable distance apart; but when the animal is contracted to a maximum degree the two are almost in contact.

The striated area therefore represents a longitudinal flexible portion of the lorica, permitting an increase or decrease in the circumference of the body. The striations are muscle fibers, by means of which the approximation of the two sides is brought about. These fibers are attached at the middle and at the two thickened edges of the area.

In *Rattulus mucosus* Stokes (pl. X, fig. 86) the two edges of the striated area are raised as pronounced ridges, leaving a broad and deep furrow between them. The striations (muscle fibers) pass from the summit of the ridges to the bottom of the furrow. Stokes (1896) states that he has seen the two ridges drawn toward each other, and I believe that I have observed the same thing.

In *Rattulus bicristatus* Gosse the two edges of the area reach their highest development, rising as two very high prominent ridges with a broad, deep furrow between them (pl. IX, figs. 77 and 78). The muscles are grouped in pronounced bundles, which pass from near the summit of the ridges to the middle of the broad groove between them. In a squarely side view of the ridges the ends of the muscle bundles are seen as irregular areas.

In another series of species, of which *Rattulus carinatus* Lamarck (pl. XI, figs. 95, 97), *Rattulus lophoessus* Gosse (figs. 98, 99), and *Diurella tigris* Müller (fig. 1), may be taken as types, only the right edge of the striated area is elevated into a ridge, the left not rising above the general surface of the body. Thus a single ridge is produced, having its edge toward the right, and sloping gradually to the left. The left edge of the striated area may usually be recognized as a sharp, well-defined line, but not at all elevated. The muscle fibers run from the summit of the ridge (on the right) to the base of the ridge, at the left boundary of the area. The interruption of the fibers in the middle of the area can usually still be made out (though it is not indicated in all the figures).

Thus we have produced the peculiar condition found in many of the *Rattulidæ* and well shown in fig. 1 and fig. 95 (pl. XI)—a high, sharp ridge passing on the right side of the body obliquely backward. Why the right ridge should thus have developed rather than the left one we shall try to bring out in our general discussion of the asymmetry of the *Rattulidæ*.

In addition to the types already described the striated area is present, in a considerable number of species, neither in the form of a well-defined ridge nor as a

well-defined groove, but merely as a flexible area with marked transverse striations. This is the case, for example, in *Rattulus rattus* Müller (pl. XI, figs. 100, 101). In this organism the striated area is in some cases apparently swollen out to form a slight rounded ridge; in other cases it seems to lie at the general level of the lorica surface, while in still other specimens it seems to form a slight depression. It is probable that these are functional differences, due to the state of contraction or extension of the specimen. Almost every intergradation is found, from the furrow of *R. elongatus* Gosse to the high ridge of *R. carinatus* Lamarck. In perhaps the majority of species (especially in *Diurella*) the striated area is merely slightly elevated at its right edge, forming a low ridge, not conspicuous in most views.

The area in which the transverse striations can be seen usually passes from the anterior edge to the middle of the length of the body, or to a point some distance behind the middle. The ridge formed by the elevation of the area sometimes continues back farther than the striations, and may extend to the beginning of the foot (as in *Rattulus lophoessus* Gosse, pl. XI, figs. 98, 99).

Among the species which I have studied with care only *Rattulus latus* Jennings and perhaps *Rattulus multicrinis* Kellicott and *Rattulus capucinus* Wierz. & Zach. show no sign of the striated area.

A word further should be said about the relation of the striated area to the teeth or spines at the anterior edge of the lorica. Those of the second category mentioned on page 280 are formed as outgrowths of the thickened edges of the striated area. Where two teeth are present both the edges project, that formed by the right edge being usually the longer. When only one tooth is present it is formed by a projection of the right edge of the area.

The anterior projections of the first category mentioned on page 280, found only in *Rattulus cylindricus* Imhof, *Rattulus capucinus* Wierz. & Zach., and *Rattulus multicrinis* Kellicott, are formed in a somewhat different way. The initial stage in the production of such a projection is found in *Rattulus elongatus* Gosse (pl. XII, fig. 102); the entire width of the striated area projects at the anterior edge as a rounded lobe. In *Rattulus capucinus* Wierz. & Zach. and *R. multicrinis* Kellicott the projection has developed into a large triangular tooth. In *Rattulus cylindricus* Imhof (pl. VII, fig. 62) the tip of this tooth has further developed into a long hook, curved down over the corona. The three species showing this peculiar differentiation occupy a different position from most of the other species in many other respects also.

(3) *Foot.*—The foot is a short, conical structure attached to the body at the posterior end. The foot shows little variation in structure, except in size and form, being in some cases short and thick, in others slender. In a few cases (*Diurella porcellus* Gosse, *D. sulcata* Jennings, etc.), the foot is very small, so as to be hardly recognizable as a separate structure. In some of these cases it is usually held completely retracted within the body. Sometimes the foot shows one or two faint annulations which have at times been described as joints.

The most peculiar thing about the foot in the *Rattulidæ* is its usually unsymmetrical attachment to the body. The joint between the foot and the body is commonly oblique, extending farther back on the left (or left dorsal) side than on the right. This is well shown in fig. 86 (pl. X), fig. 99 (pl. XI), and fig. 103 (pl. XII). In some cases the posterior edge of the lorica projects backward some distance over

the foot on the left side, but not on the right. The foot is thus attached to the lorica in such a way that it can bend to the right, but not to the left.

(4) *Toes.*—The toes form perhaps the most peculiar characteristic of the *Rattulidæ*. Most of the Rotifera have two short posterior appendages attached to the foot, placed side by side, and, like most paired organs, similar in form and size. But in the *Rattulidæ* we find the two toes in the majority of cases unequal, sometimes excessively so, and no longer side by side. In some species one of the toes has almost disappeared, while the other has become immensely developed, forming a straight rod as long as the body (in *Rattulus cylindricus* Imhof, for example, pl. VII, fig. 62).

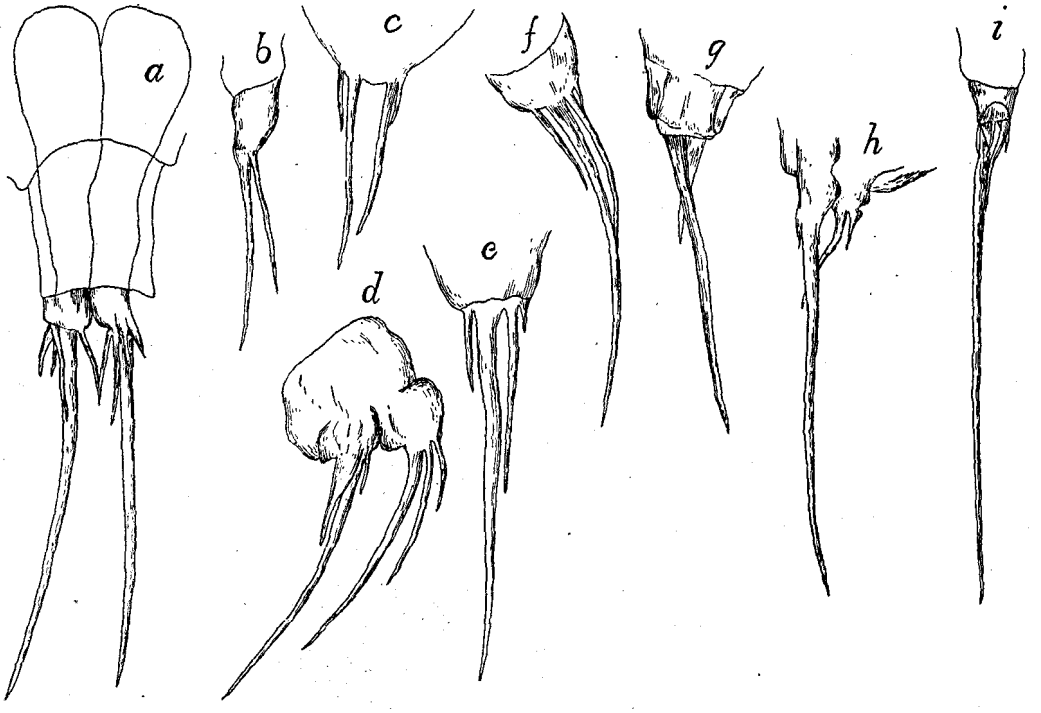

FIG. 1.—Dorsal views of the toes in a number of species of *Rattulidae*, showing gradual reduction of the right toe. (*a*) *Diurella tigris* Müller; (*b*) *D. stylata* Eyferth; (*c*) *D. brachyura* Gosse; (*d*) *D. porcellus* Gosse; (*e*) *D. insignis* Herrick; (*f*) *D. tenuior* Gosse; (*g*) *Rattulus gracilis* Tessin; (*h*) *R. lophoessus* Gosse; (*i*) *R. elongatus* Gosse.

The steps in the series of changes by which this is brought about may be clearly followed by comparing the toes of different species. In a few species (*Diurella tigris* Müller, *D. sulcata* Jennings, *D. intermedia* Stenroos, etc.) the two toes are still equal, as in other rotifers. One of these will serve best as a starting-point. We will select *Diurella tigris* Müller, whose toes are shown in text-figure 1, at *a*.

The toes form two long, curved, pointed, spine-like rods of equal size. At the base of each are four small flattened spines (so-called substyles), which usually lie closely applied to the base of the toes. The use of these substyles was pointed out by Plate (1886), and will be readily appreciated when one of the habits of the animals is understood. The posterior part of the body contains two large glands (pl. I, figs. 3, 4, *m. g.*), which secrete a quantity of mucus, which is stored up in

two large sacs (figs. 3, 4, *m. r.*). These sacs open one at the base of each toe, and discharge the mucus out upon the surface of the toe. Thence it trails behind the animal as a long thread, by means of which the rotifer attaches itself to various external objects and hangs in the water, as a spider by its thread. The mucus passes out of the sac between the substyles and the main toes, and the four substyles serve to direct its course out along the surface of the toe.

But the two toes in *Diurella tigris* Müller are not placed exactly side by side, as in most rotifers, but they partake of the prevailing asymmetry of the animal. The attachment of the toes to the foot is oblique, like that of the foot to the body, so that the right toe lies at a higher level than the left. The arrangement will be

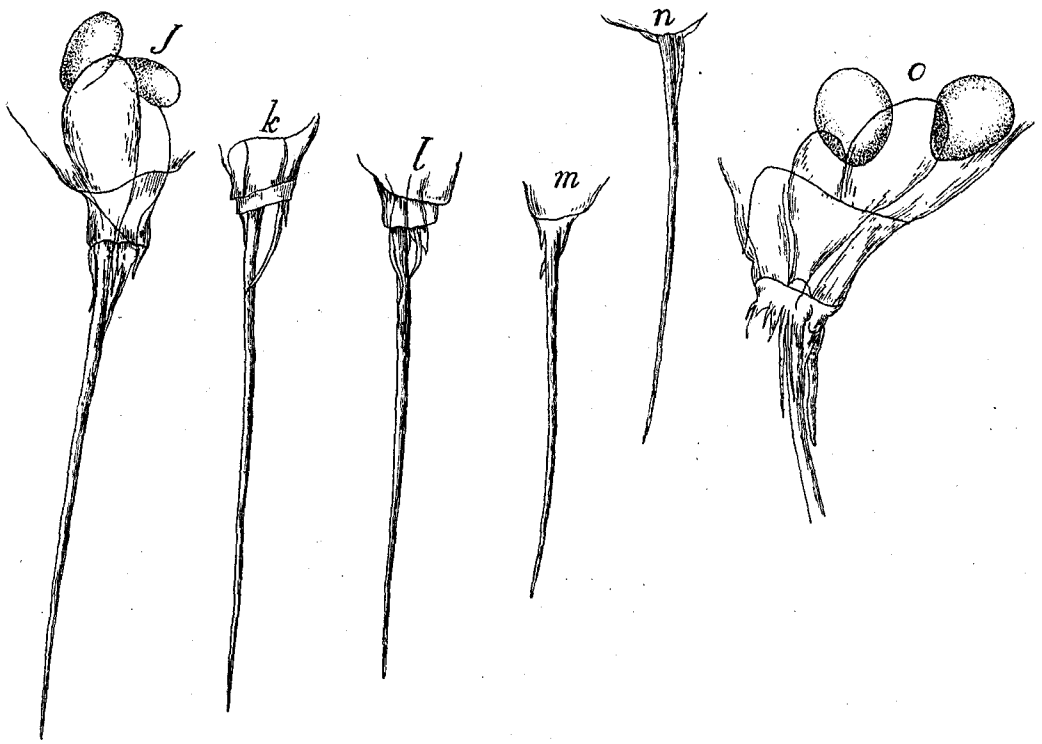

FIG. 1.—Dorsal views of the toes in a number of species of *Ratlulidæ*, showing gradual reduction of the right toe. (*j*) *R. longiseta* Schrank; (*k*) *R. scipio* Gosse; (*l*) *R. carinatus* Lamarck; (*m*) *R. multicrinis* Kellicott; (*n*) *R. pusillus* Lauterborn; (*o*) *R. bicristatus* Gosse (base of toe only).

best understood if one conceives it to have been brought about as follows: The toes, originally concave downward, have been twisted at their attachment to the foot, so that their concavity now faces to the right (pl. I, fig. 1), and the right toe lies above the left, as the animal creeps along the bottom. The toes and foot can therefore now bend only to the right, not toward the ventral side, as in most rotifers.

Now, as a result of the condition above described, the two toes no longer have the same relation to the environment as they have in a bilaterally symmetrical animal. This similar relation to the environment is usually assigned as a reason for the similarity of paired organs, and the lack of such similar relation to the environment may become an equally good ground for the loss in similarity of two

organs no longer having this relation. The lower, originally left, toe is now next to the bottom when the animal is creeping, and will more often come in contact with it than will the right toe. Moreover, when a thread of mucus hangs from the toes and catches on some object on the bottom, it will more often be that from the lower (left) toe.

So, perhaps as a consequence of this change of position and of relation to the environment, the right or upper toe begins to degenerate. The steps in degeneration are easily traceable and are shown in text-figure 1. In *Diurella stylata* Eyferth (*b*) and *D. brachyura* Gosse (*c*) the toes are almost equal, but the left is a little longer. In *Diurella porcellus* Gosse (*d*) the difference is greater. In *Diurella insignis* Herrick (*e*) and *D. tenuior* Gosse (*f*) the right toe is about half as long as the left. In *Rattulus gracilis* Tessin (*g*) it is about one-third the length of the left. The right toe now forms a small spine, which has its tip bent toward the main or left toe, and lying against the latter. *Rattulus lophoessus* Gosse (*h*) shows a still farther step; *R. elongatus* Gosse (*i*), *R. longiseta* Schrank (*j*), *R. scipio* Gosse (*k*), *R. carinatus* Lamarck (*l*), *R. multicrinis* Kellicott (*m*), and *R. pusillus* Lauterborn (*n*) still farther ones in the reduction of the right toe and corresponding increase in the left one. In the species last named (*i* to *n*) the rudimentary right toe has usually been classed with the substyles; it can generally be recognized, however, by its form and position, as well as, at times, by the fact, shown in *j*, that one of the mucus reservoirs opens at its base. Finally, there are certain species, as *Rattulus bicristatus* Gosse (*o*), *R. mucosus* Stokes, and others, in which it is very difficult, or impossible, to distinguish between the rudimentary right toe and the substyles.

It is probable that this degeneration of one of the toes is related primarily to the habit, so common in the *Rattulidæ*, of becoming suspended from foreign objects by a thread of mucus attached to the tip of the toe, and then revolving on the long axis. It is evident that a single, long rod is much better fitted to serve as a pivot than two toes side by side. These would impede the revolution by furnishing resistance to the water.

The substyles are present all through the series. Their number varies; in most cases each of the two toes seems to have two, three, or four. In *Rattulus bicristatus* Gosse (text-figure 1, *o*) at least eight can be seen about the base of the main toe; among these the rudimentary right toe can hardly be distinguished from the others.

Hand in hand with the reduction of the right toe goes a reduction of the mucus reservoir which is connected with it. The reduction of the mucus reservoir is not so extensive as that of the toe, and it never completely disappears. Indeed, in some cases where the toes are very unequal, the two reservoirs remain of the same size. This is true in *Rattulus stylatus* Gosse (fig. 92, pl. x.) Unequal reservoirs are shown in text-figure 1, *j* and *o*.

Apparently, in some species at least, the toes are of the full length when the animal is hatched from the egg, while the body is much smaller than it later becomes. Thus in young specimens the toe is much longer in proportion to the body than in adults. This is well shown by comparing figs. 18 (pl. II), 51 (pl. v), 90 (pl. x), representing young specimens respectively of *Diurella insignis* Herrick, *Rattulus scipio* Gosse, and *R. mucosus* Stokes, with the other figures representing adult specimens of these species. This is a point worthy of special note, as it may easily lead to error in specific determinations.

(5) *Corona.*—The truncate anterior end is unprotected by the lorica and bears in the *Rattulidæ*, as in other rotifers, cilia by means of which the organism moves and by which it obtains its food. Partly surrounded by the cilia are usually also a number of antenna-like organs. This whole complex of structures at the anterior end is known as the corona. In the *Rattulidæ* the structure of the corona does not vary a great deal in the different species. The main features of the corona will be seen by an examination of that of *Diurella stylata* Eyferth (pl. III, fig. 31). Partly surrounding the corona, especially in the dorso-lateral region, are two curves of cilia (*a*), forming together nearly a semicircle. These two curves are not continuous with one another, but there is a gap between them in the middle dorsal region. These cilia are the organs of locomotion of the animal.

At the sides of the mouth (*m*) are two other curves of shorter cilia (*b*). These are connected with food-taking, and may be said to belong strictly to the mastax or pharynx. When the mastax is pushed far beyond the surface of the head, as sometimes happens, these cilia are seen to be borne upon its end. This is well shown in fig. 56 (pl. VI), in *Rattulus multicrinis* Kellicott.

In the dorsal part of the corona, in the median line, is a thick dorsal projection (pl. III, fig. 31, *c*). In many *Rattulidæ* this is more slender than in *Diurella stylata* Eyferth. At the sides of this process, but lying a little ventral to it, are two smaller prominences (*d*) bearing cilia. Just above the dorsal projection, shown in fig. 31, is another thick dorsal process, shown in side view in fig. 27, *e*.

The four curves of cilia described above (*a* and *b*) are present in all the *Rattulidæ*. There is also almost invariably a single, thick dorsal process (*c*). In the other antenna-like structures there is more variation. In *Rattulus multicrinis* Kellicott (pl. VI, fig. 57) the upper median process (*e*) is very long, while the lower one (*c*) is short. There are two long lateral processes (*d*) on each side. In *Rattulus latus* Jennings (pl. VII, fig. 65) the corona is similar to that of *R. multicrinis* Kellicott. The lower dorsal process (*c*) bears on its end two small processes. The parts of the corona which can be seen easily in most species of the *Rattulidæ* are the cilia and the large dorsal process. The latter lies, as a rule, a little to the left of the end of the striated area of the lorica.

The functions of the curious club-shaped or antenna-like organs of the corona are not known beyond the general probability that they are sense organs.

In addition to the (probable) sense organs on the corona, there are three other structures which doubtless have sensory functions. These are the so-called dorsal and lateral antennæ.

Dorsal antenna.—The dorsal antenna is found, as in most rotifers, on the dorsal surface, some distance back of the anterior end of the head. It usually lies a very little behind the constriction which separates the head-sheath from the remainder of the lorica. It consists, in well-developed cases, of a small club-like structure, projecting through an opening in the lorica and bearing one or more fine setæ. It is best developed in *Rattulus cylindricus* Imhof, where the seta which it bears is very long and conspicuous (pl. VII, figs. 62, 63, 64).

From the antenna there may often be traced a fine cord running to the brain. This has, just within the lorica, a spindle-shaped thickening.

In many species no setæ can be observed on the dorsal antenna, and often the

only trace of it is the opening in the lorica, through which it should pass. This opening is probably to be found in all the *Rattulidæ*.

The position of the dorsal antenna perhaps indicates the position of the dorsal median line. This is true at least in other rotifers, and in the *Rattulidæ* the surface which bears it is above when the animal is creeping on the bottom. Its place with reference to the striated area is therefore of interest. In *Rattulus elongatus* Gosse, *R. cylindricus* Imhof, and *R. bicristatus* Gosse, and, indeed, as a rule in the species in which the striated area forms a furrow with its two sides equally developed, the dorsal antenna lies in the middle of the furrow. But in *Rattulus mucosus* Stokes this is not true. The dorsal antenna in this species lies to the left of the striated area, in a notch in the outer side of the left ridge.

A similar position is found in almost all species in which the striated area is developed as a single ridge. The antenna lies to the left of the ridge, usually at about the left edge of the striated area. (See pl. XI, figs. 95 and 100.)

Lateral antennæ.—In most free-swimming rotifers (as in the *Notommatadæ*, from which the *Rattulidæ* are without doubt derived) the two lateral antennæ are situated one on each side, in the posterior third of the body, symmetrically with relation to one another. Many species of the *Rattulidæ* have preserved nearly this primitive position, though usually with slight variations. There may be a tendency for the right antenna to be a little farther forward (as in *Rattulus scipio* Gosse, pl. V, fig. 52, and *Rattulus carinatus* Lamarck, pl. XI, fig. 95), or to be a little nearer the dorsal side, as in *Rattulus elongatus* Gosse (pl. XII, figs. 102, 103, 105), or the opposite tendencies may be shown. But in some cases there is a very remarkable asymmetry in the positions of the two antennæ. In *Rattulus cylindricus* Imhof, for example, the left antenna is at about the middle of the length of the body (pl. VII, fig. 63), while the right antenna is very far back, at the place where the lorica is joined by the foot. In *Diurella stylata* Eyferth the left antenna is still farther forward (figs. 28, 29, pl. III), while the right one is on the posterior part of the body.

There are probably no species of *Rattulidæ* in which the lateral antennæ can not be found by careful search.

INTERNAL ORGANS.

The internal organs partake, to a considerable degree, of the asymmetry so characteristic of the external anatomy of the *Rattulidæ*. Otherwise the internal structure in this group does not present a great deal that is different from what is found in most of the related Rotifera, so that I shall treat of it only briefly. The *Rattulidæ* are not a favorable group for a study of the characteristic internal structure of the Rotifera.

(1) *Alimentary canal.*—The alimentary canal shows the following parts: The mouth opens into a muscular pharynx known as the mastax, containing chitinous jaws or *trophi*. From the mastax a short, narrow tube, the œsophagus, passes backward to widen into the large, thick-walled stomach. The stomach narrows to form the intestine, which passes straight back to the anus. The entire course of the alimentary canal is well shown in fig. 63, pl. VII (*Rattulus cylindricus* Imhof), and fig. 77, pl. IX (*Rattulus bicristatus* Gosse).

Mouth.—The mouth opens on the truncate anterior end, or corona, near its ventral side (pl. III, fig. 31, *m*). At its sides are two curves of cilia (*b*) which serve the purpose of carrying small particles of food to the mouth.

Mastax.—The mastax is a muscular, pharynx-like structure, forming the first part of the alimentary canal (*mx.*, pl. VII, fig. 63). Its anterior end forms a nearly circular area on the corona, within which lies the mouth (pl. III, fig. 31, *m*). The two curves of cilia above spoken of, at the sides of the mouth, are really borne on the end of the mastax, as appears when the latter is pushed far out (pl. VI, fig. 56).

The mastax is large, filling up a considerable portion of the anterior part of the lorica. It is composed chiefly of a mass of muscles, which act upon the chitinous jaws. Only the anterior part of the mastax is hollow and receives the food, the posterior three-fourths or more being a solid mass of muscle. The transverse muscles are often very evident as striations (pl. XIII, figs. 108, 111, 115, 119).

In consequence of the asymmetry of the trophi the mastax frequently shows an unsymmetrical form, as, for example, in fig. 61, pl. VI. The œsophagus opens into the mastax on its dorsal side near its anterior part, as shown in fig. 63, pl. VII, and fig. 105, pl. XII. In many species the œsophageal opening is clearly somewhat on the right side of the mastax.

The mastax frequently has connected with it one or more prominent glands. One on the left side is especially marked in *Rattulus multicrinis* Kellicott (pl. VI, fig. 57) and *Rattulus latus* Jennings (pl. VII, fig. 65). These glands are apparently not present in all species.

Trophi.—The chitinous jaws or trophi vary a great deal among the different species, and usually show a considerable degree of asymmetry. The trophi of *Rattulus carinatus* Lamarck were well described by Gosse (1856) in his classical paper on the "Structure, Functions, and Homologies of the Manducatory Organs in the class Rotifera." The trophi of *Rattulus longiseta* Schrank (pl. VIII, figs. 71, 72) furnish a good example of the typical structure. Following Gosse, we may distinguish three main portions—the two lateral parts, known as *mallei*, and a central structure, the *incus*. Each of these is composed of several portions.

The malleus consists of two chief parts, a long distal rod, the *manubrium* (*mu.*), and a shorter proximal portion, the *uncus* (*u.*). The two mallei are unequal in size, the left one being the larger. The left uncus bears teeth, while the right one is merely a straight rod without teeth.

The incus or central portion consists of three main parts. There is a long curved median rod, the fulcrum (*fu.*), which, as the side view (fig. 71) shows, lies at a level nearer the ventral surface than do the manubria. In side view the fulcrum is seen to consist of two rods, the ventral one being very thin and united to the other by membrane. The fulcrum bears at its proximal end two large structures known as *rami* (*ra.*). These articulate with the fulcrum and inclose a space between them. At their proximal ends they, like the unci, bear a number of teeth. The rami have their lower or distal ends produced into a long process for the attachment of muscles. These, with Gosse, we may designate as the alulæ (*al.*). The left alula is considerably longer than the right.

In addition to these chief portions there are a number of chitinous rods forming a framework which lies on the dorsal side of the proximal end of the trophi (pl. VIII, fig. 71, *su.*). These arise from the manubria and are connected with the rami. The function of this framework is not very clear. In some cases it seems to support a sort of chitinous fringe about the mouth (pl. XIII, fig. 118).

The typical parts of the apparatus are the manubria, unci, fulcrum, and rami, and in our account of the variations of the trophi among different species we shall take only these into consideration.

In the small group of related species comprising *Rattulus multicrinis* Kellicott, *R. capucinus* Wierz. & Zach., *R. cylindricus* Imhof, and *R. latus* Jennings, the trophi are nearly or quite symmetrical. The manubria are approximately of the same length and the alulæ seem not strongly developed.

Most of the remaining species of the genus *Rattulus* have the trophi moderately unsymmetrical, the left manubrium being considerably larger than the right. This is the case, for example, in *R. elongatus* Gosse (pl. XII, fig. 107), *R. longiseta* Schrank (pl. VIII, fig. 72), *R. bicuspes* Pell (pl. VIII, fig. 76), and *R. bicristatus* Gosse (pl. IX, fig. 80). In *R. mucosus* Stokes (pl. X, fig. 91) there is a much greater asymmetry, and the trophi have a very peculiar character. The left manubrium and uncus, the fulcrum and rami, are heavy and massive, while the right manubrium and uncus are reduced to mere slender rods. There appear to be no teeth, the trophi seeming to be designed rather for crushing than biting.

In *Diurella* the asymmetry of the trophi is on the whole much more pronounced than in *Rattulus*, most of the species of *Diurella* having jaws fully as unsymmetrical as those last described, or even more so. In *Diurella porcellus* Gosse (pl. II, fig. 22) the right manubrium is as long as the left, but is excessively slender—a mere bristle. In *D. sulcata* Jennings (pl. II, fig. 26) and *D. tenuior* Gosse (pl. I, fig. 10) the reduction of the right manubrium has gone still farther; it has become much shorter than the left one. In *D. tigris* Müller (pl. I, fig. 2), finally, the culmination of asymmetry is reached; the right malleus is a minute rudiment, while the left one is massive.

Gosse (1856) described *Diurella porcellus* as having the right manubrium quite lacking. This is not the case with the specimens of that species which I have examined, though it is much reduced. I have found none of the *Rattulidæ* in which the right manubrium could not be discovered.

It is striking that the trophi are most unsymmetrical as a rule in the species of the genus *Diurella*, though the toes in this genus are less unsymmetrical than in *Rattulus*. This is probably due to the fact that in *Diurella* the body is as a rule more slender and more curved than in *Rattulus*. As the curve is of such a nature that the right side is concave, there is much less space on this side than on the convex left side, so the internal structures on the right side are reduced. This is especially noticeable in the trophi. In *Rattulus*, where the body is usually more swollen and less curved, there is not so much occasion for the reduction of the right side.

Œsophagus.—The œsophagus is merely a short, slender passageway with thin walls, which begins on the dorsal side of the mastax, on its anterior one-fourth. It is well shown in fig. 63 (pl. VII), fig. 77 (pl. IX), and fig. 105 (pl. XII).

Stomach.—The stomach is an enlarged sac, with thick, apparently glandular walls, forming a direct continuation of the œsophagus. In the broad-bodied species, such as *Rattulus latus* Jennings (pl. VII, fig. 65), it lies on the right side.

At the anterior end of the stomach are the two gastric glands, one on each side. These are small solid structures, often lobulated and showing a number of prominent nuclei. They are well shown in fig. 77 (pl. IX), fig. 87 (pl. X), and fig. 102 (pl. XII).

Intestine.—The stomach narrows at its posterior end to form the intestine (*in.*, pl. VII, fig. 63; pl. XII, fig. 102). The walls of the intestine are usually thinner and less

colored than those of the stomach, but there is no precise line of demarcation between the two. The intestine narrows rapidly to end at the *anus*, which lies beneath the edge of the lorica, just above the beginning of the foot, a little to the left of the middle line.

Food of the Rattulidæ.—The food of the *Rattulidæ* seems to consist chiefly of small particles suspended in the water, which are brought to it by its cilia, or of the floccose material covering the surface of water plants. The animals may often be seen creeping over the stems or leaves of water plants with the corona against the surface, as if they were feeding, but it is very rarely that one sees any definite namable thing devoured. In one case, and one only, I have seen a *Rattulus* display predatory tendencies. A *Rattulus gracilis* Tessin seized a young *Diurella tenuior* Gosse, which happened to be near it, pierced the lorica with its jaws, tore out a piece from the side of its prey, and devoured it. The jaws of many other species seem better fitted for carnivorous habits than do the comparatively weak ones of *Rattulus gracilis* Tessin, but I have seen no other instances of the character just described.

(2) *Brain.*—The brain in the *Rattulidæ* is usually a large, oblong body, rather prominent, which lies on the dorsal side of the mastax, in the anterior part of the body. In front the brain has no defined boundary, merging into the mass of substance which supports the corona. Its main mass frequently lies to the left of the striated area or ridge on the lorica. The brain is usually somewhat shorter than the mastax, but in a few cases—notably in *Diurella stylata* Eyferth—it forms a very large sac, extending backward more than half the length of the lorica (*br.*, pl. III, fig. 27). In such cases the brain is seen to be made up of large cells, whose outlines are clearly distinguishable.

In the *Rattulidæ* the brain has no opaque, chalky mass at its posterior end, such as is found in many of the *Notommatadæ*. Gosse (1889) described as *Rattulus cimolius* an animal in which the brain has such a chalk mass, but from Gosse's description and figure (see p. 342 and fig. 138, pl. XV) it seems clear that this animal was not one of the *Rattulidæ;* it should rather be classed with the *Notommatadæ*.

Connected with the brain is the single *eye*. This is a hemisphere of red pigment, usually attached to the posterior end or under side of the brain. In a number of species the brain is divided at its posterior end into two unequal lateral lobes, the left one being smaller and bearing the eye at its tip. This condition is shown in fig. 99, pl. XI (*Rattulus lophoessus* Gosse), and in figs. 102 and 103, pl. XII (*R. elongatus* Gosse); it is present in a number of other species also. The dorsal antenna is connected with the brain by a slender cord, which is very evident in *Rattulus cylindricus* Imhof (pl. VII, fig. 63). It is probable that the lateral antennæ are thus connected with the brain also. From each of these there passes forward a slender cord, but I have not succeeded in tracing this to the brain.

(3) *Excretory organs.*—The excretory organs do not differ essentially from those found in other rotifers and are not strikingly developed in the *Rattulidæ*, so that this group is not a favorable one for their study. For this reason I have not paid especial attention to the excretory system. It consists essentially of the well-known lateral canals, one on each side, which open at their posterior ends into a small bladder-like structure, the contractile vacuole. These parts are shown in fig. 24 (pl. II) and fig 32 (pl. III).

The lateral canals are two slender tubes, in some species considerably convoluted, in others much less so, which begin in the anterior part of the body and run backward, one along each side, to the contractile vacuole. The lateral canal bears on each side four or five small evaginations, each containing a long cilium; these are the so-called flame cells or vibratile tags (pl. II, fig. 24).

The contractile vacuole (fig. 24, *c. v.*) is unusually small and inconspicuous in the *Rattulidæ*. It is a spherical vesicle lying just beneath or at the side of the intestine near its posterior end. It is situated above the large mucus reservoirs (*m. r.*), which are sometimes mistaken for the contractile vacuole.

The contractile vacuole usually pulsates rather rapidly, perhaps in consequence of its small size. Twenty times per minute seems a not uncommon rate; in *Diurella brachyura* Gosse, according to Stokes (1896), there are 40 pulsations per minute. The contractile vacuole in most rotifers opens into the intestine near its posterior end; this matter has not been especially investigated in the *Rattulidæ*.

(4) *Reproductive organs.*—The male seems to be quite unknown in the *Rattulidæ*. No member of this family is given in Mr. Charles Rousselet's list of male rotifers hitherto described (1897), and I have myself seen nothing of a male in any of the species studied.

The ovary (*ov.*) is an irregular, frequently somewhat lobular, organ, differing in no important manner from the same organ in most of the related free-swimming rotifers. As Plate (1886) has shown, the ovary in most of the Rotatoria consists of two parts, a vitelline portion ("Dotterstock") and a germinal portion ("Keimstock"). The latter is smaller than the former; from it the eggs are directly produced. The germinal portion seems to lie at the right side or right anterior corner of the vitelline portion, in the *Rattulidæ*. The vitelline portion contains a small number (usually if not always eight, in this family) of large, conspicuous nuclei.

The ovary lies on the ventral side of the alimentary canal, usually mostly to the left of the median line. In *Rattulus latus* Jennings (pl. VII, fig. 65) it lies entirely to the left of the alimentary canal, not on the ventral side of the latter at all.

The eggs are formed in the germinal portion, to the right of the main body of the ovary. When the egg has reached a considerable size, it usually occupies a large space on the right side of the body, as in fig. 32 (pl. III).

In the *Rattulidæ*, so far as known, the egg, after extrusion, is carried attached to the lorica in only one species, *Rattulus cylindricus* Imhof. In this case the animal is frequently found carrying the egg attached to the posterior end of the lorica, above the foot (pl. VII, fig. 62).

(5) *Mucus glands and reservoirs.*—The glands and reservoirs for supplying the tenacious mucus-like substance, by which the animals attach themselves to various objects, are unusually well developed in the *Rattulidæ*. The reservoirs especially form a large, clear, oval sac, or a pair of sacs, filling a considerable part of the hinder portion of the body. There are typically two of the glands and two of the reservoirs in the *Rattulidæ*. They are well shown in fig. 92 (pl. X); fig. 79 (pl. IX), and fig. 69 (pl. VIII). The two glands are rounded or irregular granular bodies, lying near the ventral surface, just behind the ovary.

The two reservoirs are usually pressed close together or even united, so that it is perhaps just as correct to speak of a single reservoir divided into two chambers by a longitudinal partition, as of two reservoirs. Into these chambers passes the secretion from the glands; it may often be found in preserved specimens as a solid

mass. In living specimens the reservoirs are entirely clear, and have often been taken for the contractile vacuole, occupying as they do the position usually taken by the vacuole in other rotifers.

One of the two reservoirs opens at the base of the right toe, the other at the base of the left toe (see fig. 6, pl. I, and fig. 69, pl. VIII). The tenacious secretion passes out between the base of the toe and the substyles, being directed by the latter down along the surface of the toe. From the tip of the toe it trails off into the water, like a spider's web, and attaches itself to any object with which it comes in contact. The animal then remains suspended in the water, like a spider from its thread (though of course the rotifer, owing to the movement of the cilia, may hang upward or horizontally, as well as downward). The animal spins about on its long axis, remaining nearly in the same position, or it may of course move in the circumference of a circle about the object to which it is attached.

While thus attached, the action of the cilia brings food to the mouth, just as in the Rotifera that are permanently fixed by their posterior ends. The free-swimming Rotifera which have this secretion of mucus have thus the advantage of being able to temporarily change their roving method of life into a fixed one.

But the thread produced by the mucus is not so strong, apparently, but that by an extra effort it may be broken at any moment. Often a specimen will be seen to swing about from its point of attachment for a considerable time, then suddenly to start rapidly forward, swimming with the most complete freedom. Often too the mucus seems to act merely as a yielding thread—moderating the course of the animal a little—but being drawn out as the animal progresses.

Sometimes the mucus becomes a trap which results in the death of the animal. A specimen will sometimes bring the *base* of its toes against some solid object, as the glass slide on which it is undergoing examination, at the moment when a large quantity of the mucus has been given out. It thereupon sticks fast, perhaps by the entire length of the toe, to the glass and can not escape. It then remains attached at this point till it dies. It is probable that such an accident rarely occurs except when the animal is under such unusual and cramped conditions as it finds between the slide and the cover-glass.

In *Diurella tigris* Müller, in which the two toes are equal, the two reservoirs are also equal (pl. I, fig. 6). But in most species in which the right toe has become rudimentary, the right reservoir has likewise much decreased in size. This is the case, for example, in *Rattulus bicristatus* Gosse (pl. IX, fig. 79) and *R. longiseta* Schrank (pl. VIII, fig. 69). In *R. stylatus* Gosse, however, the two reservoirs are still nearly or quite equal in size (pl. X, fig. 92), although the right toe has nearly disappeared.

THE ASYMMETRY OF THE RATTULIDÆ AND ITS BIOLOGICAL SIGNIFICANCE.

The writer has already given in a separate paper[a] a general discussion of the significance of asymmetry in a number of lower organisms, so that only the salient points, with their application to the *Rattulidæ*, will be set forth here.

All the *Rattulidæ* are more or less unsymmetrical in their structure. If we seek for a general statement which shall express the nature of this asymmetry we shall find it most fully set forth as follows: Conceiving the middle to be a fixed point, the

[a] Asymmetry in Some Lower Organisms and its Biological Significance. Mark Anniversary Volume, N. Y., 1903.

anterior part of the body seems to be twisted over to the right, the posterior part over to the left. This will perhaps best be appreciated by examining fig. 1 (*Diurella tigris* Müller). The anterior part of the ridge is far to the right of the middle line. The single tooth is also to the right of the middle; in those species where there are two teeth (as *Rattulus longiseta* Schrank, *Diurella porcellus* Gosse, etc.) the left tooth is nearly in the middle line, the right tooth much to the right of that line.

At the posterior end, on the other hand, the indications are that what was primitively dorsal has passed to the left, while the right-hand one of the paired structures has taken a dorsal position. The dorsal projection of the lorica over the foot has become shifted to the left (shown particularly well, for example, in the figure of *Rattulus lophoessus* Gosse, pl. XI, fig. 99). The right toe has come to lie nearly on the dorsal side of the left one, so that the concavity of the toes (originally ventral) has become directed to the right (fig. 1). Thus the foot and toes can bend only to the right, not to the left.

The body has become not merely twisted on its primitive straight axis, however, but is often bent at the same time so as to form a segment of a spiral (seen especially well in fig. 1, of *Diurella tigris* Müller). As a result of this the left side has become convex, the right side concave. (Compare the following dorsal views in which this is evident: Figs. 1, 16, 29, 46, 52, 75, 78, 95, 99, 103.) These features are, of course, much more marked in some species than in others.

These general changes have induced certain secondary ones. The originally right toe, which has become dorsal, gradually degenerates until it has become in many species a mere rudiment. The right mucus reservoir is likewise involved in this change, becoming smaller than the left. Owing, perhaps, to the enlargement of the left side as a result of its convexity, and the diminution of the right side owing to the concavity falling here, there is a tendency for the internal organs to be better developed on the left side than on the right. This is most strikingly brought out in the structure of the trophi. The right half of the trophi, as shown in the account of these organs, is almost invariably smaller than the left, and in many cases is quite rudimentary.

Altogether, we may say that the body in the *Rattulidæ* tends to take the form of a segment of a spiral, and that this change from the primitive bilateral symmetry has induced also a considerable number of subsidiary changes.

What is the significance of this peculiar condition in the *Rattulidæ?*

The key to the asymmetry of this group is to be found in a study of the movements and behavior of the animals. The unsymmetrical structure is, of course, not a primitive condition, but these animals were originally bilaterally symmetrical. The fundamental plan of structure is still that of bilateral symmetry; certain parts have been reduced or changed in position so that asymmetry has resulted, but the bilateral ground plan is easily traceable. The nearest relatives of the *Rattulidæ* are still bilaterally symmetrical. Probably no one familiar with the Rotatoria will be inclined to question the view that the *Rattulidæ* are derived from the *Notommatadæ*. The *Notommatadæ* are typically creeping forms. They live among the weeds, on the surfaces of which they creep about by means of their cilia, keeping the mouth, as a rule, against the surface.

The differentiations shown by bilaterally symmetrical organisms are usually brought into relation theoretically with their methods of movement, and doubtless

very justly. Anterior and posterior ends differ because they come into different relations with the environment, owing to the forward movement. In the same way dorsal and ventral surfaces differ because they come into different relations with the environment—the ventral side being more commonly in contact with a surface, the dorsal side not thus in contact, but subjected to the light and other influences coming from above. On the other hand, the right and left sides are in a similar relation to the environment, there being no influence which acts on one differently from the way it affects the other; hence they remain alike.

Analogous considerations apply to the radially symmetrical form. But there is another type of structure, having an equally definite relation to the method of life and movement—a type which has not been hitherto recognized, at least not as having a definite relation to a widespread method of locomotion and life. This is what may, in general, be characterized as a spiral type of structure, or at least as a one-sided type. This type of structure is found in many organisms which swim freely through the water in a spiral course. Its typical representatives are the Infusoria—the Ciliata and Flagellata.

The spiral course may be characterized as the simplest device to enable an organism to make progress in a given direction through the free water without fulfilling the difficult condition of making all sides identically alike, or of making the differences exactly balance each other.[a] In the spiral course the organism continually keeps one side toward the outside of the spiral. In other words, it is in reality always turning toward one side. The tendency to deviate thus caused is compensated by a revolution on the long axis, which continually brings the side in question into a new position. The path thus becomes a spiral, while if revolution on the long axis did not occur it would be a circle.

Now, the organisms which habitually make use of this method of progression have a form which is adapted to it. In the ciliate and flagellate Infusoria, which move in this manner, the form is usually unsymmetrical, often clearly spiral; and here the spiral form seems to be primitive; at least it was not developed from an originally bilateral form. But in the *Rattulidæ* we have a group of animals, fundamentally bilateral, which are taking on this spiral, unsymmetrical form as an adaptation to their method of movement.

Movements of the Rattulidæ.—If we examine in detail the movements of one of the *Rattulidæ*, taking, for example, *Diurella tigris* Müller (fig. 1), we find that it swims through the water in a spiral, of such a course that its twisted body forms a segment of the spiral path (text figure 2). The animal revolves to the right and swerves toward its dorso-dextral side, while it at the same time progresses. The result is a path almost exactly that which would be produced if the animal were moving on the inside of a hollow cylinder and the dorso-lateral spiral ridge ran in a groove on the inner surface of the cylinder, which fitted it precisely and had the same curvature. The effect is the same as that produced by the spiral grooves on the inner surface of a rifle barrel, giving the ball a rotary motion about the axis of flight. The result is here, as in the rifle ball, to make the axis of progression a straight line.

[a] For the grounds on which this statement is based, as well as a general discussion of spiral movement and unsymmetrical structure, see the paper on *Asymmetry*, etc., already cited (p. 293); also a paper by the present author on *The Significance of the Spiral Swimming of Organisms*, in the American Naturalist, vol. 35, 1901, pp. 369-378.

It is evident, therefore, that the general form of the body is adapted to the path which the body follows through the water. And this general form is produced by a twisting of the body from its original bilateral symmetry into the condition already minutely described. The reason why only the right half of the striated area is, as a rule, elevated into a ridge, which slopes to the right, and why the ridge has an oblique course, are entirely evident in the light of the method of movement. The course is always a right spiral, and the single oblique ridge, sloping to the right, greatly favors the spiral movement, while if the left ridge were developed, it would act in opposition to the spiral course. The reason why the right side is concave, the left convex, with the consequent asymmetry of some of the internal organs (notably the trophi) is equally evident. All these things are adaptations to the spiral movement, and, specifically, to movement in a right spiral.

But there are some points which still need elucidation. Why has the foot become twisted into such a position that the toes can be bent only to the right? Why does the right toe degenerate? And why are the teeth at the anterior dorsal margin of the lorica confined to the right side?

These points will be better understood if we examine the behavior a little further. As we have seen, the animals continually swerve, while swimming, toward the dorso-dextral part of the body—that which bears the ridge. This result is due to two components, (1) a tendency to swerve toward the dorsal side, as when lifting the body from the bottom (a tendency which is present in almost all free-swimming rotifers), and (2) the revolution toward the right. The resultant of these two components is a turning toward the dorso-dextral region.

Now, as in the Infusoria,[a] the usual reaction to a stimulus in the *Rattulidæ* is closely related to the method of locomotion. When a *Diurella* or *Rattulus* while swimming freely through the water meets an obstacle it alters its course simply by turning still farther than usual toward the side to which it is already swerving—that is, toward the dorso-dextral side. If the obstacle is small it is thus at once avoided. If the obstacle on the other hand is large, such as a flat surface, which prevents further movement in the

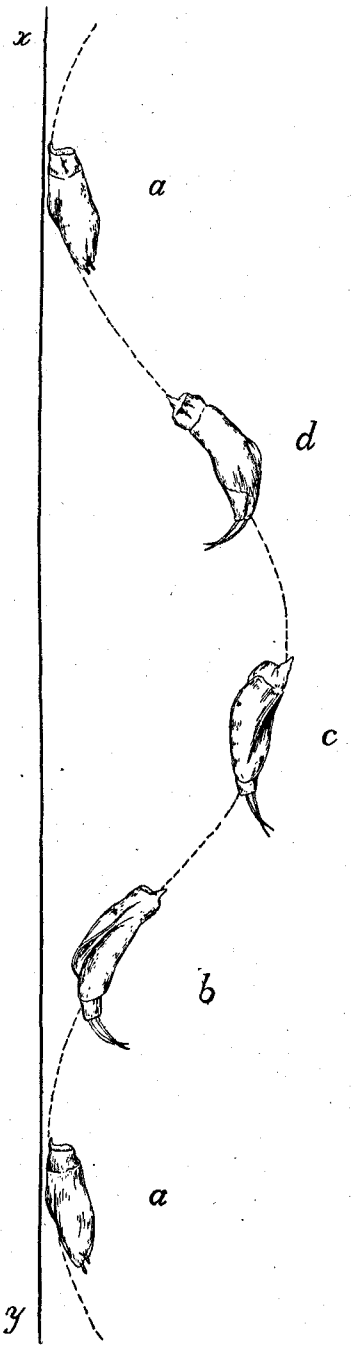

FIG. 2.—Spiral path followed by *Diurella tigris* Müller, showing that the animal continually swerves toward the dorso-dextral side.

[a] See Jennings, *On the Movements and Motor Reflexes of the Flagellata and Ciliata*. Am. Journ. Physiol., vol. 3, pp. 229-260.

axis of the spiral, the animal continues to swerve toward the dorso-dextral side till its general direction is completely changed. Text figure 3 represents such a reaction in *Diurella tigris* Müller.

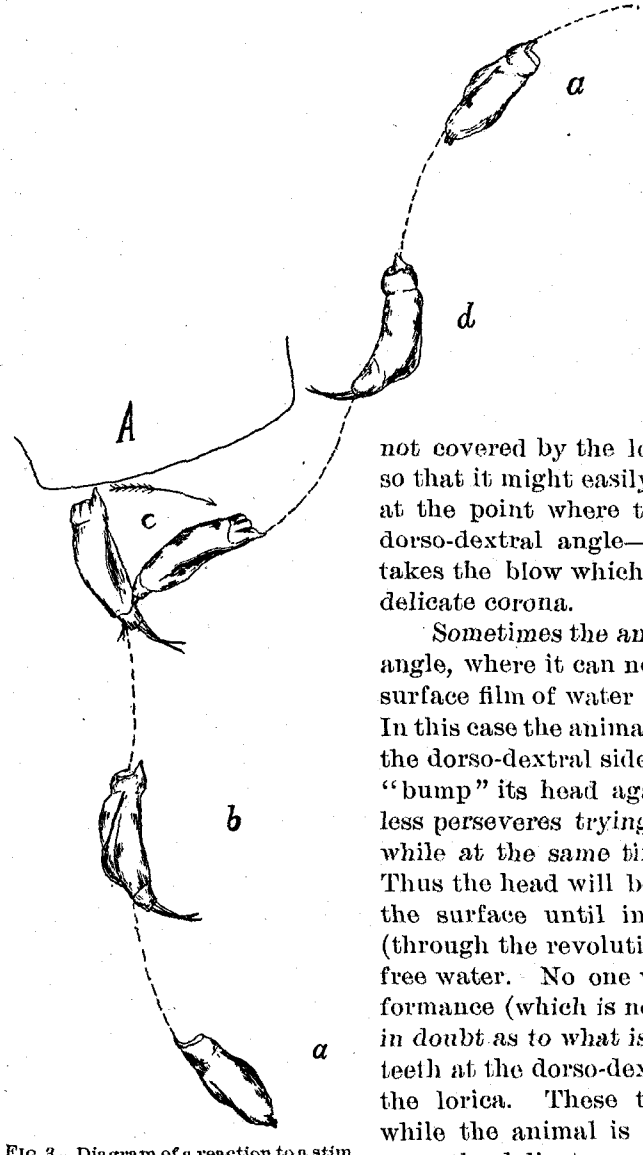

FIG. 3.—Diagram of a reaction to a stimulus in *Diurella tigris* Müller. *A* represents an obstacle. The animal turns toward the dorso-dextral side, which bears the tooth and ridge.

The animal may be stimulated in other ways; the usual result is to induce it to swerve farther toward the dorso-dextral side. If there is really no obstacle the path becomes merely a wider spiral than usual for some distance.

Now, it is evident that if the animal, when thus turning, strikes against any object, it will be the dorso-dextral angle of the head which receives the shock. The corona is of course not covered by the lorica, as is the rest of the body, so that it might easily be injured in such cases. But at the point where the corona would strike—at the dorso-dextral angle—is the tooth (or teeth). This takes the blow which would otherwise fall upon the delicate corona.

Sometimes the animal swims forward into a small angle, where it can not directly turn, as between the surface film of water and the bottom of a watch glass. In this case the animal begins, as usual, to turn toward the dorso-dextral side, but as a result it may merely "bump" its head against the bottom. It nevertheless perseveres trying to turn in the same direction, while at the same time it revolves on its long axis. Thus the head will be dragged and "bumped" along the surface until in time the dorso-dextral angle (through the revolution) becomes directed toward the free water. No one who has seen this peculiar performance (which is not at all uncommon) can remain in doubt as to what is the significance of the tooth or teeth at the dorso-dextral side of the anterior end of the lorica. These teeth take all the "bumping" while the animal is turning, in place of its falling upon the delicate corona. The teeth are placed just where they will serve to protect the delicate head when the anterior end comes in contact with anything. Owing to the invariable swerving toward the dorso-dextral side, the head, if it ever strikes against obstacles at all, will strike on this dorso-dextral angle, where the teeth are ready to protect it.

The striking against objects is by no means rare even in the ordinary swimming

of the animal. It often swims along with its spiral path tangent to a surface, almost every turn bringing the animal against the surface. Such a tangent surface may be represented by the line *x–y* in text figure 2. But, as the figure shows, of course it is always the dorso-dextral angle which comes in contact with the surface, and the tooth or teeth protect the soft head from injury. No teeth are present on the left side, because they would serve no purpose in that position.

Finally, the twisting of the foot and toes, so that they can turn only to the right, finds its explanation along the same line. The entire animal is constructed on the plan of turning to the right, and the arrangement of the toes is merely another adaptation to this. If the toes were so arranged as to bend downward, a sudden stroke with them would turn the organism toward the ventral side, quite in opposition to the other tendencies of the animal. But with the toes turning to the right, their action is brought into harmony with the rest of the behavior of the animal. On getting to a place where it can go forward no further, or as a result of other strong stimulation, the animal turns its toe or toes suddenly and strongly to the right and forward. By this the usual swerving of the animal to the right is strongly accentuated; the path of the animal is thus suddenly changed.

I have attempted to give an explanation of the decrease in size of the right toe in the general account of the toes (p. 284), which may be referred to here to complete the account of the factors which result in the production of asymmetry in this group.

A few other points should be mentioned in regard to the movements of these animals. There are a few of the smaller species of *Rattulidæ*, with short thick bodies, such as *Diurella porcellus* Gosse and *D. brachyura* Gosse, which do not invariably swim in a spiral, though they do usually. In some cases one of these animals will be seen to swim for a short distance in the following manner: With ventral side down (or up), the body swings on the long axis from side to side, giving it a peculiar rocking motion, but without revolving completely. After swimming for a short distance in this manner the animal may suddenly begin to revolve and continue its course in a spiral path like the other *Rattulidæ*.

The *Rattulidæ* not infrequently creep along the substratum with the coronal face against the surface. Under these circumstances the animal of course does not revolve. But the unsymmetrical structure produces its effect even in this case. The animal very rarely moves in a straight line, but usually follows the curve indicated by the form of the body, thus circling continually to its right. That this might perhaps be expected will be seen by examining the figures of *Rattulus lophoessus* Gosse (pl. XI, fig. 99) and *Diurella tigris* Müller (fig. 1), as seen from above.

The habit which these animals have of affixing themselves to foreign objects by a string of mucus has already been described (p. 293).

The above account of the movements of the *Rattulidæ* has been drawn from a study of a considerable number of species. Indeed, all through the work on the group special attention was paid to this matter. I have studied especially in this connection *Diurella tigris* Müller, *Diurella porcellus* Gosse, *Diurella brachyura* Gosse, *Diurella stylata* Eyferth, *Rattulus rattus* Müller, *Rattulus carinatus* Lamarck, *Rattulus bicristatus* Gosse, *Rattulus mucosus* Stokes, *Rattulus bicuspes* Pell, and *Rattulus elongatus* Gosse. In all these the behavior is essentially as set forth above.

CLASSIFICATION.

The classification of the *Rattulidæ* has been in a very confused condition. There is little agreement as to the division of the family into genera or as to the names which are to be used for the genera. The specific names are in an equally unsatisfactory condition.

In the present paper the writer attempts to use the names, both generic and specific, which are in accordance with the rules of nomenclature adopted by the International Congresses of Zoology. In view of the approaching publication, by the German Society of Zoologists, of a systematic review of the entire animal kingdom, "Das Thierreich," in which these rules are to be applied, it seems impossible that any names not in accordance with these rules can long persist. While it is of course inconvenient to be compelled to change some names that have come into rather general usage, the confusion so caused will not last long, and it will be a great advantage to get the nomenclature once established on a generally recognized basis. In the case of the *Rattulidæ* the confusion is already so great that the adoption of the names required by the recognized rules of nomenclature can scarcely be called even an inconvenience.

I shall give in the following a brief historical review of our knowledge of the *Rattulidæ*, with the purpose of showing the generic names which must be used.

Historical review.—The first of the *Rattulidæ* to be described was *Rattulus rattus*, by Eichhorn, in 1775. Eichhorn called it the "Water Rat" ("Die Wasser-Ratte"). In 1776 Müller gave it the name *Trichoda rattus*. The genus *Trichoda* included a heterogeneous group of microscopic organisms, of which the animal at present under consideration by no means formed the type, so that the genus *Trichoda* does not belong to the *Rattulidæ*. Müller described also *Rattulus carinatus* under the name "*Trichoda rattus vesiculam gerens*," and a third species of the *Rattulidæ*, *Trichoda lunaris*, which it seems impossible now to recognize. In the same year (1776) Schrank gave the name *Brachionus cylindricus* to *Rattulus rattus* Müller. The name *Brachionus* had already been used for the rotifers which still bear that name, so that it is not available for the *Rattulidæ*, and the specific name *cylindricus* is a synonym of *rattus*.

In 1786 Müller described *Diurella tigris* as *Trichoda tigris*—the specific name *tigris* thus of course having priority for this species.

Schrank next described *Rattulus longiseta*, at first (1793) under the name *Brachionus rattus;* then (1802) under the name *Vaginaria longiseta*. The type of Schrank's genus *Vaginaria* was not one of the *Rattulidæ*, so that we may leave this name out of consideration. The specific name *longiseta* evidently has priority for the animal under consideration, however, in place of Ehrenberg's name *bicornis*.

In 1816 Lamarck founded for Müller's *Trichoda rattus* and "*Trichoda rattus vesiculam gerens*" the genus *Rattulus*. This generic name therefore evidently has priority over any other for the *Rattulidæ*, and must take the place of the commonly used name *Mastigocerca* for the genus to which Müller's species (*R. rattus* and *R. carinatus*) belong.

In 1820 the same forms were placed by Goldfuss in the genus *Trichocerca*. This name is of course merely a synonym, so far as the *Rattulidæ* are concerned.

In 1824 Bory de St. Vincent founded for these same animals the genus *Monocerca*, giving them both together the name *Monocerca longicauda*. Both the generic and specific names are thus of course synonyms, and must be dropped.

Bory de St. Vincent at about the same time (1824) described under the name *Diurella tigris* the animal which I describe below as *Diurella porcellus* Gosse. As the specific name *tigris* had already been used by Müller for a member of the same genus, it can not persist. But the generic name *Diurella* is the first one given to one of the *Rattulidæ* having nearly equal toes; hence this name has the priority for the genus so distinguished.

We find, therefore, that the generic name *Rattulus* is to be used for the species having one very long toe; *Diurella* for those having two short, nearly equal, toes.

In 1830 Ehrenberg founded the genus *Mastigocerca* for *Rattulus carinatus*, while placing the species *rattus* in Bory's genus *Monocerca*. The names *Mastigocerca* and *Monocerca* have since been much used, owing to Ehrenberg's great authority; they are both, however, merely synonyms of *Rattulus*. The name *Rattulus* Ehrenberg restricted to a small organism which he identified with Müller's *Trichoda lunaris*, and to which he attributed, rather emphatically, two eyes, a character not known at present to be possessed by any of the *Rattulidæ*.

Eichwald (1847) founded the genus *Bothriocerca* for one of the *Rattulidæ*, apparently belonging to the genus *Diurella*, though his account is so vague that the animal can not be identified. In any case *Bothriocerca* is merely a synonym.

Dujardin (1841) included *Diurella tigris* Müller in his new genus *Plagiognatha*, a genus containing a heterogeneous group of organisms, supposed to resemble each other in their jaws. This genus was not a natural one and must be given up.

Schmarda (1859) founded the genus *Heterognathus* for certain species, part of them at least belonging to the *Rattulidæ*—apparently species of the genus *Diurella*. The type of this new genus had two *equal* toes, and was probably *Diurella tigris* Müller. If we are to classify in a genus by themselves the species having equal toes (thus following Gosse), this genus would have to receive, according to the laws of priority, the name *Heterognathus* Schmarda.

In 1886 Tessin gave it as his opinion that the *Rattulidæ* could not be distinguished into well-defined natural genera, *Rattulus gracilis* Tessin forming a connecting link between *Monocerca* (*Rattulus*) and *Diurella*. He therefore united all the species in the new genus *Acanthodactylus*. The giving of a new name was of course an unjustifiable proceeding, even granting the truth of Tessin's contention. If all the *Rattulidæ* are to be united into a single genus, the name *Rattulus* undoubtedly has the priority. Moreover, the name *Acanthodactylus* was already preoccupied, in the Reptilia (See Hoffman, in Bronn's Klassen und Ordnungen des Thierreichs, Bd. 6, Abth. 3, p. 1089).

Finally, in 1889, Gosse, in Hudson & Gosse's Monograph of the Rotifera, distinguished genera as follows: To the species with one long toe was given Ehrenberg's name *Mastigocerca*. The genus *Rattulus* was given an entirely new sense, different from that in which either Lamarck, Bory, or Ehrenberg had used it. In it were placed the species having two equal toes (including some species which clearly do not belong to the *Rattulidæ* at all). Finally, the genus *Cœlopus* was founded on the basis of a peculiar structural characteristic, which Gosse thought he had discovered in some of the species of *Diurella*. Gosse thought that the toes in *Diurella porcellus* Gosse, *D. tenuior* Gosse, *D. cavia* Gosse, and *D. brachyura* Gosse consisted of "one broad plate with another laid upon it, in a different plane," and on this feature he founded the genus *Cœlopus*. As has been repeatedly

pointed out of late, Gosse was quite mistaken upon this point; these species have two equal or unequal bristle-like toes. This genus *Cœlopus* must then of course be dropped, as a synonym of *Diurella*. *Mastigocerca* as used by Gosse is equivalent to *Rattulus* in its primitive application, so that it must be replaced by *Rattulus*. Finally, the group of species which Gosse distinguished as *Rattulus* can not well be separated from *Diurella*, and should be included in that genus.

Lord (1891) founded a new genus, *Elosa*, said to belong to the *Rattulidæ*, but lacking a foot. From the description which he gives of this animal, it seems clear that it is not one of the *Rattulidæ*, but belongs rather with *Ascomorpha*.

Division of the Rattulidæ into genera.—We may now inquire a little more fully into the basis for classification in this family. On what grounds can the *Rattulidæ* be divided into genera?

The characters which have been used by previous authors are mainly two: (1) the presence or absence of a lorica; (2) the number and relative length of the toes.

As to the first point, Ehrenberg distinguished two genera, *Monocerca*, without a lorica, and *Mastigocerca*, with a lorica. In the former he placed *Rattulus rattus* Müller; in the latter, *Rattulus carinatus* Lamarck. Now, these two are so closely related that it is doubtful whether they should not be considered one and the same species, and both have the cuticula stiffened to form a lorica. The same is true of the other species, *Rattulus longiseta* Schrank, included by Ehrenberg in his non-loricate genus *Monocerca*. In fact, the distinction between *Monocerca* and *Mastigocerca* had no basis in reality, and it is quite impossible to divide the family in this manner, for all have a lorica.

As to the second point, Bory de St. Vincent (1824) included in *Monocerca* the species having a single long toe, while *Diurella* had two evident toes. This distinction, in one form or another, has been kept up and is in use at present.

Tessin (1886) held that this was not a good basis for division into genera, for he saw in *Rattulus gracilis* Tessin (pl. v, figs. 45–49), a species which, with its shorter toe about one-third the length of the main toe, formed a transition from the single-toed to the two-toed forms. He therefore united all the *Rattulidæ* in a single genus.

There can be no question but that Tessin was right in believing that intermediate stages could be found between the two-toed and one-toed forms. In fact, as I have shown in the account of the toes, almost every gradation can be found between the condition with two equal toes, and that where only a single toe can at first be detected, and all the species can be shown to have two toes, though the right one is in many cases a mere rudiment.

If, therefore, we are to consider the genus a natural group, including only species that are more closely related to each other than to any species of another genus, I believe there is no escape from the necessity of classifying the *Rattulidæ* all in one genus. I have made many attempts to group them into what seemed natural genera on other bases than the toes, but found that all had the same defects; some of the species within the genus were apparently not so closely related to each other as they were to some species outside the genus.

Perhaps the nearest to a natural group within the family would be made by separating off *Rattulus capucinus* Wierz. & Zach., *R. cylindricus* Imhof, and *R. multicrinis* Kellicott as a separate genus. But *R. elongatus* Gosse is very closely

related to the two former, and seems itself closely related to *R. rattus* Müller. If the last-named species should be included in the new group it would have to carry with it *R. carinatus* Lamarck, *R. lophoessus* Gosse, etc. Moreover, *Rattulus latus* Jennings and *R. bicuspes* Pell seem related to *R. multicrinis* Kellicott. On the whole, such a group could not be separated off without being open to all the objections which may be made to the classification on the basis of the toes.

But the idea that a genus must represent a well-defined natural group, all the species of which are more closely related to each other than to any outside species, has as a matter of fact been largely given up in practice. Generic divisions are more commonly made on artificial grounds, to break up an otherwise unwieldy group into convenient divisions.

On this basis it seems to me that we may properly retain the old genera based upon the toes. In one group may be classed, as heretofore, those species which make the general impression of having a single long toe. This group must receive the name *Rattulus*. In the other group will be placed those that make clearly the impression of having two toes, and to this group the name *Diurella* belongs.

Then arises the question as to how we shall define our two genera so as to decide in doubtful cases in which genus the species shall go. None of the definitions heretofore given will suffice, for they have been made upon false grounds and without a knowledge of the real structure and amount of variation in the toes.

We shall probably do best to frame our definition so that it shall retain in the genus *Diurella* those that have heretofore been looked upon generally as having two toes, while *Rattulus* shall include those that have generally been considered one-toed forms. This will be best accomplished if we define the two groups as follows: *Diurella* includes those species in which the smaller of the two toes is more than one-third the length of the larger; *Rattulus*, the species in which the smaller toe is but one-third or less of the length of the larger, or seems to be lacking.

The history of our knowledge of the group shows that where, as in *Diurella tenuior* Gosse and *D. insignis* Herrick, the smaller toe is nearly (though not quite) one-half the length of the larger, the animal is naturally classified with the two-toed species. For this reason it is better to make the dividing point come at the proportion of one-third rather than at one-half. The division thus obtained is perhaps the most natural of any that could be made. The chief place where it fails is of course in the species that are near the dividing line, in separating such closely related species as *Diurella tenuior* Gosse and *Rattulus gracilis* Tessin.

Another genus, to include species having the toes exactly equal (answering to Gosse's genus *Rattulus*), might be recognized. But this seems to me hardly advisable. The equality of the toes is only one point on a long scale of variation and seems, in the present case at least, not worthy of being so strongly marked. In our American *Rattulidæ* this would separate from all others *Diurella tigris* Gosse, *D. intermedia* Stenroos, *D. sulcata* Jennings, and *D. cavia* Gosse, which certainly do not form a group well marked off from the other species of *Diurella*. If such a genus should be recognized it would have to receive the name *Heterognathus* Schmarda (1859), as this was the first genus founded for equal-toed forms, its type species, *Heterognathus macrodactylus* Schmarda, being without much doubt none other than *Diurella tigris* Müller.

Specific distinctions.—As to the distinction of species, this seems not intrinsically so difficult in the *Rattulidæ* as in some other groups of the Rotatoria, notably

the *Anuræadæ* and *Brachionidæ*. In the latter families individual variation is so great that it is often almost impossible to determine whether two considerably differing specimens should or should not be considered different species. In the *Rattulidæ* variation does not extend to such lengths as this, and with good specimens the species may usually be recognized with much certainty. Of the 29 species which are described in the following from my own observation, there are, I am convinced, only one or two cases where later investigation may possibly unite two into one. One of these is that of *Rattulus rattus* Müller and *Rattulus carinatus* Lamarck, which has always been considered doubtful. Two very distinct forms are certainly found—one with a ridge, the other without—and I have not succeeded in showing that the two are really identical. Further, the species grouped about *Diurella tenuior* Gosse are rather critical as to specific distinctions.

Points to be noted in descriptions of the Rattulidæ.—From many of the descriptions of the *Rattulidæ* given in the literature, it is exceedingly difficult to determine the animal in question, but this is due to the fact that the characteristic distinguishing features of the animal have not been noted. It will be well to point out, therefore, the features that are of especial importance in distinguishing species, and that should be included, if possible, in every description. I give them in the order of their importance.

1. The teeth at the anterior margin of the lorica, their absence or presence, their number and relative size, if present. Those at the dorsal or dorso-dextral margin should be clearly distinguished from others due to the folding of the head-sheath when retracted.

2. The toes, their length relatively to the body and to each other; their position.

3. The general form of the body.

4. The absence or presence of the longitudinal folds in the head-sheath; their form, especially when the lorica is retracted, and any other characteristics of the anterior margin of the lorica.

5. The "striated area," whether developed as a single or double ridge, a furrow, a smooth area, or not developed at all.

As many other features should, of course, be added as possible, but the above are the most important ones and should not be omitted from descriptions of any of the *Rattulidæ*. Of course, an accurate figure or figures (showing the above points, as well as others) is perhaps even more important than a good description.

Several of the most important points above mentioned, notably the presence, number, and relative size of the teeth at the anterior margin of the lorica, and the relative length of the toes, have very usually been omitted from specific descriptions of the *Rattulidæ;* this makes it very difficult to recognize the animals.

The following systematic account of the *Rattulidæ* is arranged thus: I first give the characteristics of the family. This is followed by a key to the genera and species, which may be of assistance in locating quickly a given species; though for a determination, of course, the entire description and the figures should be studied. Some of the poorly described or doubtful species, which I have not myself seen, could not be taken into the key owing to the uncertainty as to important technical characters; these, however, are referred to at appropriate places in the key.

Then follows a description of all the well-founded species of *Rattulidæ* under the two genera. Under each genus I divide the descriptions into two parts, the first

including the species which I am able to describe from my own observations, thus making the accounts full on all points important for classification; the second, species which I have not myself seen. Of these latter I have compiled descriptions from other authors and have copied the best figures I could find.

The species which are described from my own observations number twenty-nine, including all that have been found in America as well as a number of others. The remaining well-established species number seven.

Finally, I have added a list and notes on doubtful species, species that are insufficiently described for recognition, and animals that have been wrongly classified with the *Rattulidæ*. These are in many cases accompanied by copies of the original figures.

Family RATTULIDÆ.

Loricate rotifers, with the structure somewhat unsymmetrical in certain features. Lorica usually cylindrical and curved, or ovate or ovoid; closed all around, with an opening at each end for the protrusion of the head and the foot. The anterior portion of the lorica usually set off from the remainder as a head-sheath, by a slight constriction. On the dorsal surface of the lorica, usually if not always somewhat to the right of the median line, a longitudinal area which is transversely striated; this striated area is generally oblique, and may be developed as a single or double ridge, a furrow, or remain smooth. (It is absent in only two or three species.) Eye single, occipital, attached to the brain. Foot short, frequently attached unsymmetrically to the lorica. Toes bristle-like, their place of attachment usually twisted so as to bring the right toe somewhat to the dorsal side of the left; the toes sometimes equal, but the right or dorsal toe usually shorter; sometimes quite rudimentary. Minute, bristle-like "substyles" at the base of the toes. Trophi usually unsymmetrical, the right manubrium smaller than the left; sometimes rudimentary. Mucus glands and reservoirs much developed.

Key to the genera and species.

A. The two toes equal or the shorter toe more than one-third length of longer.....I. DIURELLA Bory de St. Vincent.
B. A single long toe with usually or always an inconspicuous shorter one, the latter not more than one-third the length of the longer one.....II. RATTULUS Lamarck.

I. DIURELLA Bory de St. Vincent.

a1. Toes equal.
  b1. With a single tooth at the dorsal or dorso-dextral anterior margin of the lorica.
    c1. The toes about one-third as long as the body; body elongated, cylindrical, curved.....1. *D. tigris* Müller.
    c2. Toes shorter, less than one-third the body length; body shorter and very small; no visible ridge.
      4. *D. intermedia* Stenroos.
      (See also 9. *D. sulcata* Jennings.)
  b2. No tooth (or tooth very inconspicuous, hardly noticeable) at the anterior dorsal margin of the lorica.
    c1. Foot minute, usually retracted within the lorica; toes very short; lorica ending behind in a sharp angle; two deep grooves surrounding the body near its middle.....9. *D. sulcata* Jennings.
    c2. Very small; lorica much swollen and rounded behind and above, bringing the foot entirely on the ventral surface. Otherwise much as in the last.....10. *D. cavia* Gosse.
    c3. Body projecting much above and behind the foot; the toes wide apart at base, about one-third the length of the body.....13. *D. sejunctipes* Gosse.
    c4. Body projecting behind and above the small foot; a ring-like fold or collar surrounding the lorica in front of its middle; toes slender, about half as long as the lorica.....14. *D. collaris* Rousselet.
      (See also 17. *D. brevidactyla* Daday.)
a2. Toes unequal (the right one shorter).
  b1. A single tooth at the anterior dorsal margin.
    c1. Body elongated, cylindrical, curved; the right toe about half as long as the left, or a little less than half.....2. *D. tenuior* Gosse.
    c2. The body short, thick, curved, with a very prominent ridge; toes short, the right one a very little shorter than the left.....3. *D. weberi*, n. sp.
      (See also *D. uncinata* Voigt, page 319, note.)

b2. With two teeth or spines at the dorsal or dorso-dextral anterior margin of the lorica.
c1. The two teeth short, the right one larger than left; body long, slender, curved; right toe about half as long as the left, or less ..... 5. *D. insignis* Herrick.
c2. The two teeth short, the right one larger than the left; body short, thick; the foot turned beneath the ventral surface; the right toe a little shorter than the left ..... 6. *D. porcellus* Gosse.
c3. The two teeth developed into long, sharp, slender spines, nearly or quite equal in length; body long-conical in shape, scarcely curved; the two toes very close together and nearly equal (the left a little longer) ..... 7. *D. stylata* Eyferth.
b3. With many (nine) teeth at the anterior margin of the lorica ..... 8. *D. rousseleti* Voigt.
b4. Without teeth at the anterior margin of the lorica; foot at the posterior end of the body.
c1. Toes very nearly equal ..... 11. *D. brachyura* Gosse.
c2. Right toe about two-thirds as long as the left ..... 12. *D. dixon-nuttalli*, n. sp.
(See also *D. brevidactyla* Daday, *D. marina* Daday, and *D. helminthodes* Gosse, which could not be taken into the key because certain important technical characters, particularly in regard to the anterior margin of the lorica, are unknown.)

II. RATTULUS Lamarck.

a1. With a single tooth or projection at the anterior dorsal (or dorso-dextral) margin of the lorica.
b1. The single, not very conspicuous, tooth situated at dorso-dextral part of anterior margin of lorica, forming a prolongation of the ridge (the ridge may be inconspicuous).
c1. Body elongated, nearly cylindrical, not strongly curved; head-sheath sharply set off from the remainder of the lorica and very contractile; main toe about half the length of the lorica, accompanied by a shorter toe one-third the length of the main one ..... 18. *R. gracilis* Tessin.
c2. Body elongated, nearly cylindrical, not strongly curved; the head-sheath not sharply set off nor very contractile; toe two-thirds the length of the lorica, or still longer ..... 19. *R. scipio* Gosse.
c3. Body elongated, nearly cylindrical, strongly curved ..... 35. *R. curvatus* Levander.
c4. Body elongated, fusiform, not strongly curved; anterior tooth very inconspicuous; toe one-half to two-thirds the length of the lorica; a small spur projecting backward from the base of the toe when the latter is turned forward ..... 20. *R. macerus* Gosse.
(See also *R. unidens* Stenroos (?) and *R. cuspidatus* Stenroos (?).)
b2. The single large tooth forming a triangular projection from the median dorsal part of the anterior margin of the lorica, overhanging the corona.
c1. The lorica oval or ovoid in form ..... 21. *R. multicrinis* Kellicott.
c2. The lorica elongated, cylindrical.
d1. The anterior tooth prolonged as a long, slender hook bending over the corona (but not always visible); toe almost or quite as long as the body ..... 22. *R. cylindricus* Imhof.
d2. The large anterior tooth forming a hood-like projection over the corona; body somewhat curved; toe about half the length of the body ..... 23. *R. capucinus* Wierz. & Zach.
(See also 36. *R. dubius* Lauterborn.)
a2. With two long teeth or spines at the anterior margin of the lorica.
b1. The two teeth at dorso-dextral margin of lorica; the right longer than the left ..... 24. *R. longiseta* Schrank.
b2. The two teeth at the ventral margin of the lorica (?) ..... *R. roseus* Stenroos. (?)
a3. Without teeth at the anterior margin of the lorica.
b1. Lorica with two prominent ridges on its dorsal (or dorso-dextral) surface.
c1. Very large; the two ridges very high and extending two-thirds length of body ..... 25. *R. bicristatus* Gosse.
c2. Smaller, the two ridges lower, reaching back only about half the length of body ..... 26. *R. mucosus* Stokes.
b2. A single very prominent thin ridge on the dorso-dextral surface of the lorica.
c1. The ridge high and thin, extending about one-half the length of the lorica ..... 27. *R. carinatus* Lamarck.
c2. The ridge high and thin, extending nearly or quite the entire length of the lorica ..... 29. *R. lophoessus* Gosse.
b3. The ridge either not prominent or lacking (a low ridge can be detected in most of these species, on careful examination).
c1. Body broad, ovate, very unsymmetrical at the posterior end; no trace of ridge ..... 30. *R. latus* Jennings.
c2. Body short, thick, arched dorsally; toe longer than the lorica; lateral antennæ protected by projecting spines ..... 31. *R. bicuspes* Pell.
c3. Large; body long, slender, straight, tapering posteriorly; toe two-thirds the length of the lorica. 32. *R. elongatus* Gosse.
c4. Body short, irregular, somewhat conical; toe less than half the length of the lorica ..... 33. *R. stylatus* Gosse.
(See also *R. brachydactylus* Glasscott.)
c5. Very small; body truncate in front, gently arched dorsally; toe about the length of the lorica; substyles very inconspicuous ..... 34. *R. pusillus* Lauterborn.
c6. Body oval, much larger than in the last; toe about the length of the lorica; substyles easily seen. 28. *R. rattus* Müller.

DESCRIPTIONS OF GENERA AND SPECIES.

I. DIURELLA Bory de St. Vincent.

Generic characters.—Two toes, either equal, or the shorter more than one-third the length of the longer. The longer toe less than one-half the length of the body. Body nearly cylindrical; curved or twisted.

A. DESCRIPTIONS OF THE SPECIES STUDIED BY THE AUTHOR.

1. Diurella tigris Müller (pl. I, figs. 1–6).

Synonyms: *Trichoda tigris* Müller (1786); *Notommata tigris*, Ehrenberg (1833, 1838); *Heterognathus macrodactylus* Schmarda (1859); *Monommata tigris*, Bartsch (1870); *Rattulus tigris*, Hudson & Gosse (1889).

Distinguishing characters.—This species may be known by the two equal toes (fig. 6), the single tooth at the dorsal anterior edge of the lorica, and the nearly cylindrical curved body. It has a striking resemblance to *D. tenuior* Gosse, from which it is distinguished by the equality of the two toes. It differs also in the usually greater size, the somewhat greater prominence of the ridge, and the slightly greater slenderness and distinctness of the foot.

External features.—The body is elongated and curved, appearing to be cylindrical, in a cursory view. Really the body rises to a ridge on the right side, so that in section it has the form shown in fig. 5. Preserved specimens usually lie, owing to the form of the body, in such a position that the ridge does not appear in profile, hence it is very easily overlooked; in living specimens it is more conspicuous.

The head-sheath is rather distinctly set off from the remainder of the lorica by a constriction. It is marked by nine longitudinal plaits (fig. 3), at which the head-sheath folds when the head is withdrawn, thus closing the anterior opening completely (fig. 4). On the right side the anterior edge bears a single prominent tooth.

The ridge (fig. 1) begins as a backward prolongation from the base of the tooth. It extends backward and to the left, seeming to have a slightly spiral course, and reaching almost to the foot. Along its left side are transverse striations, similar to those so prominent in many species of *Rattulus*, but less conspicuous.

The degree of development of the ridge varies greatly in preserved specimens. In some it can scarcely be seen at all. In others it is visible in the anterior part of the body, but seems to extend only half the length of the lorica or less. These differences are perhaps due only to optical difficulties resulting from the position of the specimen, but I am inclined to believe that there are really such differences in the development of the ridge in different specimens. These differences are perhaps functional, depending upon the degree of contraction of the animal (see the general account of the striated area, p. 281). In view of these facts the size and length of the ridge can not be considered a distinguishing character in this species.

As a whole, the body may be seen to form a segment of a spiral, a spiral that is further accentuated by the position of the toes (*q. v.*).

Corona.—The corona bears a single club-shaped frontal process; its other features have not been studied especially.

Antennæ.—The dorsal antenna (fig. 1, *d. a.*) lies just to the left of the ridge, a very little behind the constriction separating off the head-sheath. The lateral antennæ are in the usual position, on the posterior third of the body (fig. 1).

Foot.—The foot is rather slender and sharply set off from the body. The joint between the foot and body appears to lie in a transverse plane, without the asymmetry which is so marked in many of the species of *Rattulus*.

Toes (fig. 6).—The two equal toes are stout, curved rods, about one-third the length of the body. They are attached to the foot in such a way that the base of the right toe lies above that of the left, and the concavity of the toes faces to the right (fig. 1). When the toes bend (at their attachment), they bend to the right. Each toe has at its base a number (at least four) of short, sharp spines or substyles (fig. 6). At the base of each toe opens one of the two mucus reservoirs (fig. 6, *m. r.*).

Internal organs.—The eye lies at the posterior end of the brain and appears in dorsal view to the left of the ridge (fig. 1, *e.*). The two mucus reservoirs are of equal size, and each opens separately at the base of one of the toes. The trophi are well developed, and in this species their asymmetry reaches perhaps its highest development. The left manubrium is long and heavy; the right one a mere rudiment—a short, slender spicule (fig. 2). The other internal organs call for no special remark.

Measurements.—Length of body, 0.175 to 0.225 mm.; of toes, 0.050 to 0.075 mm.; total, 0.225 to 0.300 mm.

Movements.—For an account of the movements of this species, see the general discussion of the movements of the *Rattulidæ*, p. 295.

History.—In the systematic and faunistic literature this species has long been confused in a very curious way with another to which it bears very little resemblance, namely, with *Diurella porcellus* Gosse (*D. tigris* Bory). This is due to the fact that both received the name *tigris*, one from Müller, the other from Bory de St. Vincent, and they have often since been supposed to be identical. Ehrenberg (1838) confused the two, citing Bory's *D. tigris* as a synonym of his *Notommata tigris*. Gosse, in Hudson & Gosse's Monograph (1889), describes the present animal as *Rattulus tigris*, but notes in a rather perplexed way that Eckstein's account (1883) of the animal does not agree with his own. Eckstein had described under this name Bory's species (*Diurella porcellus* Gosse). Bilfinger (1894, p. 51) seems to have been the first to set forth clearly the fact that Ehrenberg's *Notommata tigris* and Bory's *Diurella tigris* are two distinct animals. Attention has been called to the same fact by Weber (1898, p. 513) and probably by others. It will be well to give here a list of the animals mentioned by different authors under the specific name *tigris* (assigned to various genera), specifying in each case which of the two animals, *Diurella tigris* Müller or *D. porcellus* Gosse, was really meant, so far as that can be determined.

Trichoda tigris Müller (1786)=*Diurella tigris* Müller.
Diurella tigris Bory de St. Vincent (1824)=*D. porcellus* Gosse.
Notommata tigris, Ehrenberg (1833, 1838)=*D. tigris* Müller.
Notommata tigris, Perty (1852)=*D. tigris* Müller.
Notommata tigris, Pritchard (1861)=*D. tigris* Müller.
Monommata tigris, Bartsch (1870, 1877)=*D. tigris* Müller.
Diurella tigris, Eckstein (1883)=*D. porcellus* Gosse.
D. tigris, Herrick (1885)=*D. porcellus* Gosse.
D. tigris, Eyferth (1885).—The figure seems to represent *D. tigris* Müller, but the description applies best to *D. porcellus* Gosse.
D. tigris, Plate (1886)=*D. porcellus* Gosse.
D. tigris, Blochmann (1886)=*D. porcellus* Gosse.
Acanthodactylus tigris, Tessin (1886)=*D. porcellus* Gosse.
Rattulus tigris, Hudson & Gosse (1889)=*D. tigris* Müller.[a]
Rattulus tigris, Wierzejski (1893)=*D. porcellus* Gosse (?).
Rattulus tigris, Levander (1894)=*D. porcellus* Gosse.
Rattulus tigris, Hood (1895)=*D. tigris* Müller.
Rattulus tigris, Scorikow (1896).—The description does not agree with either of the species under consideration.
Rattulus tigris, Stenroos (1898)=*D. tigris* Müller.
Rattulus tigris, Jennings (1900, 1901)=*D. tigris* Müller.

Distribution.—In America *Diurella tigris* Müller is very common in aquatic vegetation in the quiet parts of streams and lakes. I have recorded its presence in the following localities: Put-in Bay Harbor and East Harbor, Lake Erie; Huron River at Ann Arbor, Mich.; Portage River, Ohio. It has also been recorded from Bangor, Me., by "J. C. S." (1883), and from the neighborhood of Cincinnati, Ohio, by Turner (1892), but it is impossible to say in these cases which of the two species that have gone under this name (*D. tigris* Müller or *D. porcellus* Gosse) was meant.

In Europe: England (Gosse, 1889); Ireland (Glasscott, 1893; Hood, 1895); Germany, near Tübingen (Bartsch, 1870), and in Württemberg (Bilfinger, 1894); Tyrol (Dalla Torre, 1889); Hungary (Bartsch, 1877; Kertesz, 1894); Lake Nurmijärvi, in Finland (Stenroos, 1898).

Also in India, near Calcutta (Anderson, 1889); New Guinea (Daday, 1901); Ceylon (Daday, 1898); Natal, South Africa (Kirkman, 1901).

[a] In a previous paper, (Jennings 1900) I was inclined to believe that the animal described and figured by Gosse was not the real *Notommata tigris* of Ehrenberg, owing to the disproportionately large size of the anterior end in Gosse's figure, as well as to the unusual form of the body. But after studying many specimens of this and other *Rattulidæ* I am convinced that Gosse's figure is a poorly drawn representation of a much contracted specimen of this species.

2. Diurella tenuior Gosse (pl. 1, figs. 7–10).

Synonyms: *Cœlopus tenuior* Gosse (1889); *Mastigocerca flectocaudatus* Hilgendorf (1898).

Distinguishing characters.—This species is to be known by its elongated curved body, with a single tooth at the anterior margin of the lorica, and the unequal toes (pl. 1, fig. 9), the right toe being only about one-half as long as the left or a little less than one-half as long.

It has much resemblance to *D. tigris* Müller, from which it differs in the unequal toes and in certain other characters mentioned in the account of that species. It also greatly resembles *Rattulus gracilis* Tessin, from which it differs in the following particulars: The body in *D. tenuior* is regularly curved, so that no straight outlines appear, as in *Rattulus gracilis;* the second toe is longer in proportion to the main one than in *Rattulus gracilis*, where the lesser toe is only about one-third the length of the main toe, while here it is about one-half the length of the latter; the head is much less sharply set off from the remainder of the lorica than in *Rattulus gracilis;* the tooth is more pronounced and the ridge less prominent than in the last-named species; the foot is shorter and less prominent than in *Rattulus gracilis.*

Diurella tenuior Gosse also has a striking resemblance to *Diurella insignis* Herrick in the form and in the toes, but the latter species has two teeth at the anterior edge of the lorica in place of one, is much larger, and there are other differences in details.

This species is related, finally, to *D. intermedia* Stenroos, but *D. tenuior* is usually much larger than *D. intermedia* and is longer in proportion to its diameter. The two differ especially, however, in the toes, those of *D. intermedia* being equal.

External features.—The body is long and cylindrical, much as in *D. tigris* Müller. There is a low oblique ridge on the right-hand side, passing backward from the point of origin at the anterior tooth to about the middle of the length of the lorica. This is striated transversely, as in other species. The head-sheath is marked off from the remainder of the lorica by a slight constriction. It has longitudinal folds somewhat similar to those of *D. tigris* Müller, though perhaps hardly so prominent; by these the anterior opening of the lorica can be nearly closed when the head is withdrawn. On the dorso-dextral part of the anterior margin there is a tooth, perhaps hardly so prominent as that of *D. tigris* Müller, but rather more pronounced than in *Rattulus gracilis* Tessin.

The corona has not been especially studied.

Antennæ.—The dorsal antenna (figs. 7, 8) lies in the usual position, a little to the left of the ridge. The right lateral antenna has the usual position on the posterior third of the body (fig. 8). The left lateral antenna I have not seen.

Foot.—Rather broadly conical, not so sharply set off from the lorica as in *D. tigris* Müller.

Toes (fig. 9).—The two toes are unequal in size, the right toe being about half, or a little less than half, the length of the left toe. The main (left) toe is a curved, pointed rod, about half the length of the lorica. The right toe is much more slender and is so curved that its tip usually lies against the main toe at about the middle of the length of the latter. The right toe seems to be, as a rule, a trifle less than half the length of the main toe. This species, in its technical characters, is on the boundary line between *Rattulus* and *Diurella*, and is as closely related to *Rattulus gracilis* Tessin as to any of the species of *Diurella.*

Just outside the base of the main toe is a substyle which is nearly as long as the right toe. There is also a minute substyle just outside the base of the right toe.

Internal organs.—These call for no special remark, except in the case of the trophi (fig. 10). The trophi are very similar to those of *Diurella tigris* Müller and *Rattulus gracilis* Tessin—the right side being very rudimentary as compared with the left.

Measurements.—Different specimens of this species vary excessively in size. Two specimens drawn to the same scale are shown in figs. 7 and 8 (pl. 1). The length of body varies from 0.135 to 0.21 mm.; length of toes, from 0.055 to 0.08 mm.; total, from 0.19 to 0.29 mm.

History.—This species was first described by Gosse in Hudson & Gosse's Monograph of the Rotifera (1889). Like many of Gosse's descriptions, that of this species is inaccurate in some details. For example, he states that the head is defended by two or three projecting points. Weber (1898) has likewise given a description and figure of this species, repeating Gosse's statement that there are three or four points at the anterior edge of the lorica, though his figure shows but one. It is probably the longitudinal folds in the head-sheath that have given rise to the impression

that there were several teeth. These, when the head is contracted, often give an appearance as of projecting teeth, though a close examination reveals the incorrectness of this.

Hilgendorf (1898) described as *Mastigocerca flectocaudatus* n. sp. a rotifer which, from his description and figure, bears much resemblance to *Diurella tenuior* Gosse. Apparently the author himself concluded that the supposed new species was *D. tenuior* Gosse, for in my copy of Hilgendorf's paper the name *Mastigocerca flectocaudatus* is crossed out and "*Cœlopus tenuior*" substituted, apparently by the hand of the author. Hilgendorf gives no measurements, his figures are not very detailed and are apparently not made with the camera, so that it is difficult to form an independent judgment as to the identity of the animal. It will be best, therefore, to accept the view that this was *D. tenuior* Gosse.

Distribution.—In America: This species is not rare in the vegetation of lakes and streams. I have found it in the following localities: Old Channel, between Round Lake and Pine Lake, Charlevoix, Mich.; Put-in Bay Harbor and East Harbor, Lake Erie; Long Point, Canada, near "The Cottages"; swamps on North, Middle, and South Bass islands in Lake Erie; Portage River, Ohio; Huron River at Ann Arbor, Mich.; East Sister Lake, Ann Arbor, Mich.; ditch in tamarack swamp region, near Ann Arbor, Mich. Doubtfully reported by Kellicott (1888) from the Shiawassee River at Corunna, Mich.; Sandusky Bay, Lake Erie (Kellicott, 1896); waters connected with the Illinois River at Havana, Ill. (Hempel, 1898).

In Europe: England (Gosse, 1889); Ireland (Glasscott, 1893); Gr. Plöner See, Germany (Zacharias, 1893); Switzerland (Weber, 1898); Bohemia (Petr, 1890); Hungary (Kertesz, 1894).

Also in New Guinea (Daday, 1901); Ceylon (Daday, 1898); New Zealand (?) (Hilgendorf, 1898, as *Mastigocerca flectocaudatus*).

3. Diurella weberi, n. sp. (pl. I, figs. 11–14; pl. XIII, figs. 116 and 117).

Synonym: *Cœlopus porcellus* Weber (1898), in part.

Distinctive characters.—*Diurella weberi* is to be distinguished from its nearest relative, *Diurella porcellus* Gosse, by the single tooth at the anterior edge of the head-sheath, and by the broad, rounded projecting plate (see fig. 14) at the left side of the anterior opening—as well as by the high, thin ridge. It differs from *Diurella brachyura* Gosse in the presence of the anterior tooth and of the ridge; from *Diurella sulcata* Jennings in the prominent tooth, the inequality of the toes, and the presence of the ridge; from *Diurella intermedia* Stenroos in the unequal toes and the presence of the ridge. *Diurella tenuior* Gosse, which in technical characters resembles this, is easily distinguished from it in practice by the high, thin keel, the shorter body, and the shorter, only slightly unequal toes of *Diurella weberi*.

External features.—The body is short, and curved in the arc of a circle, much as in *Diurella porcellus* Gosse, though it is not so thick. The head-sheath is indistinctly set off from the rest of the lorica by a slight constriction. At the anterior margin of the lorica, to the right of the dorsal median line, is a single sharp, prominent tooth. From this tooth there runs backward a high, thin ridge, which is transversely striated and extends about two-thirds the length of the lorica (pl. I, fig. 12). This ridge is much more prominent than the ridge of *Diurella porcellus* Gosse. One of the most peculiar characteristics of this species is the large, rounded projection from the left side of the anterior margin of the lorica. This is especially noticeable in a retracted specimen (see figs. 13 and 14); but gives form to the head even in extended animals (see figs. 12 and 117, and compare Weber (1898), fig. 2, pl. 20). In retracted specimens a number of folds may at times be seen in that part of the head-sheath not formed by the plate just mentioned.

Corona.—The corona has not been thoroughly studied. It bears a thick dorsal process.

Antennæ.—The dorsal antenna lies in the usual position, to the left of the ridge. The right lateral antenna is in the usual place on posterior third of the body; the left lateral antenna is much farther forward, only a little behind middle of body and near dorsal side (figs. 14 and 116).

Foot.—The foot is not quite so nearly inclosed within the lorica as in *Diurella porcellus* Gosse and is not situated so far forward on the ventral side.

Toes (fig. 11).—The two toes are nearly equal, but the left toe is a little longer than the right. Possibly the difference in length is a little less in this species than in *Diurella porcellus* Gosse. The length of the main toe is about equal to the diameter of the body. Three or four inconspicuous substyles are found at the base of the toes; these are much less conspicuous than in *D. porcellus* Gosse.

Internal organs.—The internal organs offer nothing of especial interest. The trophi differ from those of *D. porcellus* Gosse in being straighter and more slender and in not showing in side view the long transverse piece which makes the left manubrium so conspicuously "crutch-shaped" in the latter species. (Compare the trophi as shown in figs. 12 and 21.)

Measurements.—Length of body, 0.09 to 0.12 mm.; of toes, 0.03 to 0.04 mm.; total, 0.12 to 0.16 mm.

History.—This species was figured by Weber (1898, pl. 20, figs. 2–4) as *Cœlopus porcellus* Gosse (*Diurella porcellus* Gosse). Weber's description confuses the two species; thus, the two teeth at the anterior edge, mentioned by Weber, but not figured, belong to the real *D. porcellus* Gosse, not to the species which he figures. That the figure represents the present species is shown by the general form, the high, sharp ridge, the single tooth, the form of the trophi, and the extension of the anterior edge of the lorica on the left side, all points which are characteristic of the present species and distinguish it clearly from *D. porcellus* Gosse.

Distribution.—*Diurella weberi* is not very common. I have recorded it from the following localities: East Harbor, Lake Erie; swamps on North and South Bass islands in Lake Erie, and on Presque Isle near Erie, Pa.; Huron River at Ann Arbor, Mich.; a ditch in the tamarack swamp region, near Ann Arbor, Mich.

Weber (1898) found this species in the Botanical Gardens at Geneva, Switzerland, and at St. Georges, Switzerland. Mr. F. R. Dixon-Nuttall informs me that he finds it in ponds in England. Mr. Charles F. Rousselet has sent me a sketch of what is evidently this species, made from specimens found in New Zealand.

4. Diurella intermedia Stenroos (pl. XIII, figs. 108–110).

Synonym: *Cœlopus intermedius* Stenroos (1898).

Distinguishing characters.—This species is to be distinguished from *Diurella brachyura* Gosse, which it much resembles, by the tooth at the dorsal anterior edge of the lorica, and by the equal toes. From *D. weberi*, with which it agrees in the single tooth, it differs in the absence of the conspicuous ridge and in the equality of the toes. From *D. porcellus* Gosse it differs in having but a single tooth at the anterior edge. From *D. sulcata* Jennings, finally, it differs markedly in the absence of the furrows surrounding the body about the middle.

External features.—The body is nearly cylindrical, not so short as in *D. porcellus* Gosse, and curved. The head-sheath is set off by a slight constriction from the remainder of the lorica. It has nine longitudinal plaits for folding when the head is withdrawn. At the dorsal edge, a little to the right of the median line, is a single well-marked tooth.

The lorica bears no distinct ridge, though a faintly striated area, in some cases apparently a little depressed, extends backward from the base of the tooth about half the length of the body.

Corona.—Corona of usual character. It bears a single sharp dorsal process (pl. XIII, fig. 108).

Antennæ.—The dorsal antenna lies a little in front of the constriction which separates the head-sheath from the rest of the lorica. The right lateral antenna lies in the usual position on the posterior one-fourth of the body. The left lateral antenna I have not found.

Foot.—Very short, not pushed so far forward on ventral side as in *D. porcellus* Gosse.

Toes (pl. XIII, fig. 110).—The two toes are equal, or so nearly so that one can not be certain of a difference in length. There are two substyles, one a little longer than the other, each more than half the length of the main toes.

Internal organs.—The trophi have not been minutely studied. Their general appearance is shown in pl. XIII, fig. 108. The gastric glands are very small and fastened to the stomach only by slender, thread-like ducts. The other internal organs call for no special remark.

Measurements.—Total length, about 0.13 to 0.16 mm.; toes, about 0.03 to 0.04 mm.

History.—This species was recently described by Stenroos (1898). I have found but a few specimens, and most of our detailed knowledge of the animal is derived from the notes and figures of Mr. F. R. Dixon-Nuttall, which he has with great kindness placed at my disposal. His figures are reproduced in figs. 108 and 110.

Distribution.—I have found only a few specimens, from the Huron River at Ann Arbor, Mich. Stenroos (1898) found the animal in Lake Nurmijärvi, Finland. Mr. Dixon-Nuttall informs me that examples have often been sent him from Dundee, Scotland, by Mr. John Hood.

5. Diurella insignis Herrick (1885) (pl. II, figs. 15–18).

Distinctive characters.—This species may be known by the long, slender, curved body; the two slightly unequal teeth at the anterior margin of the lorica, and the two unequal toes, the longer one (in adults) a little less than one-half the length of the lorica. It shows much resemblance to *Diurella tenuior* Gosse, but is distinguished from it by the possession of two teeth at the anterior margin and by the more elongated form. The toes are almost identical in the two species.

External features.—The body is more elongated and slender than in any other species with which I am acquainted, and is gently curved. It tapers slightly from a point not far from the anterior end to the foot. The anterior portion of the lorica, the head-sheath, is set off from the remainder by a constriction, and is provided with a number of longitudinal plaits at which folding takes place when the head is retracted. At its anterior edge, a little to the right of the dorsal line, it bears two teeth. These are of unequal size, the right one being considerably the longer. The length of this right tooth varies considerably in different specimens; it seems to be especially prominent in young specimens (pl. II, fig. 18). The two teeth are separated by a considerable interval. The left tooth is small and is very easily overlooked, especially when the corona is extended, so that specimens of this species are likely to be thought to have only a single tooth if a careful examination is not made.

From the teeth a low ridge extends backward, having its edge to the right, even with the right tooth, and sloping gradually to the left. The ridge is very inconspicuous and easily overlooked. It extends backward for three-fourths of the length of the lorica and is marked as usual by transverse striations.

Corona.—The corona is of the usual character, having two marginal curves of cilia and two about the mouth. There is a short, thick, dorsal process, and two lateral projections bearing cilia (as in *Diurella stylata* Eyferth, pl. III, fig. 31); other processes I have not seen.

Antennæ.—The dorsal and left lateral antennæ I have not been able to find in this species; the right lateral antenna is in the usual position on the posterior fourth of the body (pl. II, fig. 16).

Foot.—The foot is of the usual short conical form, obliquely attached to the lorica, so that it may turn to the right, but not to the left.

Toes.—The toes (fig. 17) are almost identical with those of *Diurella tenuior* Gosse, save that they are longer. The left toe in an adult animal (pl. II, figs. 15 and 16) is a little less than one-half the length of the body, while in a young specimen (fig. 18) it is considerably more than one-half the length of the body. The right toe is one-half the length of the main toe, or a little less. Just outside the base of the main (left) toe there is a substyle, which is one-half the length of the right toe. At the base of the right toe there is a minute, rudimentary substyle.

Internal organs.—The trophi (see fig. 18) are very unsymmetrical, as in *Diurella tigris* Müller and *D. tenuior* Gosse. The right malleus is very small and slender, though perhaps not quite so much reduced as in the two species last mentioned. The single eye is attached to the brain near its posterior end; in a dorsal view it lies considerably to the left of the ridge or striated area on the lorica (fig. 16). The other internal organs call for no special remark.

Measurements.—Total length, 0.32 to 0.37 mm.; main toe, 0.10 to 0.12 mm.; shorter toe, about 0.05 mm.

History.—This species was described by Herrick in 1885. Herrick's description was brief and his figure extraordinarily poor, and as the species has not hitherto been found again, it has usually been relegated to the limbo of "doubtful species." But Herrick's description fits very well the specimens which I have, while his figure looks as if it had been drawn from memory. The animal has not again been mentioned since Herrick's paper.

Distribution.—Herrick found *Diurella insignis* in Minnesota. I have found it to be rather rare, but somewhat widely distributed amid the vegetation of lakes, ponds, and streams. My records show it to have been observed in the following localities: Put-in Bay Harbor and East Harbor, Lake Erie; inlet on Starve Island, close to South Bass Island, in Lake Erie; swamp on Presque Isle near Erie, Pa.; East Sister Lake near Ann Arbor, Mich.

This species has not been found in Europe.

6. Diurella porcellus Gosse (pl. II, figs. 19–23).

Synonyms: *Diurella tigris* Bory de St. Vincent (1824); *Monocerca porcellus* Gosse (1851); *Acanthodactylus tigris* Tessin (1886); *Cœlopus porcellus* Hudson & Gosse (1889).

Distinctive characters.—This species is to be known by the short, plump, curved body; by the two toes, one a little longer than the other, usually kept folded beneath the body, and especially by the two teeth at the anterior margin of the lorica on the dorsal side. From all the other closely related species it differs in the presence of these two teeth, the others having one or none.

External features.—The body is short and thick, and strongly curved, so that the back forms an arc of a rather small circle. The posterior end is broad and rounded, the opening for the foot being on the ventral surface. The head-sheath is marked off from the remainder of the lorica by a slight constriction; it bears at its anterior margin, a little to the right of the middle line, two teeth, which are very similar to those of *Diurella insignis* Herrick. The right one of these is the longer, and is separated from the left by a slight interval. Ventrally the anterior margin has a broad, shallow notch. When the lorica is strongly contracted the two sides of this notch project as two decided points, one of which is seen in fig. 20. These two points might be called teeth, and this animal is therefore sometimes said to have four anterior teeth, two dorsal and two ventral. These two ventral teeth, due to the folding of the head-sheath, are of a different character from the dorsal ones, however, and are not to be noticed when the head is fully extended.

Extending backward from the larger one of the two dorsal teeth is a ridge, having its edge directed to the right. It is striated transversely from near its summit to a line some distance to the eft of it. The ridge is not prominent, and in some specimens there is a decided depression just to the left of the ridge, so that the ridge appears merely as the edge of the depression. In other cases the back seems nearly smooth, only the striated area being visible, with perhaps a marked line at its right edge. These differences are probably functional changes due to the varying states of contraction of the specimens, though I have not been able to demonstrate this.

Corona.—The corona has a short, median, club-shaped process. It has not been fully studied in other respects.

Antennæ.—The dorsal antenna is just to the left of the ridge, in the depressed area, when the depression is present. It is situated a little behind the constriction which sets off the head-sheath. The lateral antennæ are in the usual position on the posterior one-fourth of the body, the left one somewhat in advance of the right.

Foot.—The foot is very small and partly inclosed within the lorica.

Toes.—There are two unequal toes, the left one being about equal in length to the diameter of the body, while the right one is a little shorter (fig. 23). Each of the toes is accompanied at its base by two substyles, one of them in each case being more than half the length of the shorter toe. The right toe usually lies with its tip against or across the longer left toe. This gives an appearance which Gosse (1889) interpreted as being due to two flat, spoon-shaped toes, the one lying within the other. The inner sides of the two toes were supposed to be the outlines of the smaller toe; the outer sides those of the larger toe. On the basis of this supposed structure the genus *Cœlopus* was founded.

Internal organs.—The trophi are unsymmetrical, though the right manubrium is not lacking, as represented by Gosse (1855). It is a very slender rod, a mere bristle, but of the same length as the left manubrium. The latter is markedly "crutch-shaped" in side view (fig. 21), though this is not noticeable in a dorsal or ventral view. The remainder of the internal organs call for no special mention.

Measurements.—Length of body without toes, 0.14 to 0.15 mm.; toes about 0.05 to 0.06 mm.

History.—This species was first described by Bory de St. Vincent in 1824, as *Diurella tigris*. Since the name *tigris* had been given by Müller to another species, Bory's name can not be retained for this species. It has been used, however, by many investigators since Bory's time. For a list of accounts of this animal under the specific name *tigris*, see the list given in the account of *Diurella tigris* Müller, above. Gosse (1851) described this animal as a new species, under the name *Monocerca porcellus;* this specific name *porcellus* is therefore the correct one to use, under the accepted rules of nomenclature. In Hudson & Gosse's Monograph (1889) Gosse founded a new genus, *Cœlopus*, for this and a number of related species. As set forth in the general account of the taxonomy (p. 300), this genus was founded on a mistaken idea and was without justification,

so that the species must be reunited with *Diurella*. Weber (1898) has given an extended description, supposedly of this species, under Gosse's name *Cœlopus porcellus*. But rather curiously, his figures (pl. 20, figs. 2 and 3) do not represent this species, but afford an excellent picture of another species, which I have called *Diurella weberi* (q.v.). This has but one tooth in place of two at the anterior margin of the lorica. Weber's description introduces characters from both the species concerned. The two anterior dorsal teeth, of which he speaks (but which he does not figure) belong to *Diurella porcellus*, but the high ridge belongs to *D. weberi*. The fact that Weber had before him *D. weberi*, not *D. porcellus*, is perhaps the reason why he could not find the prominent substyles at the base of the toes, as represented by Plate and others, for these are much less prominent in the former species.

Distribution.—This species is one of the most common amid the vegetation of swamps, lakes, and streams. I have recorded its presence in the following localities: Lake St. Clair; Lake Erie (Put-in Bay Harbor, East Harbor, Long Point, Erie Harbor, and various other parts of Lake Erie); Crooked Lake, Newaygo County, Mich.; Old Channel, Charlevoix, Mich.; swamp on South Bass Island in Lake Erie; pools at Hanover, N. H.; Graveyard Pond, Presque Isle, near Erie, Pa.; Huron River at Ann Arbor, Mich.; ditch in the tamarack swamp region near Ann Arbor, Mich. Other observers have recorded it in America as follows: Ohio and Minnesota (Herrick, 1885, as *Diurella tigris*); Shiawassee River at Corunna, Mich. (Kellicott, 1888); Sandusky Bay, Lake Erie (Kellicott, 1896); waters connected with the Illinois River at Havana, Ill. (Hempel, 1898.)

Also taken in many parts of Europe, some of the more characteristic localities in Europe and elsewhere being: Germany (Plate, 1886); common in England (Gosse, 1889); Ireland (Glasscott, 1893; Hood, 1895); near Basel, in Switzerland (Ternetz, 1892); Finland (Levander, 1894, as *Rattulus tigris;* Stenroos, 1898); near Kharkow, Russia (Scorikow, 1896).

In Natal, South Africa (Kirkman, 1901).

7. Diurella stylata Eyferth (1878) (pl. III, figs. 27–31).

Synonyms: *Rattulus bicornis* Western (1893); *Cœlopus similis* Wierzejski (1893) (?); *Rattulus bicornis* n. sp. Scorikow (1896); *Mastigocerca birostris* Minkiewicz (1900).

Distinctive characters.—This species is to be known by the two very slender, nearly or quite equal spines at the dorsal edge of the anterior margin of the lorica, by the conical form, and by the two short, unequal toes, the longest being little more than one-third the length of the lorica.

External features.—The body is elongated conical, the thickest portion being near the anterior end or somewhat back of the anterior end (pl. III, figs. 27–30). Thence the body tapers regularly backward to the base of the toes. The head-sheath is set off from the remainder of the lorica by one or two marked constrictions. The head-sheath falls into many folds (fig. 30), when the head is retracted. At the anterior margin of the head-sheath, apparently a little to the right of the middle line, are the two long, slender spines which form the most characteristic features of this animal. These spines are nearly equal in length, though in most if not all specimens the right one is a trifle shorter than the left—a condition not found in any other species of the *Rattulidæ*. The length of the spines is usually about equal to the diameter of the lorica at its thickest point, though there is considerable variation. The spines are not absolutely fixed in position, but can be bent down over the corona for some distance when the latter is retracted. At times one of the spines may cross the other at its tip (fig. 28).

Extending backward from each spine is a ridge-like thickening, the two ridges including between them a narrow, transversely striated area (fig. 29). The entire area seems a little elevated above the general surface of the lorica, the side ridges being a little more elevated than the part between them.

Corona (fig. 31).—The corona, in its main features of the usual character, consists of the following parts: (1) Two semicircles of large cilia raised on elevations at the sides of the head (fig. 31, *a*). In many specimens when alive there is a prominent red spot at the dorsal or inner ends of these elevations (fig 31, *r. s.*), almost as brightly red as the eye. (2) Two semicircles of cilia on slight elevations at the sides of the mouth (fig. 31, *b*). (3) A large, central dorsal, fleshy projection (*c*). (4) Above this (fig. 27, *e*) a smaller dorsal projection. (5) Two small short lobes, apparently crowned with cilia, at the sides (and ventrad) of the central dorsal projection (fig. 31, *d*).

Antennæ.—The dorsal antenna is situated in the striated area, a little back of the constriction separating off the head-sheath. The lateral antennæ are remarkably unsymmetrical in their position, recalling the condition found in *Rattulus cylindricus* Imhof. The left lateral antenna (fig. 28, *l. a.*) is far forward, considerably in advance of the middle of the body, while the right lateral antenna is far back, near the base of the foot (fig. 28, *r. a.*).

Foot.—The foot is very slender, conical in form, and so attached to the lorica that it may bend to the right, but not to the left. In other words, the posterior part of the body is constructed as if it had been twisted over to the left. The position of the toes is likewise such as would be explained by such a twist.

Toes.—The two toes lie very close together, as a rule, so that in a cursory examination they might be taken for one. They are unequal, the right toe being a little shorter than the left. The longest toe is about one-third the length of the lorica. In correspondence with the position of the foot, as set forth above, the right toe lies with its base above the left, further adding to the difficulty of distinguishing the two toes in a dorsal view. This position is such as would be attained by a twist of the posterior part of the body to the left, as mentioned in the account of the foot. At the base of the toes there are, according to Western (1894), three small substyles; these I have not been able to see.

Internal organs.—The brain is immensely enlarged, in some specimens extending farther backward than the middle of the body and taking up a large share of the space within the lorica (see fig. 27, *br.*). In such cases the brain can be seen to be made up of large cells, the outlines of which can be clearly traced (see the figure just referred to). It is possible that this immense size is a transitory condition, not always present. The eye is attached to the dorsal surface of the brain, in front of the middle of the latter. In a dorsal view the eye underlies the thickening or ridge which runs backward from the base of the left anterior spine (fig. 29). The trophi are rather slender, and are somewhat unsymmetrical, the left manubrium being much better developed than the right (fig. 31). The mucus reservoir is divided longitudinally into two equal halves, one of which opens at the base of each toe. The other internal organs call for no special remark.

Measurements.—Total length, about 0.275 mm.; length of toes, 0.05 to 0.06 mm.; of anterior spines, 0.035 to 0.045 mm.

Movements.—*Diurella stylata* Eyferth swims in a rather wide spiral, in an awkward manner. The animal continually rotates over to the right as it swims, and at the same time it swerves continually toward the side which bears the spines; thus the spiral is produced.

When suddenly stimulated, as by swimming against an obstacle, or by the striking of some other organism against it as it swims, the animal usually reacts as follows: The cilia are partly withdrawn and the dorsal spines are bent down a little over the entrance to the lorica. If the stimulus is very strong the cilia are completely retracted and the animal remains quiet. If the stimulus is not so strong the cilia are only partly retracted and immediately begin operations again. But now they act in such a way as to turn the organism toward the side which bears the spines. The organism therefore swerves in the direction so indicated. This is, of course, the same direction in which the swerving occurs in the usual movement, only after a stimulus the swerving is more pronounced, so that the entire course of the animal is changed. For some time after the stimulation has occurred the swerving toward the side bearing the spines is much more marked than usual, so that the path followed becomes a much wider spiral.

History.—*Diurella stylata* was described by Eyferth in 1878. This description (1885, p. 111) was not clear in its account of the anterior spines, one of which he says arises from the "neck," while he seems to imply that the other rises from the brain. The folds in the anterior edge of the lorica he described as "one or two short spines" on the ventral side. Otherwise his description is good and his figure is at once recognizable as identical with the organism I have described above. Western (1893) redescribed this species as *Rattulus bicornis.* In his first description he described and figured the two toes as equal in length, a mistake which he afterward corrected (Western, 1894, p. 7). Scorikow (1896) described this species as a new one; by a rather curious coincidence he selected the same name (*Rattulus bicornis*) as Western had done. He also made the same mistake as Western in describing and figuring the two toes as equal. In the same year as Western, Wierzejski (1893) described what seems to be the same species under the name *Cœlopus similis.* In Wierzejski's figure the two equal anterior spines are shorter than usual, and the body is thicker

and shorter, while the character of the toes is not clearly shown (nor described in the text). It is possible, therefore, that Wierzejski's species is not the same as *Diurella stylata* Eyferth.

Hood (1895) gives good figures and a description of this animal under the name *Rattulus bicornis*. Minkiewicz (1900) again describes this species as new, under the name *Mastigocerca birostris*.

Distribution.—This species is not common, though it sometimes occurs in large numbers in swampy ponds. I have recorded its presence in the following places: East Harbor, Lake Erie (near Sandusky, Ohio); pond near United States fish-hatchery, Put-in Bay, Ohio; Portage River, Ohio.

In Europe: England (Western, 1893); Ireland (Hood, 1895); Württemberg, Germany (Bilfinger, 1892); bayous of the Rhine (Lauterborn, 1898); Austrian Poland (Wierzejski, 1893, as *Cœlopus similis*); near Kharkow, Russia (Scorikow, 1896); Lake Bologoe, Russia (Minkiewicz, 1900).

8. Diurella rousseleti Voigt (pl. IV, figs. 37–39).

Synonym: *Cœlopus rousseleti* Voigt (1901).

Distinctive characters.—This small species is at once known by the nine projecting points at the anterior margin of the lorica, the upper right-hand one being a little larger than the others. The animal does not closely resemble other species of *Diurella;* its closest relatives seem to be *Rattulus stylatus* Gosse and *Rattulus pusillus* Lauterborn. But the shorter toe is about half the length of the longer one, so that it is necessary to place the animal with the *Diurellas.*

External features.—The small body is usually rather short and thick (fig. 37), slightly bent, and tapering backward in conical fashion to the toes. The proportions of the body vary considerably, as will be seen by comparing fig. 37 and fig. 39. The large head-sheath is marked off from the remainder of the lorica by a slight constriction. The entire circumference of the head is set with large projecting points or teeth, there being nine of these in all. They are somewhat larger on the right side than on the left, and the dorso-dextral one is a little larger than any of the others. These teeth are formed as projections of the plaits of the head-sheath, and are represented in much less pronounced form, as mere rounded projections, in some other species. The larger dorso-dextral tooth evidently corresponds to the single tooth of *Diurella tigris* Müller and other single-toothed species. Between the teeth the lorica in *D. rousseleti* forms furrows which are flexible. These fold when the head is strongly retracted, so that the teeth are brought into close contact. Between the two dorsal teeth is a somewhat larger furrow, which passes backward to the constriction which separates the head-sheath from the body. This furrow perhaps represents the "striated area" of other species.

Corona.—This bears, according to Voigt (1901), a very long central dorsal process, bent upward and showing wavy lines on its lower side.

Antennæ.—The dorsal antenna is in the usual position on the dorsal side, near the constriction which separates off the head-sheath. The lateral antennæ have not been observed.

Foot.—The foot is a short, conical structure, of the usual form.

Toes.—There are two toes (fig. 38), the right one being about one-half the length of the left. The two toes are very close together, and the right one is very slender, so that it is easily overlooked; the impression is then received that the animal has but a single toe. The longer toe is about one-third the length of the body, or a little less than one-third. It is very slightly curved, the concave side of the curve being dorsal.

Internal organs.—According to Voigt (1901) there is a large red eye on the posterior end of the large brain. Trophi large, unsymmetrical.

Measurements.—Length of body, 0.095 mm.; of toe, 0.03 mm. Length of the long anterior dorsal process of the corona, when extended, 0.0195 mm.

History.—This species was described by Voigt, without a figure, in 1901. Through the kindness of Herr Voigt I have received a quantity of material containing specimens of the animal, and have thus been able to study it at first hand. The figures herewith given are the first published. Fig. 39 is due to Mr. Dixon-Nuttall; the others I have myself made.

Distribution.—Not yet been found in America. It should be looked for in small ponds.

In Europe: Plankton of the Schöh-See, Heiden-See, and Schluen-See, near Plön, Germany (Voigt, 1901). Also found in England.

9. Diurella sulcata Jennings (pl. II, figs. 24–26, and pl. XIII, figs. 113, 118, 119).

Synonyms: *Rattulus sulcatus* Jennings (1894); *Cœlopus brachiurus* (?) or *Rattulus cryptopus* Bilfinger (1894).

Distinguishing characters.—This species is to be known by the short, curved body, with two prominent constrictions about it; by the very short, equal toes, attached to a foot which is usually withdrawn into the body, and by the unarmed anterior edge of the lorica. It bears some resemblance to *Diurella brachyura* Gosse, but is distinguished from the latter by the equal toes, the constrictions, and the general form. It also resembles *Diurella cavia* Gosse, but is much larger, and the posterior part of the lorica ends in an entirely different manner in the two species.

External features.—The body is nearly cylindrical and strongly curved, the dorsal line forming nearly an arc of a circle. The foot is usually retracted within the lorica (fig. 25), so that the ventral line meets the dorsal in a sharp angle, giving a very characteristic feature of this animal; when the foot is extended, however, as in fig. 24, this angle does not appear. Surrounding the body a little in front of the middle are two pronounced grooves, which separate off the anterior part of the lorica from the remainder. There are no pronounced teeth nor spines at the anterior margin of the lorica, though the dorsal edge projects a little farther than the ventral, so that this might perhaps be described as a very slightly marked tooth. On the dorsal surface of the lorica (apparently in the middle line, though this is very difficult to determine in an animal of this form, in which a dorsal view is rarely obtained) there is a shallow furrow, between two slight ridges, extending back about to the first transverse groove. This furrow is striated transversely. In some specimens this furrow seems scarcely to exist at all. The ridge to the right of the furrow is a little higher than the one to the left.

Corona.—The corona has the usual two sets of cilia—those about the outer edge and a small curve on each side of the mouth. In addition to these, the following structures may be distinguished: (*a*) A large fleshy dorsal process, pointed in side view (fig. 24), but nearly rectangular from above; (*b*) two small antenna-like processes, one on either side of and below the dorsal process; (*c*) a large, rounded, central projection of the coronal surface below the dorsal process (fig. 24).

Antennæ.—The dorsal antenna is in the median furrow, about halfway back to the first circular groove. The lateral antennæ, very minute, are in the usual position, on the posterior third of the lorica.

Foot.—The foot is scarcely distinguishable as a separate structure, since it is small and is habitually retracted within the lorica (fig. 25). It can be extended, however (fig. 24), and is a very short joint of the usual form.

Toes.—The two toes are equal in length, very short, and are usually concealed for half their length within the lorica, the tips projecting downward (fig. 25). When the foot is extended, the toes point forward (fig. 24.) Each toe is accompanied on its outer side by a substyle about one-third its own length.

Internal organs.—The mastax is very large, and contains large, well-developed trophi. These are unsymmetrical, the right manubrium being a mere slender bristle, much smaller than the left (fig. 26). The mucus reservoir is large, and divided by a longitudinal partition into two equal halves. The contractile vacuole is very small, lying above the mucus reservoir, on the right side of the intestine. The remainder of the internal organs call for no special mention.

Measurements.—Length of body without toes, 0.17 to 0.18 mm.; length of toes, 0.03 to 0.035 mm.

History.—This species was described by the present author in 1894 as *Rattulus sulcatus*. In the same year Bilfinger (1894) described and figured it, considering it to be possibly Gosse's *Cœlopus* (*Diurella*) *brachyurus*. Since that time it has been mentioned, with notes, by Stenroos (1898) and figured by Jennings (1901).

Distribution.—*Diurella sulcata* Jennings is very common in summer in the vegetation of our lakes. I have found it in the following localities: Lake St. Clair; Old Channel, Charlevoix, Mich.; West Twin Lake, 6 miles from Charlevoix, Mich.; Put-in Bay Harbor and East Harbor, Lake Erie. Kellicott (1896) found this species in Sandusky Bay, Lake Erie.

In Europe: Württemberg, Germany (Bilfinger, 1894); Lake Nurmijärvi in Finland (Stenroos, 1898).

10. Diurella cavia Gosse (pl. III, figs. 35 and 36).

Synonym: *Cœlopus cavia* Gosse (1889).

Distinctive characters.—This species is to be recognized by the very small, plump body, without teeth at the anterior margin of the lorica, and the projection of the lorica as a large, rounded protuberance over and behind the foot, so that the foot arises from the ventral surface of the body, and by the short, equal toes. It differs from *D. porcellus* Gosse and *D. intermedia* Stenroos in the absence of teeth at the anterior margin of the lorica and in the equal toes, together with differences in general form. From *D. brachyura* Gosse it differs in the short, thick body and the large, rounded backward projection over the foot and in the equal toes. From *D. sulcata* Jennings, its nearest relative, it differs in its much smaller size and in the great posterior enlargement projecting as a large, rounded protuberance over the foot, giving the animal an entirely different appearance from the last-named species.

External features.—The lorica is short and thick, arched dorsally and only slightly curved ventrally (fig. 36). The lorica projects backward as a large, hollow protuberance, extending considerably back of foot. There are one or two slight constrictions about the middle of the body, much as in *D. sulcata* Jennings, but less marked. The anterior margin of the lorica is without teeth. Extending back from the anterior margin to nearly the middle of the lorica, a little to the right of the middle line, is a depressed, striated area, its two edges being a little elevated.

Corona.—The corona bears the usual thick dorsal process; in other respects it has not been specially studied. The antennæ I have not seen.

Foot.—The foot is very small, scarcely noticeable as a separate joint. It is situated considerably in front of the posterior end, on the ventral surface.

Toes.—The two toes are equal in length, the length being somewhat less than the diameter of the lorica. In the specimen studied by the author the two toes extended backward and were crossed (fig. 35). This is doubtless by no means the rule. In Mr. Gosse's specimens the toes were turned forward, as in *D. porcellus* Gosse. There is a substyle at the base of each of the toes (not shown in the figures). The internal organs seem to offer nothing exceptional. In the single specimen at my disposal I was not able to make out the trophi.

Measurements.—Length of body without toes, 0.115 mm.; length of toes, 0.032 mm.

History.—This species was described as *Cœlopus cavia* by Gosse in Hudson & Gosse's Monograph of the Rotifera (1889). It has not since been described or figured.

Distribution.—I have found but a single specimen of this species, from the northern swamp on Middle Bass Island, in Lake Erie.

In Europe: Epping Forest, England (Gosse, 1889); Ireland (Glasscott, 1893); Austrian Poland (Wierzejski, 1893).

11. Diurella brachyura Gosse (pl. III, figs. 32–34, and pl. XIII, figs. 114 and 115).

Synonyms: *Monocerca brachyura* Gosse (1851); *Diurella rattulus* Eyferth (1878 and 1885); also Eckstein (1883); *Acanthodactylus rattulus* Tessin (1886); *Cœlopus brachyurus* Hudson & Gosse (1889); *Rattulus palpitatus* Stokes (1896).

Distinctive characters.—This species is to be known by the small, curved body, less plump than in *D. porcellus* Gosse and *D. cavia* Gosse; the lack of teeth at anterior margin of lorica; the fact that the foot is not on the ventral surface; and the nearly equal toes, of length about equal to diameter of lorica. It is nearest to *D. cavia*, from which it is distinguished by the more slender body, tapering to the posterior end, and the fact that the foot is not on the ventral surface.

External features.—The body is cylindrical in form, much more slender than in *D. porcellus* Gosse, and tapers toward the posterior end. In extended specimens the thickest part of the body is the middle, the head region being a little narrower (fig. 32). The body is curved, so that the dorsal line forms nearly an arc of a circle. Together with the toes, which continue the curve of the body (when not bent up against the lorica), a full semicircle is thus formed. The head-sheath is not sharply set off from the remainder of the lorica, though a slight constriction between the two is evident. There are no teeth at the anterior margin of the lorica. The head-sheath may be folded longitudinally when the head is retracted, as in many other species. At such times one of the folds on the left extends a little beyond the others, forming thus a slight rounded, very inconspicuous, projection (fig. 33). This projection disappears when the head is fully extended. Usually no ridge is apparent, though on some specimens there is evidently a slight elevation of the

lorica in the usual position of the ridge, to the right of the dorsal line. Careful examination of favorable specimens shows that a striated area, such as marks the ridge when it exists, is always present (fig. 33). This is broad, and extends back to about the middle of the body; it has two sets of the striations, meeting each other along a central rhaphe.

Corona.—The corona is of the usual character. It bears a single thick dorsal process (fig. 32), and apparently two very slender lateral processes, though of these I could not be quite certain.

Antennæ.—The dorsal antenna is in the striated area, a little behind the constriction setting off the head-sheath. The lateral antennæ are in the usual position, on posterior third of body.

Foot.—The foot forms a continuation of the tapering body at its posterior end, not being pushed forward on the ventral side, as in *D. cavia* Gosse and *D. porcellus* Gosse. It is of the usual short conical form.

Toes (figs. 34 and 114).—The two toes are very nearly equal, the left being a very little longer than the right. Frequently the tip of the right toe lies against the left, but this is by no means always true. The longest toe is about equal in length to the diameter of the body. At the base of each toe on its outer side is a single substyle, about one-third the length of the toe.

Internal organs.—The trophi are of the usual character, the right manubrium being much reduced. The small contractile vacuole (fig. 32, *cv.*) lies above the mucus reservoir and contracts very rapidly (according to Stokes (1896) 40 times per minute). The rest of the internal organs call for no special remark.

Measurements.—Length without toes, 0.10 to 0.13 mm.; length of toes, about 0.03 mm.

History.—This species was described by Gosse in 1851 as *Monocerca brachyura*. Eyferth (1878) proposed, for a form which he said was much smaller than *D. stylata*, the name *Diurella rattulus*, but he gave no further account of the animal. Eckstein (1883) described and figured the animal under the name proposed by Eyferth. Tessin (1886) gave a few notes on the animal under the name *Acanthodactylus rattulus*. In Hudson & Gosse's Monograph (1889) this species was transferred to Mr. Gosse's new genus *Cœlopus*, receiving the name *Cœlopus brachyurus*. As this genus was based on an error, the species must of course go back to *Diurella*. Finally, Stokes (1896) described this as a new species, under the name *Rattulus palpitatus*, the specific name relating to the rapidity of the pulsations of the contractile vacuole. Stokes's description and figure apply in every detail to *D. brachyura*, so that there was no reason for giving the animal a new name.

Figures of this species have also been given by Jennings (1900 and 1901).

Distribution.—This species is not very common and seems as a rule to inhabit swampy ponds. I have recorded it from East Harbor, Lake Erie, near Sandusky, Ohio; from the Huron River at Ann Arbor, Mich.; from pools near Hanover, N. H.; and from marshy ponds on North, Middle, and South Bass islands, and on Presque Isle, all islands in Lake Erie. Kellicott (1888) reported its presence in the Shiawassee River at Corunna, Mich.; Stokes (1896, as *Rattulus palpitatus*) found it near Trenton, N. J.

In Europe: England (Gosse, 1889); Ireland (Glasscott, 1893); near Rostock, Germany (Tessin, 1886); Württemberg, Germany (Bilfinger, 1892, as *D. rattulus*); Finland (Levander, 1894, as *D. rattulus*).

12. Diurella dixon-nuttalli n. sp. (pl. IV, figs. 40 to 44).

Distinctive characters.—This species is to be known by the absence of teeth at the anterior margin of the lorica and by the two toes, one about two-thirds the length of the other. It is closely related to *D. brachyura* Gosse, from which it differs in the greater inequality of the two toes, as well as in general form. (Compare the figures of the two species.) From *D. sulcata* Jennings and *D. cavia* Gosse this species differs in having unequal toes.

External features.—The body is nearly cylindrical, somewhat curved, and tapers toward the posterior end. The dorsal line is convex, the ventral line nearly straight, or concave. The head-sheath is set off from the remainder of the lorica by a constriction, and has a number of longitudinal folds, where it yields when the head is retracted. It is without teeth at its anterior edge. On the dorsal surface of the lorica a short furrow extends backward from the anterior margin to a point some distance behind the constriction which separates the head-sheath from the remainder of the body (fig. 40). This evidently corresponds to the striated area of other species.

Corona.—The corona bears the usual median dorsal club-shaped process, as well as a number of other prominences (fig. 40). Otherwise it seems to be of the usual character.

Antennæ.—The dorsal antenna is situated in the dorsal furrow mentioned above, a little behind the constriction which separates off the head-sheath. The lateral antennæ are in nearly the usual position on the posterior third of the body, but the left anterna is considerably farther forward than the right. (Compare figs. 41 and 44.)

Foot.—A short, thick joint, which can apparently be retracted within the lorica (see fig. 40).

Toes.—There are two toes, very close together. The longer left toe is about half as long as the body of the animal, while the right toe is about two-thirds the length of the left (fig. 43). There are two minute substyles at the base of the main toes (fig. 43).

Internal organs.—The prominent brain bears a large red eye at its posterior end. The trophi (fig. 42) are unsymmetrical, the right malleus being much reduced.

Measurements.—Total length, 0.15 to 0.18 mm., of which the toe forms about one-third.

History.—This species has not been described before. It was drawn by Mr. Dixon-Nuttall some years ago, and copies of his drawing have been distributed to many workers on Rotifera under the name *Cœlopus brachyurus*, but he agrees with me that this is not really the *Cœlopus brachyurus* of Gosse (see the account of *Diurella brachyura*), so that it is necessary to give it a new specific name. I name it therefore after the investigator who first figured it. The figures herewith presented (figs. 40–44) are all by Mr. Dixon-Nuttall, and my description is based upon them.

Distribution.—This species has not been found in America. According to Mr. Dixon-Nuttall it is common in ponds in England.

DESCRIPTIONS COMPILED FROM OTHER AUTHORS.[a]

13. Diurella sejunctipes Gosse (pl. XIV, figs. 120, 121).

Synonym: *Rattulus sejunctipes* Gosse (1889).

Distinguishing characters.—"Body projecting much above and behind the foot; toes, two, coequal, slender, decurved, set side by side, wide apart" (Gosse, 1889, p. 66). The body is said to be stout, plump, and curved; the foot is short and thick. Gosse described what is evidently the mucus reservoir as "a great basal bulb, wholly internal," forming part of the foot. The toes are two equal acute slender styles, so curved as to continue the outline of the body, and are wide apart at the base. The trophi were figured by Gosse "conjecturally."

Described by Gosse from notes by Dr. F. Collins. Found by the latter in a pool near Wellington Military College, Birks, England.

Stenroos (1898) found this species in Lake Nurmijärvi, in Finland, and gave a figure (fig. 121) and measurements. Length of body, 0.109 mm.; thickness, 0.03 mm.; length of toes, 0.03 mm.

Distribution.—As above and in Bohemia (Petr, 1890).

14. Diurella collaris Rousselet (pl. XIV, fig. 127).

Synonym: *Rattulus collaris* Rousselet (1896).

I give herewith Mr. Rousselet's description of this species in his own words:

"In shape the body is roughly cylindric, slightly curved behind; the lorica is finely pitted or stippled, giving it a roughened appearance; it has no dorsal ridge and is fairly stiff, except in the neck region, where the integument is more flexible and frequently forms a thickened collar when the animal is bending or retracting, and from this characteristic peculiarity the animal derives its specific name. The foot opening is oblique, nearly ventral, and the lorica overhangs the foot dorsally in a marked degree. The head is elongated, truncate in front, and somewhat tapering anteriorly, and it is furnished with a simple wreath of cilia; it contains a conical brain mass, with a red eye at the tip, and long jaws of the *Rattulus* type. The long, thin œsophagus is attached to

[a] *Diurella uncinata* Voigt.—While this paper was passing through the press, Voigt published a brief diagnosis of a new species of *Diurella*, under the name *Cœlopus uncinatus* (Zoologischer Anzeiger, Bd. 25, 1902, p. 679). For the sake of completeness I append a translation of his description: "Body short, curved. Anterior edge of the lorica slightly denticulate. Somewhat to the right of the middle line, when the animal is viewed from the dorsal side, arises a long, rapidly narrowed, somewhat curved process. The short foot shows two unequal curved toes. Jaws unsymmetrical. A large red eye-spot. Length of the body without the process, 0.095 mm. Length of the largest toe 0.02 mm. Length of the frontal process, 0.027 mm. Occurrence: November, 1900 and 1901 in the Schluen-See and Schöh-See, amid *Potamogeton* and *Phragmites*. Specimens few."

The diagnosis is not accompanied by a figure. A full description, with figures, is promised for the forthcoming (ninth) Heft of the Forschungsberichte aus der Biol. Station zu Plön.

the antero-dorsal part of the mastax and widens into the large saccate stomach and intestine. Rounded gastric glands are attached to the anterior part of the stomach in the usual way. The ovary is an oval plate with large nuclei embedded in its granular substance, and it has generally a large maturing egg attached to it. Lateral canals, with flame cells attached, and a contractile vesicle are present. The dorsal antenna emerges from a small depression in the head just behind the tip of the brain, and the lateral antennæ are situated in the lumbar region, on each side of the body. The foot emerges nearly ventrally; it consists of two short joints and is furnished with two very long, thin, narrow, glassy toes, about half the size of the body in length. The toes are nearly straight for about half their length, then they are decurved; one or two very small substyles are present at the base of each toe. In swimming the animal moves slowly, as if the small ciliary wreath were not powerful enough to move the comparatively large body, and I always found it at the bottom of my tanks among the sediment.

"Length: Total, with toes, $\frac{1}{80}$ inch (0.317 mm.); of body alone, $\frac{1}{120}$ inch (0.212 mm.); of toes alone, $\frac{1}{242}$ inch (0.105 mm.). Habitat, Sandhurst, Berks."

Stenroos (1898) found this species in Lake Nurmijärvi, in Finland, and gives a description and figure. Stenroos's specimens were larger than those of Rousselet, the body shorter and thicker, the projection of the lorica back of the foot larger, and the foot consisted of but a single joint, instead of two, as described by Rousselet. (This last-named difference probably arises merely from a variation in interpretation as to what should be called a "joint.")

15. Diurella helminthodes Gosse (pl. XIV, fig. 122).

Synonym: *Rattulus helminthodes* Gosse (1889).

Distinguishing characters.—"Body very slender, especially in front; the width less than one-fifth the length; toes without accessory styles at base; brain clear." (Gosse, 1889, p. 65.) This species was described by Gosse from a single dead specimen. He says that it approaches *Diurella tigris* Müller in form, in the slenderness and in the comparative length of the toes, but it is much more elongated and the anterior part especially is more slender than in *D. tigris* Müller. He thinks there is a low dorsal ridge, beginning insensibly near the middle of the length and ending in an oblique angle near the foot. Gosse thought that no substyles were present, but was not absolutely certain of this. Whether or not a tooth is present at the anterior edge, as in *D. tigris* Müller, Gosse does not say. Length to tips of toes, 0.25 mm.; of toes, 0.066 mm.; width and depth of body, 0.05 mm.

Glasscott (1893) lists this species from Ireland and states that the anterior part was of the same diameter as the posterior.

Scorikow (1896) has given a description of a rotifer which he identified doubtfully as this species, without a figure, but his account adds nothing of importance to that of Gosse.

Distribution.—Gosse (1889) found *D. helminthodes* in a pool near Birmingham, England; Glasscott (1893) in Ireland; Scorikow (1896) near Charkow, Russia; Wierzejski (1893) in Austrian Poland.

16. Diurella marina Daday (1889) (pl. XIV, figs. 123–126).

This species was described by its author in the Magyar language, so that I am unfortunately unable to make use of his description. His figures are reproduced in pl. XIV, figs. 123–126.

In a brief note in German, Daday (1890) says that *Diurella marina* most resembles *Diurella tigris* of Ehrenberg, but is distinguishable from it by the structure of the mastax and the peculiar border of the head-sheath of the lorica. What these peculiarities are must be judged from the figures. The figures do not show whether the toes are equal or unequal.

This species is marine and was found by Daday in the Bay of Naples.

17. Diurella brevidactyla Daday (1889) (pl. XIV, fig. 128).

This species, like the last, was described in the Hungarian language, so that I can not use the description. In a brief résumé Daday (1890) says that this species is distinguished from *D. marina* Daday by the simple anterior edge of the lorica, that its toes are very short, and that its mastax is different from that of *D. marina*. It is likewise a marine species and was found in the Bay of Naples.

II. RATTULUS Lamarck.

Generic characters.—One long toe, which is usually accompanied by another (the right toe), which is rudimentary, being not more than one-third length of main toe. The main toe usually more than half the length of body. Body cylindrical, oval, or ovoid; usually less curved than in *Diurella*.

DESCRIPTIONS OF THE SPECIES STUDIED BY THE AUTHOR

18. Rattulus gracilis Tessin (pl. v, figs. 45–49).

Synonyms: *Acanthodactylus gracilis* Tessin (1886); *Mastigocerca iernis* Gosse (1889).

Distinguishing characters.—This species is to be distinguished by the elongated, only *slightly* curved body, with the head-sheath sharply set off, and with many longitudinal folds, the main (left) toe about one-half to two-thirds the length of the body and the rudimentary (right) toe about one-third the length of the main one. Its nearest relative is *Diurella tenuior* Gosse, from which it differs in having the shorter toe only one-third the length of the longer, in the less curved form, and the head-sheath sharply set off from the body. From *Rattulus scipio* Gosse it differs in having a shorter main toe, with the right toe longer in proportion, and in the marked folds of the head-sheath when the head is retracted.

External features.—The body is elongated and shaped much as in *R. scipio*, save that it is a little more curved, the dorsal line being markedly convex, while the ventral line is nearly straight. In a dorsal view the sides of the body frequently appear nearly straight, as shown in fig. 46. There is a ridge on the dorso-dextral side, extending from the foot to the head. On the head-sheath the ridge is less prominent; it ends anteriorly in a minute tooth (figs. 45, 47). The ridge is transversely striated, the striations extending some distance to the left on the lorica. These striations are very inconspicuous, owing to the opaqueness of the internal organs, so that they can be seen only in especially favorable specimens.

The head-sheath is sharply set off from the rest of the body by a deep constriction, and is as a rule much narrower than the rest of the lorica. It has many longitudinal folds, by which it can be folded into very small compass and the anterior opening almost completely closed when the head is strongly retracted (fig. 48). These folds almost disappear when the head is unusually extended (fig. 45). The dorsal portion of the head-sheath projects considerably beyond the ventral portion when the head is strongly retracted.

On its right side, in the continuation of the ridge of the lorica, the head bears a single tooth (figs. 46–48). This is very minute, so that it is easily overlooked; it is not mentioned by Tessin (1896) nor Gosse (1889), though it was observed by Bilfinger (1894).

As to the general form, it is perhaps possible to distinguish two varieties of this species. Those which were sent me by Mr. Rousselet from Prescot, England, differed from the specimens found in America in the more slender body, perhaps a little more curved, and with the head-sheath not so sharply set off from the rest of the lorica. This English form is shown in figs. 45 and 47, while American specimens are shown in figs. 46, 48, and 49. The differences do not seem to me sufficient to justify considering these different species. In other characteristics than those mentioned the specimens are alike.

Corona.—The corona bears a prominent dorsal process; otherwise it has not been minutely studied.

Antennæ.—The dorsal antenna lies to the left of the ridge, at the junction of the head-sheath with the rest of the lorica (fig. 46, *d. a*). The two lateral antennæ are in the usual position on the sides, on the posterior fourth of the body (fig. 46).

Foot.—The foot is short and thick as compared with that of *Rattulus scipio*, and the lorica does not project over it in a free edge on the left dorsal side, as in the last-named species.

Toes (fig. 46, 47).—The main or left toe is from one-half to two-thirds the length of the lorica. The smaller or right toe (*r. t.*) is about one-third the length of the main one, and its distal end lies across the latter. At the left side of the main toe is a large substyle, about one-half or more of the length of the right toe. On the outer side of the right toe is a similar but very minute substyle. The larger of the two mucus reservoirs is connected with the main or left toe; the smaller with the rudimentary right toe.

Internal organs.—These offer nothing of unusual interest. The stomach is usually large and very opaque, making it difficult to study the internal structure. The eye lies considerably to the left of the ridge. The jaws are rather weak and are unsymmetrical, the right manubrium being a short, very slender rod, while the left one is stout and very much larger.

Measurements.—Length of lorica, without toes, 0.17 mm.; of longest toe, 0.08 mm.; of shorter toe, 0.03 mm.; total length, 0.25 mm.

Movements.—*Rattulus gracilis* Tessin is a slow swimmer. As it moves through the water it revolves upon its long axis to the right, so that the path becomes a spiral. The dorso-dextral ridge is always directed toward the outside of the spiral. In other words, the animal swerves continually toward the ridge, the latter serving thus to cut the water. When stimulated suddenly, as by coming in contact with an obstacle, the animal swerves strongly toward the dorso-dextral side—that is, toward the ridge.

A specimen of this species was seen to feed upon a young specimen of *Diurella tenuior* Gosse. The jaws of *Rattulus gracilis* Tessin were extended far out (as in fig. 49) and seized the side of the prey; a piece of the *Diurella* was then torn out and devoured.

History.—This species was first described by Tessin (1886) under the name of *Acanthodactylus gracilis.* In 1889 Gosse described the same animal in the supplement to Hudson & Gosse's Monograph under the name *Mastigocerca iernis.* Bilfinger (1894) has given a better description of this animal than either Tessin or Gosse, but did not give a figure.

Distribution.—In America: East Harbor, Lake Erie; Graveyard Pond, on Presque Isle, near Erie, Pa.; Huron River at Ann Arbor, Mich. (abundant in *Ceratophyllum*).

In Europe: Near Rostock, Germany (Tessin, 1886); lakes in England (Gosse, 1889); Ireland (Hood, 1895); Württemberg, Germany (Bilfinger, 1894).

19. Rattulus scipio Gosse (pl. v, figs. 50–52; pl. XIII, figs. 111–112).

Synonyms: *Mastigocerca scipio* Gosse (1889); *Mastigocerca unidens* Stenroos (?) (1898); *Mastigocerca cuspidata* Stenroos (?) (1898).

Distinguishing characters.—This species is distinguished by the usually somewhat prismatic lorica, sometimes curved, widely open in front, with the head-sheath not sharply set off from the rest of the lorica; the single tooth near the anterior margin, and the single long toe three-fourths or more of the length of the lorica, accompanied by a short "substyle" (the right toe).

External features.—The lorica is elongated, often with nearly straight sides (fig. 50), though sometimes curved (fig. 111). In adult specimens (figs. 50 and 52) the diameter of the body is nearly uniform for three-fourths of the length, being very little narrower in the head region, and at the posterior end tapering in conical fashion to the foot. In young specimens (fig. 51) the largest part of the body is nearer the anterior end, and the lorica tapers thence regularly backward to the foot. The form of the lorica is not greatly changed in fully retracted specimens.

Considerably to the right of the middle line the lorica rises to a pronounced dorsal ridge, which aids much in giving the body a prismatic appearance. The ridge inclines sharply to the right and extends from the anterior edge fully three-fourths of the length of the body. It is marked with the usual transverse striations; these extend for a considerable distance to the left of the ridge (fig. 52). At the anterior end the ridge bears a tooth, which is fairly prominent though not large. The tooth is not at the very anterior margin of the lorica, but arises from a little behind this. In a retracted specimen (fig 52) it projects slightly beyond the edge of the lorica, while in extended specimens (fig. 51) its tip may not reach the edge.

The head-sheath is not very sharply marked off from the rest of the lorica, though a slight constriction between the two may be detected, especially marked on the ventral side. The head-sheath does not show longitudinal folds or flutings, such as are prominent in *Rattulus longiseta* Schrank and *R. gracilis* Tessin, and does not constrict or change its form greatly when the head is fully retracted. This gives one of the most striking characteristics of this species. At the anterior edge the head-sheath flares a little (fig. 51) and the anterior aperture remains widely open, even when the head is retracted (fig. 52).

Corona.—The corona bears a thick, in dorsal view somewhat triangular, dorsal process.

Antennæ.—The dorsal antenna lies to the left of the ridge, at left edge of striated area. The two lateral antennæ are in the usual position, the right one being a little in advance of the left.

Foot.—The foot is rather sharply set off from the rest of the body. The posterior dorsal edge of the lorica projects on the left side some distance over the point of attachment of the foot, so that the latter can not bend to the left, but bends almost directly to the right (fig 52).

Toes.—The single main toe (representing the left toe of *Diurella*) is nearly or quite as long as the lorica; the right toe (figs. 50 and 111, *r. t.*) is rudimentary and small. The main toe apparently does not grow during the life of the animal, while the remainder of the body does, so that in a young specimen the toe is as long as the entire body (fig. 51), while in adult specimens (figs. 50, 52, and 111) it is only about three-fourths or less the length of the body.

Internal organs.—These offer nothing especially noteworthy. The trophi (fig. 51) are very unsymmetrical, the left manubrium being long, stout, and curved; the right one, a slender, straight rod about three-fourths the length of the left.

Measurements.—Length of adult body, 0.2 mm.; of toe, 0.15 mm.; total, 0.35 mm.

History.—This species was first described by Gosse in 1889, on page 61 of Hudson & Gosse's Monograph, vol. 2. Like many of Gosse's descriptions, the account of this species is somewhat inexact, the figure and description not agreeing in all points. It is on account of this inexactness in Gosse's descriptions that I have considered it justifiable to identify the species here described with that described by Gosse. The resemblance in general appearance and form of the body is great, as will be seen by comparing Gosse's figure with my fig. 51. But Gosse describes the animal as having three spines at the anterior margin of the lorica, each running back some distance as a sharp ridge. His figure shows but one of these spines, and no rotifer is known which would answer to this description. Gosse probably took the profile of the flaring edges of the lorica for two of the spines.

A more important difference is in the length of the toe. Gosse describes and figures the main toe as a little less than half the length of the lorica, while in the species here described it is much longer. Gosse's notes and figures are often inaccurate, however; for example, he states that in this species the mastax occupies more than half the body length, while in his figure it does not occupy one-third the body length. I have thought it best, therefore, to give this species Gosse's name, at east until one corresponding more exactly to Gosse's description is found.

No description or figure of this species, except that of Gosse, has been published.

Distribution.—In America: Put-in Bay Harbor and East Harbor, Lake Erie; Graveyard Pond, Presque Isle, near Erie, Pa.; near "The Cottages," Long Point, Canada, on north shore of Lake Erie.

In Europe: England (Hudson & Gosse, 1889); Ireland (Glasscott, 1893); Württemberg, Germany (Bilfinger, 1892); Gr. Plöner See, Germany (Zacharias, 1893); near Basel, Switzerland (Ternetz, 1892); Lake Nurmijärvi in Finland (Stenroos, 1898); Bohemia (Petr, 1890).

Also in Ceylon (Daday, 1898).

20. Rattulus macerus Gosse (pl. v, figs. 53, 54).

Synonyms: *Mastigocerca macera* Gosse (1889); *Mastigocerca fusiformis* Levander (1894).

Distinguishing characters.—This species is to be known by the elongated fusiform body (sometimes a little curved); the toe one-half to two-thirds the length of the body, *the short spur* (figs. 53, 54, *sp.*) *projecting backward from the base of the toe* when the latter is bent forward, and the single, very small and inconspicuous tooth at the right anterior edge of the lorica.

External features.—The body is elongated and fusiform, the dorsal surface much more convex than the ventral. In some specimens (fig. 53) the body is slightly curved. The head-sheath is marked off, as usual, by a slight constriction. It bears at its anterior margin, to the right of the dorsal middle line, a small, very inconspicuous tooth. This tooth is very easily overlooked, being hidden commonly by the fleshy head; it was not observed by Gosse or Levander. What corresponds to the ridge or striated area is not strongly marked; in contracted specimens (fig. 53) it may be noticed as a broad, elevated area extending backward from the region of the tooth. In fully extended specimens it can hardly be seen at all.

The corona has not been studied.

Antennæ.—The dorsal and lateral antennæ are in the usual positions, the former a little behind the constriction separating off the head-sheath; the latter on the posterior fourth of the lorica, at the sides.

Foot.—The foot is slender and cylindrical. It bears at its tip a spur, which is described in the account of the toes.

Toes.—The main toe is a nearly straight rod; in the adult (fig. 54) about half the length of the lorica; in a young specimen (fig. 53) it is about two-thirds as long as the lorica. There are two "substyles" (one doubtless representing the right toe); the longer of these is about one-fourth the length of the main toe.

The most peculiar feature of the foot and toes in this species is a spur-like point which extends backward from the distal end of the foot, at the base of the toes. It is shown in figs. 53 and 54 (*sp.*) as well as in the figure of this species given by Levander (1894). This spur is not found, so far as I am aware, in any other species. When the toe is extended straight back from the body the spur is not visible.

Internal organs.—The few specimens at my command did not permit a study of the trophi. Otherwise the internal organs seem to offer nothing worthy of special mention.

Measurements.—Length of adult without toe, 0.3 mm.; length of toe, 0.14 mm.; total, 0.44 mm.

History.—*Rattulus macerus* was described by Gosse (1889) from a single, partly disorganized specimen. He did not notice the anterior tooth on the lorica (which is very inconspicuous), and he describes and figures the lorica as thicker in its posterior part. But in his specimen the head and part of the internal organs had flowed out in a disorganized mass, leaving the anterior part of the lorica collapsed, so that it is natural that the posterior half should have been a little thicker than the anterior. Otherwise his description agrees well with the specimens I have found.

Levander (1894) described this animal as *Mastigocerca fusiformis* n. sp., and gave a very characteristic outline figure. His figure shows the spur at the base of the toe, but he did not notice the inconspicuous tooth at the right anterior margin of the lorica (his figure shows a view from the left side, where this would not be seen). It seems to me that there is not sufficient difference between the accounts of Gosse and Levander to justify considering them as describing different species. Gosse's description is a little less full than Levander's, though both give only brief general descriptions—neither of them mentioning (for example) the tooth or the very characteristic spur (though Levander shows the latter in his figure).

Scorikow (1896) describes this species without a figure. He considered *R. macerus* Gosse and *R. fusiformis* Levander to be the same, but incorrectly included *R. gracilis* Tessin as a synonym.

Distribution.—I found four specimens of this species in material taken from the marshy part of Lake Erie about "The Cottages," on Long Point, Canada. Gosse (1889) met with it in water from Woolston Pond, Hants, England; Levander (1894) in ponds and pools in Finland; Stenroos (1898) in Lake Nurmijärvi in Finland; Scorikow (1896) in a swamp near Kharkow in Russia.

21. Rattulus multicrinis Kellicott (pl. VI, figs. 55–58).

Synonym: *Mastigocerca multicrinis* Kellicott (1897).

Distinguishing characters.—This species is distinguished at once from all others by its broad, regularly ovate form. From *Rattulus latus* Jennings, the only species which resembles it at all in general appearance, it is markedly distinguished by the symmetrical form of the posterior part of the lorica. (Compare fig. 57 of *R. multicrinis* with fig. 65 of *R. latus.*)

External features.—The lorica is broadly ovate in dorsal or ventral view, widest in the middle region, narrowing a little in front to the capacious head-sheath and tapering rapidly and regularly behind to the foot. The form is remarkable for the almost complete lack of the asymmetry which is so striking in most of the *Rattulidæ.*

In side view (fig. 56) the lorica swells out strongly on both the dorsal and ventral sides.

There is in this species nothing comparable to the usual ridge or striated area.

The anterior part of the lorica or head-sheath is not sharply separated from the rest of the lorica, though there is a wide, shallow constriction in its base. The head-sheath is marked by numerous longitudinal folds and the anterior edge is crenate, each fold projecting a little as a rounded point. In the dorsal middle line there is a large, prominent triangular point projecting considerably beyond the rest of the lorica. When the head is retracted (fig. 58) the head-sheath becomes folded and the anterior opening nearly closed. The anterior part of the lorica then has a striking resemblance to the same portion in *Rattulus capucinus* Wierz. & Zach. (pl. VI, fig. 59) and *R. cylindricus* Imhof (pl. VII, fig. 62), indicating that *R. multicrinis* is closely related to these.

Corona.—This species shows the more complicated type of rattulid corona with especial clearness (figs. 56, 57). The following parts may be distinguished: (1) Two large half circles of

cilia about the dorsal and lateral margins of the corona (*a*). (2) Two smaller arcs of cilia, one on each side of the mastax (*b*). When the mastax is protruded far out, it appears that these two arcs are actually borne on the tip of the mastax itself (fig. 48, *b*). (3) A long, blunt central process (*e*) borne on the dorsal margin of the corona. (4) A short, pointed central process (*c*) just below the last. (5) On each side of the last named two straight, slender processes (*d*), the inner one in each pair being pointed, the outer one blunt. All these processes were well described by Kellicott (1897). The corona resembles considerably that of *Rattulus latus* Jennings, and is still more like that of *R. capucinus* Wierz. & Zach., as described by Wierzejski & Zacharias (1893).

Antennæ.—The dorsal antenna is nearly or quite in the middle line, just in front of the line separating the head-sheath from the remainder of the body (fig. 55). The lateral antennæ are situated one on each side, about half way back from the middle of the body (fig. 55, *l. a.*).

Foot.—The foot forms a short cone, tapering rapidly to the toes.

Toes.—The main (left) toe is not quite so long as the lorica, and is nearly straight. The right toe is rudimentary, forming a short spine which lies obliquely across the base of the left or main toe. Between this and the main toe is a minute substyle, and there is a similar one at the left of the base of the main toe.

Internal organs.—The eye is attached to the large brain some distance in front of its posterior end. The trophi (fig. 57) are stout and almost symmetrical, a condition found in only a few of the *Rattulidæ*, but occurring in *R. capucinus* Wierz. & Zach., evidently the nearest relative of *R. multicrinis* Kellicott. The mastax can be protruded far out from the lorica, as shown in fig. 56. The remainder of the internal structure calls for no special remark beyond the statement that this species furnishes an excellent opportunity for a study of the characteristic internal organs of the *Rattulidæ*, these being particularly well displayed in the broad body of this animal.

Measurements.—Length of body, 0.18 to 0.20 mm.; of toe, 0.09 to 0.10 mm.; total, 0.27 to 0.30 mm.

History.—This species was described by Kellicott in 1897, from Sandusky Bay, Lake Erie. It has not been reported by anyone else until the present time.

Distribution.—*Rattulus multicrinis* Kellicott has thus far not been found elsewhere than in Lake Erie. I found it in East Harbor, Lake Erie; Kellicott (1897) in Sandusky Bay, Lake Erie.

22. Rattulus cylindricus Imhof (pl. VII, fig. 62–64).

Synonyms: *Mastigocerca cylindrica* Imhof (1891); *Mastigocerca setifera* Lauterborn (1893); *Mastigocerca hamata* Zacharias (1897); *Mastigocerca hamata*, var. *bologoensis* Minkiewicz (1900).

Distinguishing characters.—This species is to be distinguished by the median anterior curved hook which hangs down over the anterior opening of the lorica (not always visible); by the longitudinal folds of the head-sheath when the head is retracted; by the very long, prominent dorsal antenna (not always visible); by the nearly cylindrical body, usually highest a little in front of the foot; by the long toe, nearly or quite equaling, or sometimes exceeding, the length of the body, and by the habit of carrying the egg attached to the posterior end of the lorica.

External features.—The body is nearly cylindrical in form, but in many specimens it rises gradually toward the posterior end, its highest point lying just in front of the foot (fig. 62). Here the body falls off steeply to the foot (figs. 62 and 63). In some specimens, however, the body tapers gently backward to the foot (fig. 64). It was from such specimens, only still more slender than fig. 64, that Zacharias's species *Mastigocerca hamata* was described. The dorsal line shows in side view a characteristic slight depression just behind the dorsal antenna, rising again back of this region. The ventral line is very nearly straight.

The head-sheath is not sharply set off from the rest of the lorica, though there is usually a gentle, shallow constriction where the lorica passes onto the head. The head-sheath has longitudinal folds similar to those found in *Rattulus multicrinis* Kellicott and *R. capucinus* Wierz. & Zach. By means of these folds the anterior opening of the lorica can be quite closed (fig. 62). The median dorsal part of the anterior edge projects as a triangular point (as in the two species just mentioned), but in *R. cylindricus* Imhof the tip of this point is prolonged to form a hook, which bends downward over the anterior opening of the lorica (fig. 62, 64). This hook is thickened just distad of the place where it joins the lorica. *R. cylindricus* Imhof is distinguished by this hook from all other species of *Rattulidæ*. It is important to note, however, that when the head is fully

extended this hook is frequently not visible; it seems to be either turned back or hidden by the cilia. Such a case is shown in fig. 63. This fact, if not carefully noted, is likely to lead to incorrect determinations of specimens not showing the hook. There is a slight furrow passing back from the base of the hook in the dorsal median line for about one-third the length of the lorica, and this furrow is marked with faint cross-striations. We have in this species, therefore, a slightly marked "striated area," which seems to be quite lacking in its nearest relatives, *R. multicrinis* Kellicott and *R. capucinus* Wierz. & Zach.

Corona.—The corona has not been studied thoroughly. The preserved specimens at my disposal did not permit of such study. There are two slender, lateral, antenna-like appendages, however, as seen in fig. 63.

Antennæ.—The dorsal antenna is long and usually very prominent, as shown in figs. 62 and 63. In other cases it is merely a bundle of short, hair-like processes (fig. 64), while in still other preserved specimens I have not been able to see it at all. In these cases the antenna may have been injured.

Lauterborn (1893) described this species as new under the name *Mastigocerca setifera*, merely because Imhof (1891) did not mention the dorsal antenna in his original description. Lauterborn held that owing to the prominence of the dorsal antenna it could not have been overlooked if Imhof had really had this species before him. This is negatived by the fact, just stated, that specimens are often met with in which the antenna is inconspicuous or invisible. Minkiewicz (1900) described this same species anew—again without mention of the dorsal antenna—though specimens of his species, received through his courtesy, show the prominent antenna clearly. It is thus evident that because the antenna is not mentioned in a description one can not conclude that it is nonexistent nor even that it is inconspicuous. The name *Mastigocerca setifera* has therefore no foundation and must be considered a synonym of *R. cylindricus* Imhof.[a]

The lateral antennæ, as Bilfinger (1894) has shown, are strikingly unsymmetrical in position. The left is on the flank, at about the middle of the length of the lorica (fig. 63), while the right is far back, almost exactly at the junction between the lorica and foot.

Foot.—The foot is very small, and not clearly marked off from the rest of the body.

Toes.—In this species the disproportion between the right and left toes has reached its maximum. The right is a mere, minute, scale-like bristle, hardly noticeable, while the left (forming the "toe proper") is a long, straight rod, almost or quite as long as the entire body of the animal. There is a small substyle on the outer side of the main toe, nearly as long as the rudimentary right toe (fig. 64). The latter lies, as usual, across the base of the main toe.

Internal organs.—The eye is situated at about the middle, or a little behind the middle, of the long brain (fig. 64). The trophi have not been thoroughly studied. The specimens which I have had at hand have not shown these clearly. According to Bilfinger (1894), they are nearly symmetrical. The ovary (fig. 64, *ov.*) may be seen to be connected behind with the cloaca. The egg is carried in this species attached to the posterior part of the lorica, above the foot (fig. 62). No other species of the *Rattulidæ* is known which thus carries the egg with it. The other internal organs call for no special remark.

Measurements.—Length of body, 0.26 mm. to 0.31 mm.; of toe, 0.23 mm. to 0.32 mm.; total, 0.49 mm. to 0.63 mm.

History.—This species was described briefly, without a figure, by Imhof (1891). In 1893 Lauterborn redescribed it, at first identifying it with Imhof's species, but in a postscript to his paper giving it a new name (*Mastigocerca setifera*), because Imhof had failed to mention the prominent dorsal antenna. (See the account of the dorsal antenna above.) The first figure of this species was given by Bilfinger (1894), together with a good description. Zacharias (1897) redescribed the animal under the name *Mastigocerca hamata.* The specimen figured by Zacharias shows a more slender form than any of the other figures given, and the body slopes even more gradually to the foot than in my fig. 64. But as these points are clearly very variable (compare fig. 62 and fig. 64), and Zacharias's specimens agreed in other points with this strikingly characterized form, especially in the hook and the very long toe, it seems beyond doubt that his species is the same as *R.*

[a] If this were not done, we should be forced to the absurdity of identifying as *R. cylindricus* those specimens in which for any reason we could not see the antenna, while others would receive the name *R. setifer.*

cylindricus Imhof. Finally, Minkiewicz (1900) redescribed and figured this species under the name *Mastigocerca hamata* var. *bologoensis*.

Distribution.—I have found this species in East Harbor, Lake Erie, near Sandusky, Ohio. Specimens were also sent me by Prof. E. A. Birge from inland lakes in Wisconsin.

In Europe this species has been recorded as follows: Bayous of the Rhine (Lauterborn, 1893); Württemberg, Germany (Bilfinger, 1894); Lake Bologoe in Russia (Minkiewicz, 1900); a pond in Germany (Zacharias, 1897).

23. Rattulus capucinus Wierzejski & Zacharias (pl. VI, figs. 59–61).

Synonyms: *Mastigocerca capucina* Wierzejski & Zacharias (1893); *Mastigocerca hudsoni* Lauterborn (1893).

Distinguishing characters.—This species is at once distinguished from its nearest relative, *R. multicrinis* Kellicott, by the elongated, cylindrical form of the body. From all other known species it is distinguished by the large triangular projection of the lorica above the head, a character which it shares with *R. multicrinis* Kellicott alone.

External features.—The body is an elongated cylinder, somewhat curved toward the ventral side, as shown in fig. 60. There appears to be considerable variation in the proportions of the body. Those studied by the author (from Germany, obtained through the kindness of Mr. C. F. Rousselet) were of the proportions shown in figs. 60 and 61; but the figures of Wierzejski & Zacharias (1893) show a much shorter animal, while the figure of Lauterborn (1893) is still shorter, and the ventral surface forms almost a straight line. The specimens which I have examined agree more nearly in their proportions with those found by Levander (1894) and Stenroos (1898) in Finland. The lorica seems to have nothing which can be compared with the ridge or the striated area in most *Rattulidæ*.

The head-sheath is set off by a marked constriction from the remainder of the lorica. There are many longitudinal seams at which the sheath folds when the head is retracted (fig. 59). Between these seams the parts of the head-sheath project at the anterior margin, so that the edge is crenate. The dorsal part of the head-sheath runs out to a strong triangular point, projecting far over the ventral edge of the lorica. This gives the retracted head the appearance of a capucin cap, whence the specific name. The whole structure is almost identical with that of *R. multicrinis* Kellicott.

Corona.—The corona, according to Wierzejski & Zacharias (1893), is very similar to that described above for *R. multicrinis* Kellicott. There are two central antenna-like processes, the more dorsal one being longer, and two lateral processes on each side. There are likewise two dorsolateral semicircular wreaths of cilia. These are shown in fig. 61.

Antennæ.—The dorsal antenna has not been observed in this animal. The lateral antennæ are in the usual position on the flanks, about half way back from the middle of the body (fig. 60).

Foot.—The foot is a short, conical structure. It is overhung on its dorsal surface by a roof-like backward projection of the lorica (fig. 60).

Toes.—The main (left) toe is a nearly straight rod about half the length of the body. The rudimentary right toe is one-fourth to one-third the length of the main toe, and lies across the proximal part of the latter. A small, scale-like substyle lies against the side of the main toe.

Internal organs.—These call for no special remark, save in the case of the trophi. These, according to Wierzejski & Zacharias (1893), are not unsymmetrical.

Measurements.—Length of body, 0.30 mm.; of toes, 0.125 mm.; total, 0.425 mm.

History.—This species was described in 1893 by Wierzejski & Zacharias, under the name *Mastigocerca capucina*. In the same year Wierzejski (1893) gave a description (in Polish) and repeated the figures given by Wierzejski & Zacharias (1893), while Zacharias (1893) also gave a brief description and a new figure. In the same year Lauterborn (1893) described this animal as *Mastigocerca hudsoni*. A figure and brief description were given by Levander in 1894, and notes by Stenroos (1898).

Distribution.—In America: Lake St. Clair and West Twin Lake, near Charlevoix, Mich.

In Europe: Gr. Plöner See, in Germany (Zacharias, 1893); bayous of the Rhine (Lauterborn, 1893); Württemberg, Germany (Bilfinger, 1894); Galicia, Austro-Hungary (Wierzejski, 1893): Lake Nurmijärvi in Finland (Stenroos, 1898); Lohijärvi-See in Finland (Levander, 1894); River Oudy near Kharkow, Russia (Scorikow, 1896); Lake Bologoe in Russia (Minkiewicz, 1900).

24. Rattulus longiseta Schrank (pl. VIII, figs. 67–72).

Synonyms: *Brachionus rattus* Schrank (1793); *Vaginaria longiseta* Schrank (1802); *Monocerca bicornis* Ehrenberg (1830, 1838); *Monocerca cornuta* Eyferth (1878); *Acanthodactylus bicornis* Tessin (1886); *Mastigocerca bicornis* Hudson & Gosse (1889).

Distinguishing characters.—The characteristic features of this animal are the two long spines at the anterior dorsal edge of the lorica. Of these the right is much longer than the left. The only species which at all resembles this is *Rattulus roseus* Stenroos, which is said to have the spines at the ventral anterior margin instead of the dorsal (but see the account of that species, p. 341).

External features.—The body is usually fusiform in shape; when well extended it is elongated, widest at about the middle or a little in front of the middle, and tapering thence regularly backward to the foot. But the form of the lorica varies greatly with the degree of extension of the animal, as well as with the age of the individual. Young specimens are often broadest near the anterior end (especially when the head is retracted, fig. 68), and the body is slender and tapers rapidly to the foot. The lorica is flexible and permits great changes of form in one and the same individual. When strongly retracted the animal is shorter and thicker, and the body becomes almost oval in form (fig. 70). The anterior portion of the lorica or head-sheath is not distinctly marked off from the rest in this species, though a notch at the point of separation can usually be detected on the ventral side when the animal is retracted (fig. 70).

The lorica is marked on the dorsal surface a little to the right of the middle line by a shallow longitudinal furrow, passing backward from the anterior end to about the middle of the length of the body (fig. 67). The direction of the furrow is slightly oblique, its anterior end lying a trifle farther to the right than its posterior end. The furrow is marked by transverse striations, really muscle fibers, attached within the two ridges which form the boundaries of the furrow. These two bounding ridges project at the anterior margin of the lorica as two long spines, forming the most characteristic feature of this animal. The right one of the two spines is the longer, usually twice as long or more than twice as long as the left. (Weber, 1898, figures the left spine as the longer, and Gosse, 1855, states that the left spine is the longer in this species. It is, of course, possible that there is variation in this matter, but I examined a large number of preserved specimens with this matter in mind, and found that in all cases the right spine was longer.)

The head-sheath has longitudinal plaits or flutings, where folding takes place when the head is retracted. The anterior margin of the lorica differs exceedingly in the contracted and expanded conditions. In a fully extended living individual (fig. 67), the anterior part of the lorica is wide open, and the margin shows, in addition to the two long dorsal teeth, four or more minute points, lateral and ventral. There is usually no trace of the longitudinal folds so prominent in the retracted individual. In retracted specimens (figs. 68, 70), on the other hand, the anterior opening is much smaller, and many ridges and grooves are visible, owing to the folding of the lorica. Each of the longitudinal ridges runs out to form a small point or tooth, so that the anterior margin seems to bear many teeth.

Corona.—The corona bears a large dorsal frontal process; otherwise it has not been thoroughly studied.

Antennæ.—The dorsal antenna lies within the striated furrow, a short distance from the anterior end (fig. 67). The two lateral antennæ are in the usual position, one on each side, about one-fourth the body length in front of the foot. In specimens where an exact comparison between the two was possible, the left antenna was situated a little anterior to the right.

Foot.—The foot is a short, conical structure, attached to the body only slightly obliquely, so that its movement is not so nearly limited to a turning to the right as we find it to be in many of the *Rattulidæ*.

Toes.—The right toe (fig. 69, *r. t.*) has nearly disappeared, so that it is customary to speak of the left one as *the* toe, while the right is classed merely with the substyles. The main toe is usually about two-thirds the length of the body. The substyles are small scales, one of which lies on each side of the main toe and the rudimentary right toe. The latter lies a little above the main toe, with its tip against it.

Internal organs.—The eye is attached to the brain, and in a dorsal view lies usually considerably to the left of the dorsal furrow on the lorica. The trophi (figs. 71 and 72) are unsymmetrical, the right malleus being much more slender than the left. (For a full description of the trophi in this species see the general account of the trophi, p. 289.)

Measurements.—Length of body without toe or anterior spines, 0.30 mm.; length of toe, 0.20 mm.; length of longest anterior spine, 0.06 mm.; total, 0.56 mm.

History.—This is one of the best known of the *Rattulidæ* and has, ever since the time of Ehrenberg, gone under the specific name *bicornis*, though Ehrenberg admitted that Schrank's name *longiseta* was the first one given.

The animal was first described by Schrank in 1793. He confounded it at that time with *Rattulus rattus*, and gave it, therefore, the name *Brachionus rattus*. In 1802 Schrank recognized the distinction between this and *Rattulus rattus*, and gave the present animal the specific name *longiseta*, placing it, along with a heterogeneous group of organisms, in the genus *Vaginaria*. The specific name *longiseta* must, according to the rules of priority, be used for this animal in place of Ehrenberg's name *bicornis*. Ehrenberg (1830) recognized this animal as Schrank's species, but changed the name to *bicornis*, because he thought this name more appropriate than *longiseta*. This proceeding is, of course, not a justifiable one according to the rules of nomenclature.

The only synonym which has been added for the specific name since the time of Ehrenberg is the *Monocerca cornuta* of Eyferth (1878). There can be no question, it seems to me, that this is the same species as *Rattulus longiseta* (*Monocerca bicornis*). Eyferth himself seemed of that opinion, saying that even if this is the same species as Ehrenberg's *bicornis*, the name must be changed to *cornuta*, and giving the new name *cornuta* with a mark of interrogation. The new name was based upon the number of teeth at the anterior edge of the lorica, but Eyferth's account (1885) of these agrees very closely with what may be observed in *Rattulus longiseta*, save that he considered one of the two long spines to be an antenna, an error similar to that which he made in the case of *Diurella stylata* (q. v.).

Eyferth says that in *Monocerca cornuta* there is a dorsal ridge, ending in a spine, and that at the sides and on the "chin" at the anterior edge there are two pairs of smaller points, statements which are true for *R. longiseta*, as shown in fig. 67. He did not recognize the doubleness of the ridge nor of the spine, errors of a character which were frequently made at that time and which occur repeatedly in Eyferth's account of the *Rattulidæ*. Hudson & Gosse (1889, Supplement, p. 35) have made quite unnecessary difficulties for the recognition of *Monocerca cornuta* Eyferth as *Rattulus longiseta* (*Monocerca bicornis* Ehrenberg) by altering and adding to Eyferth's description, though their account is supposedly taken from that of Eyferth. They say that the two lateral teeth are half the length of the dorsal spine, though Eyferth makes no such statement. In Eyferth's figure the exact position of the real anterior edge of the lorica is not discernible, so that the relative length of the spines can not be judged from this. Hudson & Gosse add "no substyles," though Eyferth states exactly the contrary. A comparison of fig. 68 of the present paper with Eyferth's fig. 24, Taf. VII (1885), will show at once how such a figure as that of Eyferth could be made from the present species.

The following figures or descriptions of this animal have been given (doubtless the list could be increased): Schrank (1793, 1802, 1803); Ehrenberg (1830, 1838); Dujardin (1841); Perty (1852); Leydig (1854); Pritchard (1861); Bartsch (1870, 1877); Eyferth (1878, 1885); Blochmann (1886); Tessin (1886); Hudson & Gosse (1889); Bilfinger (1892); Bergendal (1892); Glasscott (1893); Wierzejski (1893); Eckstein (1895); Scorikow (1896); Stenroos (1898); Weber (1898); Jennings (1900, 1901).

Distribution.—In America: *Rattulus longiseta* Schrank is common amid plants in lakes and streams, though it rarely occurs in large numbers. I have recorded its presence in the following places: Put-in Bay Harbor and East Harbor, Lake Erie; marsh on the shores of Lake Erie at "The Cottages," Long Point, Canada; Huron River at Ann Arbor, Mich.; Lake St. Clair; Chippewa Lake, Mecosta County, Mich.; Round Lake and Pine Lake at Charlevoix, Mich; pools at Hanover, N. H. Other observers have recorded it as follows: Pond near Bangor, Me. (J. C. S., 1883); waters connected with the Illinois River at Havana, Ill. (Hempel, 1898).

In Europe (only typical localities given): Germany (Ehrenberg, 1838, and many other authors); England (Gosse, 1889); Ireland (Glasscott, 1893); Hungary (Bartsch, 1877); Greenland (Bergendal, 1892); Bohemia (Petr, 1890); Russia (Scorikow, 1896); Finland (Levander, 1894); Tyrol (Dalla Torre, 1889); Austrian Poland (Wierzejski, 1893); Switzerland (Weber, 1898); Roumania (Cosmovici, 1892).

25. Rattulus bicristatus Gosse (pl. IX, figs. 77–80).

Synonym: *Mastigocerca bicristata* Gosse (1889).

Distinguishing characters.—This very large species is distinguished from all others by the two high dorsal ridges passing from the anterior end backward for about three-fourths the length of the lorica. From *Rattulus mucosus* Stokes, the only other species which has two prominent ridges, it is distinguished by the greater height and length of the ridges; these in the last-named species extend only about one-half the length of the lorica, or less, and they are much lower than in *R. bicristatus*. The two species differ in many other respects also.

External features.—The body in side view (fig. 77) is oblong, two to three times as long as wide, the dorsal line forming a nearly regular arch from head to foot, the ventral line less convex and notched at the junction of the head-sheath with the rest of the lorica. The body is not so thick from side to side as it is dorso-ventrally, a dorsal view (fig. 78) showing an oblong form, the length about three times the width.

The whole appearance of the animal is dominated by the two great longitudinal ridges. These begin at the anterior end, some distance apart, and extend backward and a little to the left, ending about one-third the length of the body from the beginning of the foot. The ridges are high, thin at the edges, and grow thicker toward their bases. They inclose between them a wide V-shaped trough (fig. 78).

Within the ridges are broad, well-defined bands of muscle fibers, passing from the upper part of each ridge to the floor of the furrow between them. These bands evidently correspond to the transverse striations occurring in other species; the fibers are not usually grouped into distinct bands, as they are in *R. bicristatus*.

The head-sheath is marked off from remainder of lorica merely by a slight constriction, largely confined to ventral side. The ridges continue on head-sheath to anterior margin. There is a slight notch between the ends of the two ridges (fig. 78), and a very slight one on the ventral side.

Corona.—The corona is of the usual character. It bears two slender lateral processes (fig. 77); a medial dorsal process has not been observed.

Antennæ.—The dorsal antenna is situated at the bottom of the groove midway between the two ridges (fig. 78). In the retracted specimen the eye appears just in front of it. The lateral antennæ (fig. 78) are in the usual position, a short distance in front of the base of the foot.

Foot.—The foot is rather large, conical, and so attached to the lorica that it can bend to the right and ventrally, but not to the left nor dorsally.

Toes.—There is a single, very long, curved toe, accompanied by numerous substyles (fig. 79). One of these substyles is longer than the others and may represent the rudimentary (right?) toe. But the primitive arrangement seems entirely lost, so that it is not possible to demonstrate this or to show certainly which of the two original toes is represented by the main one. The length of the main toe is in young individuals equal to or greater than that of the body; in larger specimens the toe is somewhat shorter than the body. As many as eight substyles can be counted, in favorable specimens, at the base of the main toe; possibly the number is still greater. They are much more prominent than in most species, some of them standing at a considerable distance from the base of the toe (fig. 79).

Internal organs.—The eye is situated sometimes at the middle of the brain, sometimes at its posterior end. It lies beneath the groove between the two ridges. The trophi are very large and strong, and bear many teeth. The left side is less developed than the right (fig. 80).

Rattulus bicristatus Gosse, owing to its great size, is unusually favorable for a study of the viscera, but there are no special features to add to the description given in the general account of the anatomy of the *Rattulidæ* (p. 288).

Measurements.—Length of body, 0.25 to 0.30 mm.; of toes, 0.24 to 0.25 mm.; total, 0.49 to 0.55 mm. Greatest height of body, 0.10 to 0.14 mm.

This species was described by Gosse (1889) in the supplement to Hudson & Gosse's Monograph of the Rotifera. Figures or descriptions of it are also given by Glasscott (1893, poor), Stenroos (1898), and Jennings (1900 and 1901).

Distribution.—In America: This species is not uncommon amid the vegetation of rivers, lakes, and ponds. I have found it in the following localities: Put-in Bay Harbor and East Harbor, Lake

Erie; West Twin Lake near Charlevoix, Mich.; Huron River at Ann Arbor, Mich. Hempel (1898) records it from waters connected with the Illinois River at Havana, Ill.

In Europe: Dundee, Scotland (Gosse, 1889); Ireland (Glasscott, 1893; Hood, 1895); Württemberg, Germany (Bilfinger, 1894); Basel, Switzerland (Ternetz, 1892); Lake Nurmijärvi in Finland (Stenroos, 1898); Galicia, Austro-Hungary (Wierzejski, 1893).

26. Rattulus mucosus Stokes (pl. x, figs. 86–91).

Synonyms: *Mastigocerca mucosa* Stokes (1896); *Mastigocerca rectocaudatus* Hilgendorf (1898)?

Distinguishing characters.—This species shares with *Rattulus bicristatus* Gosse the peculiarity of having two well-marked dorsal ridges with a furrow between them. But in *R. mucosus* Stokes the ridges are lower and extend back only to about the middle of the length of the lorica; the entire animal is considerably smaller and of a different form and there are many other points of difference. *Rattulus mucosus* bears much resemblance in general form to *R. rattus* Müller, *R. carinatus* Lamarck, and *R. lophoessus* Gosse, but the presence of the two ridges distinguishes it at once from these.

External features.—In side view (fig. 87) the body of an adult specimen is broadly oblong, the length being little more than twice the depth. The head-sheath is marked off from the remainder of the lorica by a slight constriction, most marked on the ventral side. The anterior margin is without teeth or spines. On the ventral side there is, when the head is retracted, a deep, narrow, longitudinal fold, which looks like a gap (fig. 89), and on the dorsal side there is a slight notch between the two ridges.

The two ridges extend from the anterior edge backward and a little to the left to a point a little behind the middle of the lorica (fig. 86). They are not so high as in *R. bicristatus* Gosse, and the furrow between them is not so wide. For this reason the two ridges may appear in side view as but a single one (figs. 87, 88), one completely hiding the other, or they may be entirely overlooked. They are marked with transverse striations, similar to those of *R. bicristatus* Gosse.

In young specimens (fig. 90) the body is narrower behind than in adults and the toe is longer in proportion to the length of the body.

Corona.—The corona bears the usual wreaths of cilia about its outer margin, two small arcs at the sides of the mouth, and three antenna-like processes. One of these is dorsal and club-shaped; the other two are very slender lateral rods.

Antennæ.—The dorsal antenna is situated, not within the groove between the ridges, as in *R. bicristatus* Gosse, but to the left of the left ridge. It projects from a rounded depression on the left side of this ridge. (This depression, though not the antenna, is indicated in fig. 86.) The lateral antennæ occupy the usual position on the sides, considerably behind the middle of the lorica.

Foot.—The foot, of the usual short, conical form, is joined to the body in a more unsymmetrical manner than usual. The lorica projects far over it on the left side (fig. 86), but not on the right. Thus the foot and toe can be bent to the right side (fig. 88), but not to the left.

Toes.—There is a single, long, main toe, accompanied by three (possibly more) substyles. The rudimentary right toe is here hardly distinguishable from the substyles. The main toe is nearly straight, and is frequently carried for long periods bent up against the right side (as in fig. 88); the animal then swims about as if it had no toe. In a young specimen (fig. 90) the toe is about as long as the body; in older specimens it is shorter than the body.

Internal organs.—These offer nothing of especial interest, except in case of the trophi (fig. 91). These are very massive, but the right manubrium has almost disappeared, persisting merely as a short, slender rod. The trophi are thus more unsymmetrical than is usual in the genus *Rattulus*.

Measurements.—Length of body, 0.18 to 0.20 mm.; of toe, 0.12 to 0.15 mm.; total, 0.30 to 0.35 mm.

History.—This species was first described by Stokes, in 1896, as *Mastigocerca mucosa*. It had been observed by various investigators and referred, doubtfully, to *Rattulus bicristatus* Gosse. Thus, Jennings (1894, p. 19) and Kellicott (1897, p. 50) mention finding a species which has two ridges, but does not agree with accounts of *R. bicristatus* Gosse. In addition to the description and figure of Stokes, this species has been figured by Jennings (1900 and 1901).

Hilgendorf (1898) describes as *Mastigocerca rectocaudatus* a species which resembles the present one in many respects. Hilgendorf does not mention the two ridges, but says there is a

"median dorsal cleft" which is especially noticeable when the head is withdrawn; this may well have been the furrow between the two ridges. It would be very easy to interpret the structure as merely a furrow or cleft, the ridges being considered merely the sides of the cleft. Hilgendorf's figures are not detailed, so that it is difficult to be certain of the identity of his species; it certainly resembles the present one, and his account hardly justifies the founding of a new species.

Distribution.—This species is one of the most abundant of the Rotatoria amid the vegetation of the shallower parts of the lakes. I have found it in the following places: Lake St. Clair; Chippewa Lake, Mecosta County, Mich.; Crooked Lake, Newaygo County, Mich.; Round Lake at Charlevoix, Mich.; pond at Hanover, N. H.; Huron River at Ann Arbor, Mich., and at the following stations on Lake Erie: Put-in Bay Harbor, East Harbor, Long Point (Canada, near "The Cottages").

Stokes (1896) found this animal in a pond near Trenton, N. J.; Kellicott (1897, under the name *Mastigocerca bicristata*) in Sandusky Bay, Lake Erie.

New Zealand (?), Hilgendorf (1898) as *Mastigocerca rectocaudatus*.

This species has not yet been recognized in Europe.

27. Rattulus carinatus Lamarck (pl. XI, figs. 95–97).

Synonyms: *Trichoda rattus vesiculam gerens* Müller (1786); *Rattulus carinatus* Lamarck (1816); *Trichocerca rattus* Goldfuss (1820); *Monocerca longicauda* Bory de St. Vincent (1824); *Mastigocerca carinata* Ehrenberg (1830, 1838), and most subsequent authors; *Monocerca carinata* Eyferth (1885); *Acanthodactylus carinatus* Tessin (1886).

Distinguishing characters.—This species is at once known by the high, thin keel or ridge extending somewhat more than half the length of the lorica. It differs from *R. lophoessus* Gosse in the fact that the ridge does not reach the entire length of the lorica. There are also differences in the toes and in other features.

External features.—The body is a long oval, widest near the middle and tapering toward both ends. The dorso-ventral and lateral diameters are nearly the same (compare figs. 95 and 97). The part of the lorica enveloping the head is marked off from the remainder by two slight constrictions. The anterior edge of the lorica is quite unarmed, and forms a gentle curve, bounding the anterior opening, without teeth, angles, or notch. In the ventral region the curve forms a slight shallow concavity (fig. 97); at this point the lorica can be folded inward when the head is strongly retracted, forming what appears to be a deep, narrow gap.

The most striking feature of this organism is the very high, narrow ridge. This begins at the anterior end, considerably to the right of the median line, and extends obliquely backward and to the left (fig. 95), stopping a little behind the middle of the body. The ridge is inclined strongly to the right and is marked with transverse striations. These striations appear to be muscle fibers passing from the top of the ridge (at its right edge) to the left and downward. When the ridge is seen from the side the ends of the fiber bundles show the arrangement given in fig. 97. The striations extend on the surface of the lorica some distance to the left of the ridge (fig. 95).

Corona.—The corona has the usual two arcs of cilia about its dorso-lateral margin and two at sides of mouth. There is a short, thick median dorsal process and two slender lateral ones (fig. 97).

Antennæ.—The dorsal antenna lies on the left side of the ridge, just behind the head-sheath (fig. 95). The lateral antennæ are in the usual position on the posterior part of the body, the right one considerably in advance of the left (fig. 95).

Foot.—The foot is of the usual short, conical form. The lorica projects over it dorsally much farther on the left side than on the right (fig. 95), so that the foot may be bent to the right or down, but not to the left nor up.

Toes (fig. 96).—The single main toe (*l. t.*), representing the left toe of the genus *Diurella*, is an almost straight rod of nearly or quite the length of the lorica. It is accompanied at its base by a number of short scales and spines, one of which, curved so that the tip lies against the main toe, seems (by comparison with a number of other species) to represent the right toe (fig. 96, *r. t.*). This is in the present species shorter than one of the substyles proper.

Internal organs.—The internal organs offer nothing of especial interest except the trophi. These are decidedly unsymmetrical, the right malleus being considerably smaller than the left. The trophi are essentially like those of *Rattulus longiseta* Schrank (pl. VIII, fig. 72), but with the right malleus perhaps a little smaller.

Measurements.—Length of body, 0.16 to 0.17 mm.; of toe, 0.14 to 0.15 mm.; total, 0.30 to 0.32 mm.

History.—*Rattulus carinatus* Lamarck seems to have been the second species of the *Rattulidæ* that was described. Müller (1786) considered it a variety of *Rattulus rattus* Müller, and described it under the name of *Trichoda rattus vesiculam gerens.* He thought that the ridge was an egg sac; hence, the above name. Lamarck (1816) founded the genus *Rattulus* for this species and *R. rattus*, considering them as one species—a view which is, perhaps, not fully disproved yet. To this species he gave the name *Rattulus carinatus*, thus evidently basing his description on the characteristics of the species having the ridge. The name *carinatus* has therefore been properly used ever since for this species. The animal has been repeatedly transferred from one genus to another (see synonymy), the name *Rattulus* becoming completely supplanted by Ehrenberg's name *Mastigocerca.* According to the recognized rules of nomenclature this species must be restored to the first genus (*Rattulus*) which was founded to contain it.

Distribution.—In America *Rattulus carinatus* Lamarck occurs widely distributed in ponds, lakes, swamps, and rivers, but is usually taken in small numbers. I have found it as follows: Put-in Bay Harbor and East Harbor, Lake Erie; swamps on North, Middle, and South Bass islands, in Lake Erie; Huron River at Ann Arbor, Mich.; Portage River, Ohio; Lake St. Clair, Lake Michigan, Round Lake, and Pine Lake, near Charlevoix, Mich.; pools at Hanover, N. H.; ditch 5 miles south of Ann Arbor, Mich.; and in the following inland lakes of Michigan: West Twin Lake, Muskegon County; Crooked Lake, Newaygo County, and Chippewa Lake, Mecosta County.

By other observers it has been recorded as follows: Pond near Bangor, Me. (J. C. S., 1883); Shiawassee River at Corunna, Mich. (Kellicott, 1888); Sandusky Bay, Lake Erie (Kellicott, 1896); waters connected with the Illinois River at Havana, Ill. (Hempel 1898).

In Europe: Common in England (Gosse, 1889); Ireland (Hood, 1895); Württemberg, Germany (Bilfinger, 1892); Gr. Plöner See (Zacharias, 1893); near Rostock, Germany (Tessin, 1886); near Basel, Switzerland (Ternetz, 1892); near Geneva, Switzerland (Weber, 1898); Tyrol (Dalla Torre, 1889); Finland (Levander, 1894, and Stenroos, 1898); Galicia, Austro-Hungary (Wierzejski, 1893); Hungary (Kertesz, 1894; Daday, 1897); Bohemia (Petr, 1890); Livland, Russia (Eichwald, 1847); Kharkow, Russia (Scorikow, 1896). (Many other authors have listed this animal.)

Also at Sandringham, Australia (Anderson and Shepherd, 1892); in Ceylon (Daday, 1898); in New Guinea (Daday, 1901).

28. Rattulus rattus Müller (pl. XI, fig. 100, 101).

Synonyms: *Trichoda rattus* Müller (1776 and 1786); *Brachionus cylindricus* Schrank (1776); *Trichoda cricetus* Schrank (1803); *Rattulus carinatus* Lamarck (1816, in part); *Trichocerca rattus* Goldfuss (1820); *Monocerca longicauda* Bory de St. Vincent (1824, in part); *Monocerca rattus* Ehrenberg (1830, 1838); *Mastigocerca rattus* Hudson & Gosse (1889).

This animal is practically identical with *Rattulus carinatus* Lamarck, save that it lacks the ridge which forms so conspicuous a feature of that species. Some observers (Müller, Lamarck, Bory, Dujardin, etc.) have held that *R. rattus* and *R. carinatus* are merely varieties or variations of the same species. It is possible that this is true; in the lack of positive evidence that one may be transformed into the other it will be more convenient to retain the separate names, however, so that they may be recorded separately when desirable.

After study of a large number of specimens of these two species from many different localities I am convinced that there is no sharp distinguishing character except the presence or absence of the ridge. Yet in general the specimens of *R. rattus* Müller which I have seen have been larger than those of *R. carinatus* Lamarck and the body not so strikingly fusiform in shape, but more equal in diameter throughout.

In place of the high ridge of *R. carinatus* the present species has a broad longitudinal area, not elevated, which is marked with transverse striations and occupies the same position as the ridge in *R. carinatus* (fig. 100). The dorsal antenna lies in a notch on the left side of this striated area; a little behind it lies the eye (fig. 100).

The foot and toes are identical with those of *R. carinatus* Lamarck.

Measurements.—Length of body, about 0.17 to 0.18 mm.; of toe, 0.13 to 0.16 mm.; total, 0.30 to 0.32 mm.

History.—This seems to have been the first of the *Rattulidæ* observed. It was discovered by Eichhorn in 1775 and was called by him the Water-Rat ("die Wasser-Ratte"). Müller in 1776 gave it the name *Trichoda rattus*. Müller, Lamarck, Bory de St. Vincent, Dujardin, and various others have considered this species to be identical with *R. carinatus* Lamarck. This view has some evidence in its favor, though it can not be considered established. If it should ever be shown conclusively that the two are only forms of the same species, the name *Rattulus rattus* would prevail over *R. carinatus* as being the older name.

Descriptions or figures of this species are to be found in Ehrenberg (1838), Perty (1852), Eyferth (1885), Tessin (1886), Plate (1886), Hudson & Gosse (1889), Levander (1894), Scorikow (1896), Stenroos (1898).

Distribution.—In America this species is very common amid vegetation in quiet waters. I have found it in the following localities: Put-in Bay Harbor, Lake Erie; Long Point, Canada, near "the Cottages," on the north shore of Lake Erie; pools and swamps on South Bass Island in Lake Erie. It has been recorded by other observers in the United States as follows: New York (Ehrenberg, 1843); near Minneapolis, Minn. ("J. W.," 1883); near Cincinnati, Ohio (Turner, 1892); Sandusky Bay, Lake Erie (Kellicott, 1897).

In Europe: England (Gosse, 1889); Ireland (Glasscott, 1893; Hood, 1894); Germany (Bartsch, 1870; Plate, 1886; Tessin, 1886); Tyrol (Dalla Torre, 1889); Bohemia (Petr, 1890); Finland (Levander, 1894; Stenroos, 1898); Switzerland (Ternetz, 1892); Hungary (Toth, 1861; Bartsch, 1877; Kertesz, 1894; Daday, 1897); Livland, Russia (Eichwald, 1847); near Kharkow, Russia (Scorikow, 1896); also in Ceylon (Daday, 1898); abundant in Greenland (Bergendal, 1892).

29. Rattulus lophoessus Gosse (pl. XI, figs. 98, 99).

Synonym: *Mastigocerca lophoessa* Gosse (1889).

Distinguishing characters.—The distinctive features of this animal are the long, high ridge, reaching from the anterior end to the very foot and inclined far over to the right; the fusiform body, the unarmed anterior margin of the lorica, and the short rudimentary right toe, one-fourth the length of the main toe. It closely resembles *R. carinatus* Lamarck in many respects, but differs from it in the length of the ridge and in the toes.

External features.—The body is fusiform in shape, and somewhat more elongated than in *R. carinatus* Lamarck. The head-sheath is marked off from the remainder of the lorica by an evident constriction. The anterior edge of the lorica is without teeth or spines; it has a shallow depression in the ventral middle region (fig. 98).

The ridge is nearly as high as in *R. carinatus* and extends from the anterior edge of the lorica to the very foot. It is situated considerably to the right of the middle line and is inclined far over to the right, resembling thus the right one of the two ridges in *R. bicristatus* Gosse. It is striated, as in *R. carinatus* Lamarck, and the striations extend considerably to the left of the ridge, ending at a well-defined line (fig. 99). Gosse (1889) and Weber (1898) describe the ridge as being interrupted, so as to form two or more arches. This was not the case in the specimens which I studied nor in those described by Bilfinger (1894).

Corona.—The corona has the usual dorsal club-shaped process, according to Bilfinger (1894); it has not been studied otherwise. In the preserved specimens at my disposal the corona was partly withdrawn.

Antennæ.—The dorsal antenna is situated considerably to the left of the ridge at the edge of the striated area. The lateral antennæ I have not been able to see in the preserved specimens. The right one is figured by Bilfinger (1894) in the usual position on the posterior third of the body.

Foot.—The foot is a short cone, of the usual character. The lorica projects far back over its base on the left side (fig. 99), so that the foot is free to bend to the right, but not to the left.

Toes (fig. 98).—The left or main toe (*l. t.*, fig. 98) forms a long, nearly straight rod, about two-thirds as long as the body. Above its base, separated from it by a well-marked gap, is the right toe (*r. t.*), about one-fourth to one-third as long as the main toe. The right toe is bent toward the main toe, its tip overlying the latter. At the base of both the main toe and the smaller one are one or two scale-like substyles. The larger lobe of the mucus reservoir (*m. r.*) opens at the base of the main toe; the smaller lobe at the base of the rudimentary right toe.

Internal organs.—The eye lies on the left side of the large brain (fig. 99). The trophi could not be studied in detail in the specimens at my command. As noted above, the mucus reservoir is divided into two unequal lobes, opening at the bases of the right and left toes, respectively. The other internal organs offer nothing of especial importance.

Measurements.—Length of body, 0.23 mm.; of toe, 0.15 mm.; total, 0.38 mm.

History.—This species was described by Gosse, in Hudson & Gosse's Monograph of the Rotifera, as *Mastigocerca lophoessa*. Figures and descriptions have since been given by Bilfinger (1894) and Weber (1898).

Distribution.—*Rattulus lophoessus* Gosse has not yet been found in America. For the opportunity of studying it I am indebted to Mr. Charles Rousselet, of London, England, who sent me excellent mounted specimens of this rare species.

In Europe: England and Scotland in pools (Gosse, 1889); Ireland (Hood, 1895); Württemberg, Germany (Bilfinger, 1894); Tyrol (Dalla Torre, 1889); Switzerland (Weber, 1898); Lake Nurmijärvi in Finland (Stenroos, 1898).

30. Rattulus latus Jennings (pl. VII, figs. 65, 66).

Synonym: *Mastigocerca lata* Jennings (1894).

Distinguishing characters.—This species is at once distinguished from all others by the broad ovate lorica, coupled with the striking lack of symmetry at the posterior end. This asymmetry distinguishes it at once from *R. multicrinis* Kellicott, the only species that resembles it at all in general appearance.

External features.—The lorica is broadly ovate in dorsal or ventral view, the width being about five-eighths of the length. The dorso-ventral measurement is about two-thirds that of the width, so that the animal is dorso-ventrally somewhat depressed. When seen in side view the dorsal line is a uniform curve from the front of the head to the base of the large foot. The ventral line is a similar but less convex curve from the junction of the head-sheath with the lorica to the base of the toe, so that the two curves are not symmetrically placed. The lorica is peculiarly unsymmetrical in a dorsal or ventral view, for the posterior part of the body, bearing the foot, is a thick, truncate cone lying not in the middle line, but on the left side (fig. 66). On the right side there is a blunt projection corresponding in position to that bearing the foot, but a little smaller. Between it and the left projection is a well-defined notch.

There is no sign of a ridge or striated area in this species.

The head-sheath is scarcely marked off from the remainder of the lorica at all; only a slight angle on the ventral side marks where it begins. In front the ventral edge of the lorica ends in a broad notch, at the bottom of which is a projecting tooth (fig. 65). Dorsally the anterior edge of the lorica is a slightly uneven curve, with neither a distinct notch nor a projecting tooth (fig. 66). The form of the lorica is not changed appreciably when the head is retracted.

Corona.—The corona consists of the following parts: (1) A dorsal and lateral fringe of cilia, forming about two-thirds the circumference of the head and interrupted in the dorsal middle region; (2) at the middle of the dorsal edge a flattened non-setigerous column, truncate at the end; (3) below the last, a similar flattened process, bearing at its free end a pair of minute styles. Below and at the side of this are (4) a pair of somewhat club-shaped processes curving ventrad. At either side of the middle of the coronal disk are (5) four small papillæ, the two inner of which, at least, bear long setæ. These are partially surrounded by (6) an incomplete circle of cilia.

Antennæ.—The dorsal antenna appears as a small tube, reaching the dorsal surface of the lorica near the dorsal middle line, some distance from the anterior margin of the lorica (fig. 66, *d. a.*). The lateral antennæ are visible in a dorsal view, lying one above each of the two posterior projections of the lorica (fig. 66, *l. a.*).

Foot.—The foot is very short, scarcely distinguishable as a separate joint. It is borne by the left one of the two projections in which the lorica ends.

Toes.—The main toe (representing the left toe) is a slender, pointed rod, continuing the curve of the left side of the lorica. It is about four-fifths as long as the lorica. It is accompanied by three short, unequal substyles, the longest (representing the right toe) about one-fifth the length of the main toe, the others much shorter. The toe is united to the body in such a way that it can be turned to the right, but not to the left.

Internal organs.—The mastax is oblong, truncate at either end; its circular end appears in a ventral view in front of the broad pectoral notch of the lorica. To its sides are attached two projecting glandular bodies (fig. 65, *gl.*). The trophi are nearly or quite symmetrical. The internal organs partake in their arrangement of the peculiar asymmetry that appears in the lorica. The stomach lies to the right of the middle; its walls contain many large, spherical, light-yellowish, refractive granules. The ovary lies to the left of the stomach, not ventral to it. The lateral canals of the left side lie ventral to the ovary and present three flame cells, one at the side of the posterior end of the mastax, one at the side of the anterior end of the stomach, and one just in front of the contractile vesicle. The two halves of the mucus reservoir (fig. 65, *m. r.*) are pushed widely apart, the left one being much the larger. The brain is of the usual form; on its dorsal surface it bears the eye, formed of a large clear sphere, embedded in a deep red cup.

Measurements.—Length of body, 0.17 to 0.18 mm.; of toe, 0.12 mm.; total, 0.29 to 0.30 mm.

History.—This species was described by the present author in 1894. A description and figure are given by Stenroos (1898) and a figure by Jennings (1901).

Distribution.—In America: I have found this species in the following localities: East Harbor, Lake Erie, near Sandusky, Ohio; Lake St. Clair; West Twin Lake near Charlevoix, Mich.; Graveyard Pond on Presque Isle near Erie, Pa.; Huron River at Ann Arbor, Mich. Kellicott (1896) records this species from Sandusky Bay, Lake Erie; Hempel (1898) from waters connected with the Illinois River at Havana, Ill.

In Europe: Lake Nurmijärvi, Finland (Stenroos. 1898).

31. Rattulus bicuspes Pell (pl. VIII, figs. 73–76).

Synonyms: *Mastigocerca bicuspes* Pell (1890); *Mastigocerca spinigera* Stokes (1897).

Distinguishing characters.—This very peculiar species may be known by its short, plump body, high arched dorsally; by the unarmed anterior edge of the lorica; the very prominent lateral antennæ, protected by stout spines; and by the long toe, longer than the body.

External features.—The body is very short and thick, the ventral line nearly straight, while the dorsal line is a high arch. The highest part of the body is a little behind the middle; thence it falls off suddenly to the foot, there being in some cases even an inward curve just above the foot (fig. 73). The anterior part of the lorica, or head-sheath, is not strongly marked off from the remainder, though a slight constriction can sometimes be seen behind it (fig. 73). There are no teeth or spines at the anterior margin. Considerably to the right of the dorsal middle line is a ridge, which is fairly prominent in living individuals, but seems less noticeable in preserved specimens. It is rather broad and reaches from near the anterior edge to a point some distance behind the middle of the lorica (fig. 75). It is transversely striated (i. e., it contains transverse muscle bands).

Corona.—The corona is of the usual character, the only point deserving especial mention being the antenna-like processes. There are five of these, as in *R. latus* Jennings, *R. multicrinis* Kellicott, and *R. capucinus* Wierz. & Zach. The median dorsal process is stout and club-shaped; on each side of this, and nearer the ventral side, are two slender processes close together (fig. 75).

Antennæ.—The most peculiar feature of this species are the lateral antennæ. These are in the usual position, on the posterior part of the lorica, near the dorsal side. Each forms (or is accompanied by) a large, sharp spine, with its basal part enlarged. According to Stokes (1897), fine setæ may be seen just in front of these spines, close against them; these I have not seen.

The dorsal antenna is in the usual position, a short distance behind the anterior edge of the lorica. It lies just to the left of the striated area (fig. 75).

Foot.—The foot is a small, short structure, arising as a continuation of ventral part of body.

Toes.—There is one main toe (representing the left toe of *Diurella*); this is longer than the body and is nearly straight. The rudimentary right toe is very small and curves toward the main toe, its tip lying against the latter.

Internal organs.—This species is not a favorable one for the study of the internal organs, these being crowded together in the short, thick lorica in such a way as to make it very difficult to disentangle them. There seems in any case to be nothing calling for special remark. The trophi (fig. 76) are rather stout, and of the usual unsymmetrical form, the left side being much better developed.

Measurements.—Length of body, 0.12 mm.; of toe, 0.13 to 0.14 mm.; total, 0.25 to 0.26 mm.

History.—This species was described by Pell in 1890 as *Mastigocerca bicuspes*. Stokes redescribed it in 1897 as *Mastigocerca spinigera*. It has been figured by Jennings (1900 and 1901).

Distribution.—I have found this species as follows: East Harbor, Lake Erie, near Sandusky, Ohio; Graveyard Pond, Presque Isle, near Erie, Pa.; Huron River at Ann Arbor, Mich. Pell (1890) does not note where he found this species. Stokes (1897) described it from a pool near Trenton, N. J. It has not yet been recorded from Europe.

32. Rattulus elongatus Gosse (pl. XII, figs. 102–107).

Synonyms: *Mastigocerca elongata* Gosse (1889); *Mastigocerca grandis* Stenroos (1898).

Distinguishing characters.—This species may be known by its large size, its elongated form tapering toward the posterior end, the very long main toe accompanied by a "substyle" one-sixth to one-fourth its length, and the unarmed anterior edge of the lorica.

External features.—The body is long and slender, somewhat larger at or near the anterior end and tapering back to a slender foot. The dorsal line is somewhat arched, the ventral line nearly straight (fig. 105). The anterior portion of the lorica, or head-sheath, is not marked off from the remainder of the lorica by a constriction. The anterior edge is without spines or teeth.

The dorsal surface of the lorica bears a broad, transversely striated area extending backward about one-third the length of the lorica. The anterior part of this striated area (a little less than one-half of its length) is depressed, so that there is a rather broad furrow extending from the anterior edge backward for a distance somewhat greater than the diameter of the body (to the point *x*, figs. 102 and 105). Near the posterior end of this furrow is the opening for the dorsal antenna (fig. 102, *d. a.*). That part of the lorica forming the bottom of the furrow projects a little at the anterior edge of the lorica (fig. 102).

When the head is extended it is covered with a somewhat stiffened membrane which lies in transverse folds, giving this region a wrinkled appearance (figs. 103 and 104).

Corona.—The corona seems of the usual character. There is a large club-shaped dorsal process (not shown in the figures), but lateral processes have not been observed with certainty.

Antennæ.—The dorsal antenna is in the dorsal furrow near its posterior end. The lateral antennæ are in the usual position (figs. 102 and 105) save that the right one lies much farther toward the dorsal side than does the left, if the position of the dorsal antenna is taken as indicating the dorsal middle line. In a dorsal view only the right one of the lateral antennæ shows (figs. 102 and 103).

Foot.—The foot is more slender than usual, but is otherwise of the ordinary form. The lorica projects farther over it on the left side than on the right, so that the foot may bend to the right, but not to the left.

It will be noticed that there are a number of features in this region which seem to indicate that the posterior part of the animal is to be considered as twisted, so that the primitively dorsal side is now turned to the left, the primitively right side being dorsal. The attachment of the foot to the body is one of these features; usually in rotifers the body projects over the foot on the dorsal side, not on the left side. The position of the lateral antennæ indicates the same thing; the left one is now far over toward the ventral side, the right one nearly dorsal (fig. 103). Still more striking, from this point of view, is the attachment of the toes to the foot. The two toes are no longer side by side, but the primitively right (rudimentary) toe lies almost directly above the left (main) toe (fig. 105). If the hinder part of the body could be twisted about 90° to the right all these structures would regain their usual positions.

Toes (fig. 106).—The main toe (*l. t.*), representing the left toe of the genus *Diurella*, is a long, nearly straight, tapering rod, two-thirds to four-fifths the length of the lorica. The right toe (*r. t.*) is rudimentary, but is nevertheless much better developed than in many species of the genus *Rattulus;* it is a crooked spine from one-sixth to one-fourth the length of the main toe. From its base it curves ventrally toward the main toe, which it crosses (fig. 105). As has been set forth in the account of the foot, the base of this, primitively the right toe, lies in this animal almost directly dorsal to the main (left) toe. Both the main toe and the rudimentary toe are accompanied at the base by scale-like substyles, each toe having at least two of these (fig. 106).

Internal organs.—The internal organs are beautifully and clearly displayed in *R. elongatus* Gosse, rendering this perhaps the most favorable species that exists for a study of the anatomy. Beyond what was given in the general account of the anatomy of the *Rattulidæ* (p. 288), only two or three points need special mention. The brain is unsymmetrical, there being a broad right lobe or division, and a narrow left lobe, shorter than the right one. This left lobe bears at its end the eye (fig. 103). The trophi are well developed and decidedly unsymmetrical, the left half being much larger and stronger than the right (fig. 107).

Measurements.—Length of body, 0.38 to 0.46 mm.; of toe, 0.28 to 0.35 mm.; total, 0.66 to 0.81 mm.

History.—This species was described by Gosse (1889) in Hudson & Gosse's Monograph of the Rotifera, as *Mastigocerca elongata.* A description (in Russian), without figure, is given by Scorikow (1896), and figures are given by Jennings (1900 and 1901). Stenroos (1898) redescribed this animal (with a figure of the anterior end) as *Mastigocerca grandis* n. sp. His description of *Mastigocerca grandis* fits *Rattulus elongatus* Gosse perfectly, the figure of the anterior end showing the form when the head is partly extended.

Distribution.—In America: *Rattulus elongatus* Gosse is not rare in the quiet parts of rivers, ponds, and lakes, though large numbers are not usually found together. I have taken this species in the following localities: Put-in Bay Harbor and East Harbor, Lake Erie; pools at Hanover, N. H.; Portage River, Ohio; Huron River at Ann Arbor, Mich. It has also been found in Sandusky Bay, Lake Erie (Kellicott, 1897), and in waters connected with the Illinois River at Havana, Ill. (Hempel, 1898).

In Europe: England and Scotland (Gosse, 1889); Ireland (Hood, 1895); Württemberg, Germany (Bilfinger, 1892); bayous of the Rhine (Lauterborn, 1893); near Basel, Switzerland (Ternetz, 1892); Galicia, Austria-Hungary (Wierzejski, 1893); Lake Nurmijärvi in Finland (Stenroos, 1898, as *Mastigocerca grandis*); Bohemia (Petr, 1890); near Kharkow, Russia (Scorikow, 1896).

Also in Ceylon (Daday, 1898).

33. Rattulus stylatus Gosse (pl. x, figs. 92–94).

Synonyms: *Monocerca stylata* Gosse (1851); *Mastigocerca stylata* Gosse (1889).

Distinguishing characters.—This species is to be distinguished by the very short toe, one-half or less the length of the body; by the irregular form of the body, with the head-sheath strongly set off from the remainder of the lorica, and by the unarmed anterior edge. There is no other species which bears a very close resemblance to it.

External features.—In this species the body is more irregular in form than in perhaps any other. In dorsal or ventral view the body is ovate in general shape, truncate in front, but tapering rapidly behind to the toe. The posterior half of the body is thus conical, the apex of the cone being surmounted by the toe. In side view the ventral line is nearly even, while the dorsal line is arched (fig. 93). The head-sheath or anterior portion of the body is smaller than the remainder, and set off from it by a broad and deep furrow, so that in side view a prominent "hump" is observed just behind the furrow (fig. 93). The furrow does not run uninterruptedly around the body, but is rather an irregular fold; it is farther forward on the ventral side than on the dorsal.

The anterior margin of the lorica is without teeth or projections of any kind.

Of this species I was able to study only mounted specimens (and these through the kindness of Mr. Charles F. Rousselet), and none of those available presented a directly dorsal view. It was therefore difficult to tell whether there was anything corresponding to the ridge or striated area or not. There seemed no sign of a ridge, but apparently there is a dorsal depression running backward from the median dorsal anterior margin of the lorica; this could not be determined with certainty, however. The animal is clearly not so markedly unsymmetrical as are many of the *Rattulidæ.*

Corona.—The corona bears the usual club-shaped dorsal process; it has not been minutely studied in other respects.

Antennæ.—Dorsal and lateral antennæ in the usual positions, as shown in figs. 92 and 94.

Toes.—The main toe is very short, as compared with that of most of the species of *Rattulus,* being usually somewhat less than one-third the length of the body. It is slightly curved, the concavity of the curve being on the dorsal side, as shown in figure 93. Closely appressed against the

main toe is a substyle (perhaps the rudimentary right toe), which tapers very rapidly. Owing to its slenderness and close approximation to the main toe it is very difficult to determine the length of the substyle. In one case it appeared to be from one-third to one-half the length of the main toe. It is very easily overlooked.

Internal organs.—The trophi are a little unsymmetrical. The mucus reservoir is divided into two equal halves, in spite of the fact that one of the toes has become rudimentary.

Measurements.—Length of body, 0.18 mm.; of toe, 0.05 mm.; total, 0.23 mm.

History.—This species was described by Gosse (without a figure) in 1851. It is figured and described by Gosse (1889) in Hudson & Gosse's Monograph. No description or figure of this species has been given since, though Bilfinger (1894) and Eckstein (1895) have a few notes on it. Eyferth (1885) thought it might be identical with *Diurella stylata* Eyferth, though the two seem not to have the remotest resemblance.

Distribution.—This species has not been found in the United States, and my figures and description are from specimens kindly sent me by Mr. C. F. Rousselet, of London, England.

In Europe: England (Gosse, 1851, 1889); Ireland (Hood, 1895); Württemberg, Germany (Bilfinger, 1894); Müggel-See, Germany (Eckstein, 1895); bayous of the Rhine (Lauterborn, 1898).

34. Rattulus pusillus Lauterborn (pl. IX, figs. 81–85).

Synonym: *Mastigocerca pusilla* Lauterborn (1898).

Distinguishing characters.—This species may be known by its minute size, the short, plump body without teeth or spines, and the rod-like toe about four-fifths the length of the body.

External features.—The body is short and thick, without striking external features of any sort. The head-sheath is marked off by as light constriction from the remainder of the body. Considerably to the right of the dorsal median line is a small, shallow furrow running obliquely backward and corresponding to the striated area of other *Rattulidæ*. This is very inconspicuous, so that it may very easily be overlooked. In some specimens it appears to extend less than half the length of the animal; in others it passes to a point considerably back of the middle, while in still others it is scarcely observable at all. Possibly the furrow disappears when the lorica is distended, as by strong contraction. The form of the lorica shows considerable variation, as will be seen by a comparison of the figures given on plate IX. There are no teeth, spines, or notches at the anterior edge of the lorica.

Corona.—This is of the usual structure. There are two curves of cilia at the sides of the coronal disk and two about the mouth. A median dorsal club-shaped process exists, but no lateral processes are to be observed.

Antennæ.—The left lateral antenna is in the usual position (fig. 83), but the others have not been observed.

Foot.—The foot is very small; it shows no peculiarities in other respects.

Toes.—There is a single bristle-like toe, usually about four-fifths as long as the lorica, but varying. In some cases it is little more than half the length of the lorica. It is nearly straight, though there is a slight bend a short distance from its base, like that to be observed in *Rattulus stylatus* Gosse. Closely appressed to the base of the main toe, so as to be very inconspicuous, is a short substyle, about one-sixth the length of the main toe.

Internal organs.—These offer nothing peculiar. The trophi are of the usual type, the left side being considerably more developed than the right.

Measurements.—Length of body, 0.085 to 0.11 mm.; of toe, 0.06 mm.; total, 0.14 to 0.17 mm.

History.—Lauterborn (1898) lists this species under the name *Mastigocerca pusilla*, but does not give a description. Through the kindness of Dr. Lauterborn I received a sketch of his animal, which shows that it is identical with the rotifer which I have found in the Great Lakes. I have therefore used Lauterborn's specific name.

Distribution.—*Rattulus pusillus* is rare. I have found it in East Harbor, Lake Erie, near Sandusky, Ohio, and in ponds on Middle and South Bass islands, in Lake Erie. Mr. Rousselet has sent me specimens collected at Hanwell, in England. Lauterborn (1898) found it in the bayous of the Rhine.

DESCRIPTIONS COMPILED FROM OTHER AUTHORS.

35. Rattulus curvatus Levander (pl. XIV, fig. 129).

Synonym: *Mastigocerca curvata* Levander (1894).

This species is distinguished by the long, cylindrical, slender body, very strongly curved, and by the prominent movable spine at the anterior margin of the lorica. The rather long head-sheath is set off from the body, as in most species, by a slight constriction. The toe is about one-third the length of the body. Other details are not given by Levander.

Measurements.—Length of body, 0.176 mm.; thickness of body, 0.033 mm.; length of toe, 0.055 mm.

Distribution.—This species was found by Levander in Finland along the shores of the island Löfö.

36. Rattulus dubius Lauterborn (pl. XIV, fig. 133).

Synonym: *Mastigocerca dubia* Lauterborn (1894).

This marine species was described briefly by Lauterborn from a single specimen found near Helgoland. The body is rather short, with a slight constriction between the head portion and the remainder. At the anterior end, both dorsally and ventrally, a triangular projection of the lorica. The toe about half the length of the body; without substyles. Length of the body, 0.11 mm.; thickness in front, 0.032 mm.; length of toe, 0.058 mm. Other details not given.

DOUBTFUL SPECIES, SPECIES INSUFFICIENTLY DESCRIBED, AND SPECIES WRONGLY ASSOCIATED WITH THE RATTULIDÆ.

Rattulus unidens Stenroos (?) (pl. XV, fig. 135).

Synonym: *Mastigocerca unidens* Stenroos (1898).

I give in the following a translation of Stenroos's description of this animal. His account of the internal organs is omitted, since these show nothing peculiar.

"The body is elongated, cylindrical, scarcely narrowed posteriorly. The head portion is set off from the body by a line, and its length is somewhat less than its width. On the ventral side it appears to be cleft backward to the boundary. On the dorsal side there is a chitinous ridge or dorsal keel, which is extended forward as a tooth. At its broad basis, at the boundary of the head portion, a small opening is visible. Dorsal setæ, on the other hand, I have not found. The foot joint is about as long as broad, narrowed posteriorly, and furnished with three spines or toes, the medial one of which is more than half as long as the body, while the two lateral ones are bristle-like, equal in length, and somewhat curved.

"Length of the body with the foot-joint, 0.26 mm.; thickness of the body, 0.06 mm.; length of the toe, 0.125 mm.; of the substyles, 0.034 mm.

"The rotatory organ is furnished with about four short and thick finger-like papillæ. The large, crescent-shaped red eye is furnished with a refractive lens, and lies upon the large, oval brain." (Stenroos, 1898, p. 145).

It will be noticed that this species agrees with *Rattulus gracilis* Tessin in the single tooth at the anterior end, and approximately in the body form and in the toes. Possibly it should be considered a synonym of the species just named. Or it may have been described from specimens of *Rattulus scipio* Gosse. It was found by Stenroos in Lake Nurmijärvi in Finland.

Rattulus cuspidatus Stenroos (?) (pl. XV, fig. 136).

Synonym: *Mastigocerca cuspidata* Stenroos (1898).

This species bears much resemblance to *Rattulus scipio* Gosse, and should probably be identified with that species. It was described by Stenroos from a camera sketch made some time before the description was written.

Stenroos notes its resemblance to *R. scipio* Gosse, but considers the two distinct. The body is broadest in front, and gradually narrowed toward the rear. The head-sheath is set off by a slight constriction, and is furnished with a tooth which is said to rise from the right ventral side;

the figure shows it to be in the same position as the tooth of *Rattulus scipio* Gosse (q. v.). The main toe is not quite half the length of the body, and is furnished with two substyles, of which one is long and S-shaped.

The peculiarly formed head-sheath, the sharp lateral spine at the anterior end, and the long substyle are considered the characteristic features of this species.

Length of body, 0.30 mm.; thickness, 0.067 mm.; length of toe, 0.138 mm.; of the longest substyle, 0.05 mm.

The animal was found in Lake Nurmijärvi in Finland.

Rattulus roseus Stenroos (?) (pl. xv, fig. 137).

Synonym: *Mastigocerca rosea* Stenroos (1898).

This species has a close resemblance to *Rattulus longiseta* Schrank (*Mastigocerca bicornis* Ehrb.), from which it is said by Stenroos to differ chiefly in two points. One is in the form of the body—in this species broadest in the anterior half of the body, while *Rattulus longiseta* is said by Stenroos to be broadest in the middle. This, however, is a character which will by no means always hold for *R. longiseta;* it is not at all rare to find specimens that are broadest near the head. The chief point of difference is, however, that the two teeth at the anterior edge of the lorica are said to be on the ventral side, in place of on the dorsal side, as in *R. longiseta.*

This difference is unquestionably sufficient to justify the formation of a new species. But when we consider the relation of the anterior teeth in other *Rattulidæ* to the dorso-dextral striated area or ridge, and to the method of movement of the animal, as described in the first part of this paper, it is difficult not to question the presence of two teeth like those of *Rattulus longiseta* Schrank on the *ventral* anterior margin of the lorica. In Stenroos's figure (reproduced in fig. 137, pl. xv), which seems clearly a dextro-ventral view, if we suppose that the shorter tooth is seen through the transparent head of the animal (which may sometimes be done), the figure would agree throughout with *R. longiseta* Schrank. Stenroos states, however, that he has compared the two species, and that they are different.

Length of body, 0.336 mm.; thickness, 0.086 mm.; length of toe, 0.218 mm.; of the substyle, 0.05 mm.

This species was found by Stenroos in Lake Nurmijärvi, in Finland.

Rattulus brachydactylus Glasscott (pl. xiv, fig. 130).

Synonym: *Mastigocerca brachydactyla* Glasscott (1893).

I copy herewith the entire account (as well as the figure) of this species.

"*Sp. ch.*—Body irregularly cone-shaped; head lumpish; toe style-like, short, straight, no substyles, no ridge.

"Allied to *M. stylata* [*Rattulus stylatus* Gosse], but broadest at the head; body an irregular cone, puckered into constrictions, but not gibbous in the middle; the toe straight and finely pointed, only one-fourth the length of the body; no substyles; gait wobbling.

"*Habitat.*—A pond, County Wexford."

It is, of course, not entirely evident from the above description that this animal is really one of the *Rattulidæ* at all, and it is doubtful if the description and figure are sufficient to permit of its recognition if found again.

Rattulus antilopæus Petr (1890).

This may have been *Diurella tigris* Müller, though from the figure and description it is impossible to be certain. The description given by Petr is as follows:

"Body cylindrical, somewhat narrowing toward both ends; foot broad, one-jointed, ending in two toes bent toward each other sickle-wise; these about half the length of the body. At the base they are provided with two pairs of little spines." (Petr, 1890, p. 222).[a]

The figure resembles a poorly drawn contracted specimen of *Diurella tigris* Müller, with the toes strongly bent in opposite directions and crossing one another. This condition of the toes, on which the new species seems to be based, is almost certainly due to distortion. A species so inadequately described and figured can only be dropped.

[a] For the translation of this diagnosis from the original Czech language, in which it was written, I am indebted to Prof. George Rebec, of the University of Michigan.

"Rattulus lunaris" (pl. XIV, figs. 131, 132).

(*Trichoda lunaris* Müller, 1776; *Rattulus lunaris* Ehrenberg, 1838; *Mastigocerca lunaris* Weisse, 1847.)

"*Rattulus lunaris*" was evidently described from one of the smaller species of *Diurella*, but the descriptions have been so inexact, and perhaps erroneous, that it seems impossible to recognize the animal with certainty. In fact, it is probable that several different species of *Diurella*, inaccurately observed, have been given this name, so that it was really a collective designation, which can not be restricted to any particular species.

Judging from the description and figure of Ehrenberg (1838), *Rattulus lunaris* has a striking resemblance to *Diurella brachyura* Gosse. The form of the body, the position of the foot, the length of toe relatively to that of the body, and the unarmed anterior edge of lorica, are striking points of similarity. But Ehrenberg assigns to this animal two eyes, which, if credited, prevents the identification of the two. Ehrenberg decidedly emphasizes the presence of the two eyes; names the animal "Brillenratte" on account of them, and discusses their position, in a way that makes it difficult to believe he could have been entirely mistaken as to their existence. A number of other investigators, notably Eichwald (1847), Perty (1852), Bartsch (1877), and Wierzejski (1893), have reported finding Ehrenberg's *Rattulus lunaris*, and Eichwald especially mentions that it can be distinguished from closely related species by the two eyes. Ehrenberg states also that the toe is simple and styliform. Two of his figures are reproduced in figs. 131, 132.

Weisse (1847) describes as *Mastigocerca lunaris* what he considers to be Müller's original species. Weisse's animal had *but one eye*, and he seems to incline to the belief that the assignment of two eyes to this animal by other observers was a mistake. He notes that he himself had reported finding Ehrenberg's *Rattulus lunaris*, but that after once noticing the single eye he was never again able to find specimens with two. But Weisse's description does not help greatly in deciding what animal should be called *lunaris*, owing to the fact that his description was evidently based on observation of at least two different animals. He says that some specimens had the toe about one-third the length of the body, while in others the toe was full half the length of the body. The former is represented in his figs. 4 and 5, the latter in his fig. 6. Judging from his description and figures, the former may have been *Diurella brachyura* Gosse, the latter *Diurella tenuior* Gosse. But there is no statement as to the presence or absence of teeth at the anterior edge of the lorica, and the figures and descriptions are in other respects also so general in character that it is quite impossible to be certain in the matter.

Taking all together, it seems necessary to let the name *lunaris* drop, it being impossible to recognize any definite species as corresponding to the description given.

Distemma setigerum Ehrenberg (pl. XIV, fig. 134).

This animal, from the structure of its toes and its general appearance, seems to belong to the *Rattulidæ*, where it would be assigned to the genus *Diurella*. But the assignment to it of two eyes by Ehrenberg prevents its identification with any known species. Ehrenberg's specific characters are: Body oblong-ovate; the two eyes red; the toes seta-like and decurved. He mentions the fact that it might easily be confounded with *Rattulus* (*lunaris*).

Bartsch (1877) reports this species from Hungary.

Monocerca valga Ehrenberg (1838).

As noted by Hudson & Gosse (1889), this was apparently a male rotifer of some sort.

"Rattulus cimolius" Gosse (1889) (pl. XV, fig. 138).

There is nothing in Gosse's description to indicate that this animal belongs to the *Rattulidæ*, except, possibly, the unsymmetrical trophi. But this is a character which is not at all rare, as Lund (1899, p. 70) has observed, in various *Notommatadæ*. For the rest, all the characters mentioned by Gosse are quite foreign to the *Rattulidæ*, but are characteristic for some of the *Notommatadæ*. The skin is flexible (there being, so far as can be judged from description or figure, no sign of a lorica); brain opaque; toes blade-like; there are no substyles; apparently no eye; auricles present on corona. None of these characters are found in the *Rattulidæ*, so that it seems that there is absolutely no ground for including this species in the present family.

Gosse found one specimen at Sandhurst, Berks, England; another specimen in a pool near Birmingham, England. Glasscott (1893) reports finding it in Ireland.

"Rattulus calyptus" Gosse (1889) (pl. xv, fig. 139).

The case stands with this species as with "*Rattulus cimolius.*" There is nothing in Gosse's figure or description that gives the least indication that this organism is one of the *Rattulidæ*. It is without a lorica; toes blade-shaped; brain clear; no eyes; face furnished with "pendent veil-like lobes of flesh." The animal was marine, being found in the tide pools on the Scottish coast.

Found also in Ireland (Hood, 1895).

Cœlopus (?) minutus Gosse (1889) (pl. xv, fig. 144).

This species was described from a single specimen, which was nearly dead. Only its general appearance gave it any claim to be placed among the *Rattulidæ*, for in its other characteristics it gave little indication of belonging to this family. It had two eyes, wide apart; apparently no mastax or rotatory organ. The toe appeared to be a single short, slender spine. In place of mastax and trophi there was a tube leading from the anterior end to the stomach. The body was thick, short, and rounded; the foot short and thick. The animal was excessively minute, being but 0.05 mm. long. It was found in Black Loch, near Dundee, Scotland.

Glasscott (1893) reports finding a dead specimen of this animal in Ireland, and says that the toes were two broad, decurved blades, exactly alike, and stretched out in a line with the body. If her specimen was really the same as Gosse's, this account of the toes, of course, removes all reason that may have existed for considering this one of the *Rattulidæ*.

Elosa worrallii Lord (1891) (pl. xv, fig. 140–143).

This rotifer was assigned by Lord to the *Rattulidæ*, so that an account of it should perhaps be given here. The animal is without a foot and toes, but in some respects, notably in its asymmetry, it perhaps does show some resemblance to the *Rattulidæ*. I should consider that it belongs rather with the genus *Ascomorpha;* others of this genus have some points of resemblance with the *Rattulidæ*. Lord's description (Lord, 1891, p. 324) is as follows (somewhat abridged):

"Lorica ovate, widest behind, trilobate in optical section; eyes two, one frontal, one cervical; trophi unsymmetrical; foot and toes absent. The lorica, which, as stated, is three-lobed, is on the dorsal aspect oval, widest behind, with a posterior rounded projection, the continuation of the dorsal lobe. There is a peculiar crescentic opening posteriorly on the left under side, visible both on dorsal and ventral aspects. * * * On the sides of the head are two triangular, movable pieces, the points of which can be made to meet and protect the retracted corona, much as in *Cœlopus porcellus*, an evident approach to the more perfect defensive armature of *Dinocharis*. The cervical eye is dark and rather large; the frontal one, which is to the right of the median line, is small and pale, and in many of the specimens can be easily overlooked. The mastax is long, pear-shaped, and three-lobed; the trophi are protrusile and asymmetrical; there is a long fulcrum, with a terminal knob. The left manubrium is nearly as long, while the right one is short and rudimentary. The stomach is generally filled with brown alimentary matter, and there is a distinct intestine, which in newly collected specimens is invariably of a pale-green color; neither salivary nor gastric glands were discoverable, and I think they would hardly have escaped notice had they been present."

Bothriocerca affinis Eichwald (1847) (pl. xv, fig. 145).

This animal was evidently a species of *Diurella*, but what species it is impossible to decide, owing to the indefiniteness of Eichwald's figure and description. In fact it was probably described from observation of more than one of the smaller species of *Diurella*, for he says that specimens found in pools near Kaugern differed from those found in the Drixe, in the presence of a small tooth at the dorsal and ventral anterior margin of the lorica. Eichwald had thus evidently at least two different species before him, though they were described as one.

Eichwald says that the "foot" (meaning what is now called the toe) had a longitudinal furrow; this appearance was due of course to the space between the two toes. Altogether it is evident that both the generic and specific names must be dropped; the former as synonymous with *Diurella*, the latter because the species is unrecognizable.

Bothriocerca longicauda Daday (1889) (pl. xv, fig. 146).

This marine organism Daday apparently classes with the *Rattulidæ*. As the description is in Hungarian, I am unable to make use of it. In a brief German résumé Daday (1890) says that this species differs from *Bothriocerca affinis* Eichwald in the fact that the anterior edge of the

lorica has several excavations, and that the toe is very long. Other characteristics must be judged from the figure (pl. xv, fig. 146.)

Heterognathus brachydactyla Schmarda (1859).

This species is so inadequately described as to be quite unrecognizable, so that it will have to be dropped completely.

Heterognathus notommata Schmarda (1859).

Insufficiently described for recognition. The figure bears a slight resemblance to *Diurella tenuior* Gosse.

Heterognathus diglenus Schmarda (1859).

This was not one of the *Rattulidæ*, but a *Diglena*, apparently *Diglena catellina* Ehr.

DISTRIBUTION OF THE RATTULIDÆ.

As an examination of the foregoing list will show, of the 36 well-established species 25 have been found in America and 32 in Europe. Four species described from America have not yet been found in Europe; these are *Diurella insignis* Herrick, *Rattulus multicrinis* Kellicott, *R. mucosus* Stokes, and *R. bicuspes* Pell. Eleven European species have not been found in America, namely: *Diurella rousseleti* Voigt, *D. dixon-nuttalli* Jennings, *D. sejunctipes* Gosse, *D. collaris* Rousselet, *D. helminthodes* Gosse, *D. marina* Daday, *D. brevidactyla* Daday, *Rattulus lophoëssus* Gosse, *R. stylatus* Gosse, *R. curvatus* Levander, and *R. dubius* Lauterborn.

It is not improbable that all the species found in Europe will in time be found in this country, and that future workers in Europe will detect the four American species there. It was only within a few years that *Rattulus latus* Jennings was described from the United States; it was soon after found by Stenroos in Finland. Several of the species described in this paper for the first time are shown to be distributed in both Europe and America. Ten of the species here listed from America were not known hitherto to exist in this country.

Some of the better-known species are shown to have a very wide distribution. For example, *Diurella tigris* Müller has been found widely distributed in Europe and America and in India, New Guinea, Natal, and Ceylon. *Diurella tenuior* Gosse has been found in New Guinea, Natal, and New Zealand, as well as in Europe and America. *Rattulus carinatus* Lamarck is recorded from all parts of Europe and the United States, and from New Guinea, Ceylon, and Australia. It is probable that the group as a whole will be found to have a cosmopolitan distribution.

Of the 25 American species 23 have been found in Lake Erie. A characteristic feature in the distribution of these animals is the fact that many species may be found in a single restricted area. Thus, from a small pool not more than 30 feet across, in the Huron River at Ann Arbor, Mich., 14 species were taken, 6 species of *Diurella* and 8 of *Rattulus*. From East Harbor, Lake Erie, 20 species have been taken; this, however, is a rather extensive region.

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INDEX TO GENERIC AND SPECIFIC NAMES.

DESCRIPTION OF PLATES.

PLATE I.

Diurella tigris Müller.

1. Dorsal view, showing the ridge (× 350).
2. Ventral view of trophi, a little from the left (× 665).
3. Ventral or ventro-sinistral view (× 350).
4. Ventral or ventro-sinistral view of strongly retracted specimen (× 350).
5. Optical section of body from rear (× 350).
6. Ventral view of foot and toes, with mucus reservoirs (*m. r.*) (× 600).

Diurella tenuior Gosse.

7. Small specimen, dorsal or dorso-dextral view (× 350).
8. Larger specimen, dorsal or dorso-dextral view (× 350).
9. Ventral view of toes (× 600).
10. Trophi, dorsal view (× 600).

Diurella weberi n. sp.

11. Ventral view of toes under pressure (× 665).
12. Right side view (× 600).
13. View of anterior edge of lorica, from the right (× 350).
14. Lorica, from left side (× 350).

PLATE II.

Diurella insignis Herrick.

15. Ventro-dextral view, head retracted (× 350).
16. Dorsal view, retracted (× 350).
17. Toes, pressed out, ventral view (× 350).
18. Young specimen, ventro-dextral view (× 350).

Diurella porcellus Gosse.

19. Dorsal view (× 350).
20. Lorica, from right side (× 350).
21. Left side of extended specimen (× 350).
22. Trophi, ventral view (cf. trophi in fig. 21) (× 665).
23. Foot and toes, dorsal view (the toes were bent beneath body, as in fig. 21; animal viewed from ventral side) (× 665).

Diurella sulcata Jennings.

24. Left side, foot extended (× 350).
25. Right side, foot retracted (× 350).
26. Trophi, dorsal view (× 665).

PLATE III.

Diurella stylata Eyferth.

27. Right side (× 385).
28. Dorsal view of retracted specimen (× 385).
29. Dorsal view of extended specimen (× 385).
30. Left side of retracted specimen (× 385).
31. Corona (× 600).

Diurella brachyura Gosse.

32. Right side (× 600). *ev.* for *c. v.*=contractile vacuole.
33. Left side of lorica, showing projecting point on left side of anterior margin (× 600).
34. Toes, dorsal view (× 665).

Diurella cavia Gosse.

35. Dorsal view (× 350).
36. Right side, showing sac-like protrusion of lorica above and behind toes (× 350).

PLATE IV.

The figures on this plate, except figs. 37 and 38, were drawn by Mr. F. R. Dixon-Nuttall, of Eccleston Park, near Prescot, England, who kindly placed them at the disposal of the author for the present paper.

Diurella rousseleti Voigt.

37. Side view of retracted specimen (× 600).
38. Toes, ventral view (× 665).
39. Side view of retracted specimen.

Diurella dixon-nuttalli n. sp.

40. Right side.
41. Right side of another specimen.
42. Trophi, dorsal view.
43. Toes, dorsal view.
44. Left side.

PLATE V.

Rattulus gracilis Tessin.

45. Right side of much-extended specimen (from Prescot England) (× 350).
46. Dorsal view (from Huron River, Michigan) (× 350).
47. Dorsal view of lorica (from Prescot, England) (× 350).
48. Dorsal view of anterior part of retracted specimen (× 350).
49. Ventral view, trophi extended (× 350).

Rattulus scipio Gosse.

50. Ventro-dextral view of extended specimen (× 350).
51. Dorso-dextral view of extended specimen, young (× 350).
52. Dorsal view of retracted specimen (× 350).

Rattulus macerus Gosse.

53. Right side of young specimen, retracted (× 285). *sp.* = spur.
54. Right side of adult specimen, extended (× 285). *sp.*= spur.

PLATE VI.

Rattulus multicrinis Kellicott.

55. Dorsal view of lorica (× 350).
56. Side view, with head and mastax extended (× 350).
57. Ventral view of extended specimen (× 350).
58. Side view of anterior part of lorica when the head is strongly retracted (× 350.)

Rattulus capucinus Wierz. & Zach.

59. Side view of anterior part of lorica when the head is strongly retracted (× 285).
60. Right side (× 285).
61. Ventral view. The toe extends obliquely toward the observer, so that its full length is not seen (× 285).

PLATE VII.

Rattulus cylindricus Imhof.

62. From Lake Bologoe, Russia, left side of retracted specimen, bearing egg (× 245).
63. Left side of extended specimen (from Germany) (× 285).
64. Left side of specimen from East Harbor, Lake Erie (× 245).

Rattulus latus Jennings.

65. Ventral view of extended specimen (× 350).
66. Dorsal view of lorica (× 285).

PLATE VIII.

Rattulus longiseta Schrank.

67. Right side view (× 285).
68. Ventral view of young specimen, retracted (× 285).
69. Ventral view of posterior part of body, with toes, mucus glands and reservoirs (× 600).
70. Specimen strongly retracted (× 285).
71. Trophi, from left side (× 665).
72. Trophi, dorsal view (× 665).

Rattulus bicuspes Pell.

73. Left side (× 350).
74. Young specimen, right side (× 350).
75. Dorsal view (× 350).
76. Trophi, dorsal view (× 665).

PLATE IX.

Rattulus bicristatus Gosse.

77. Right side (× 350).
78. Dorsal view, to show furrow and ridges (× 285).
79. Posterior part of body, foot, and base of toes, showing the mucus reservoirs and substyles (× 665). (The guide line from *m. r.* should extend farther to the left, to reach the reservoirs.)
80. Trophi, flattened by pressure.

Rattulus pusillus Lauterborn.

81. With head partly retracted, from Wehrle's Pond, Middle Bass Island, Lake Erie (× 350).
82. With head extended, from same locality as the last (× 350).
83. Dorsal view (× 665).
84. Side view (× 665).
85. From Hanwell, England (× 350).

PLATE X.

Rattulus mucosus Stokes.

86. Dorso-dextral view of lorica, to show ridges (× 350).
87. Side view (× 350).
88. Side view of contracted specimen (× 350).
89. Ventral view of lorica (× 350).
90. Young specimen (× 350).
91. Trophi, dorsal view (× 665).

Rattulus stylatus Gosse.

92. Ventral view (× 285).
93. Left side (× 285).
94. Dorso-sinistral view (× 350).

PLATE XI.

Rattulus carinatus Lamarck.

95. Dorsal view (× 350).
96. Foot and toes, dorso-sinistral view (× 600).
97. Right side (× 350).

Rattulus lophoëssus Gosse.

98. Right side (× 285).
99. Dorsal view (× 285).

Rattulus rattus Müller.

100. Dorsal view (× 350).
101. Left side (× 350).

PLATE XII.

Rattulus elongatus Gosse.

102. Retracted, from East Harbor, Lake Erie, dorsal view (× 285).
103. Extended, from England, dorsal view (× 190).
104. Ventral view of anterior end with head extended (× 190).
105. Left side (× 285).
106. Dorso-sinistral view of foot and toes (× 350).
107. Trophi, ventral view (× 600).

PLATE XIII.

The figures on this plate, except fig. 109, were drawn by Mr. F. R. Dixon-Nuttall, of Eccleston Park, near Prescot, England, who kindly placed them at the disposal of the author for the present paper.

Diurella intermedia Stenroos.

108. Right side (from England).
109. From Huron River, Mich. (× 350).
110. Toes pressed out.

Rattulus scipio Gosse.

111. From a living specimen.
112. Toes pressed out.

Diurella sulcata Jennings.

113. Toes pressed out.

Diurella brachyura Gosse.

114. Toes pressed out.
115. Right side.

Diurella weberi n. sp.

116. Left side.
117. Right side.

Diurella sulcata Jennings.

118. Trophi.
119. Left side.

PLATE XIV.

Diurella sejunctipes Gosse.

120. Dorsal view, after Gosse (1889).
121. Left side (× 568), after Stenroos (1898).

Diurella helminthodes Gosse.

122. After Gosse (1889).

Diurella marina Daday.

123. After Daday (1889).
124. Ventral view of anterior edge of lorica, after Daday (1889).
125. Mastax, after Daday (1889).
126. Anterior end, strongly contracted, after Daday (1889).

Diurella collaris Rousselet.

127. After Rousselet (1896).

Diurella brevidactyla Daday.

128. After Daday (1889).

Rattulus curvatus Levander.

129. (× 360), after Levander (1894).

Rattulus brachydactylus Glasscott.

130. After Glasscott (1893).

"*Rattulus lunaris*" Ehrbg.

131. Dorsal view, after Ehrenberg (1838).
132. Side view, after Ehrenberg (1838).

Rattulus dubius Lauterborn.

133. After Lauterborn (1894).

Distemma setigerum Ehr.

134. After Ehrenberg (1838).

PLATE XV.

135. *Rattulus unidens* Stenroos (× 296), after Stenroos (1898).
136. *Rattulus cuspidatus* Stenroos (× 450), after Stenroos (1898).
137. *Rattulus roseus* Stenroos (× 220), after Stenroos (1889).
138. "*Rattulus cimolius*" Gosse, after Gosse (1889).
139. "*Rattulus calyptus*" Gosse, after Gosse (1889).
140. *Elosa worrallii* Lord, side view, drawn by F. R. Dixon-Nuttall.
141. *Elosa worrallii* Lord, trophi, drawn by F. R. Dixon-Nuttall.
142. *Elosa worrallii* Lord, dorsal view, after Lord (1891).
143. *Elosa worrallii* Lord, section of body, after Lord (1891).
144. "*Cœlopus* (?) *minutus*" Gosse, after Gosse (1889).
145. *Bothriocerca affinis* Eichwald, after Eichwald (1847).
146. *Bothriocerca longicauda* Daday, after Daday (1889).

Abbreviations used in the plates.

al. alula.
br. brain.
c. v. contractile vacuole.
d. a. dorsal antenna.
e. eye.
f. foot.
fu. fulcrum.
g. g. gastric gland.
gl. gland.
h. s. head-sheath.
in. intestine.
l. left.
l. a. left lateral antenna.
l. mu. left manubrium.
l. t. left toe.
m. mouth.
m. g. mucus gland.
m. r. mucus reservoir.
mu. manubrium.
mx. mastax.
œ. œsophagus.
ov. ovary.
r. right.
ra. ramus.
r. mu. right manubrium.
r. t. right toe.
sp. spur.
st. stomach.
u. uncus.

FIG. 1

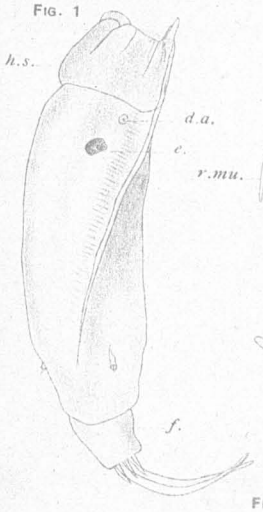


FIG. 2

FIG. 3

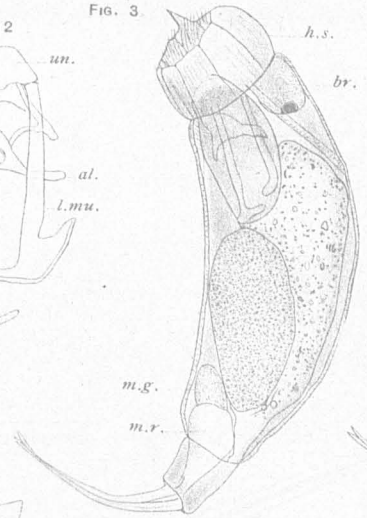


FIG. 4

FIG. 5

FIG. 6

FIG. 7

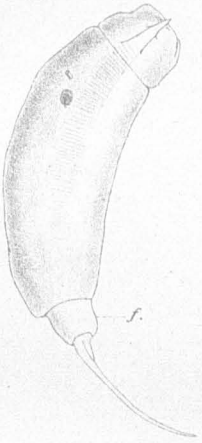


FIG. 8

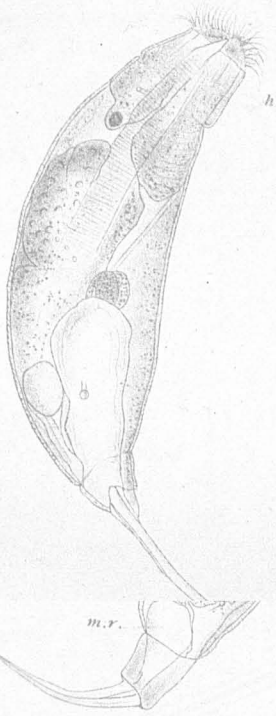


FIG. 9

FIG. 10

FIG. 11

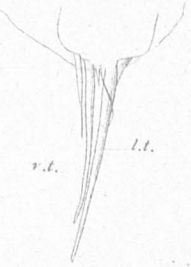


FIG. 14

f.

m.r.

FIG. 5

m.r.

FIG. 6

FIG. 7

FIG. 8

h.s.

FIG. 9

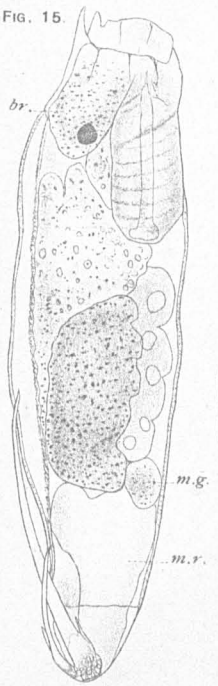
FIG. 11

l.l.

v.l.

FIG. 10

FIG. 15.



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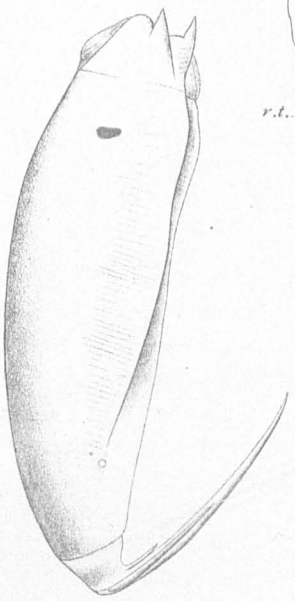

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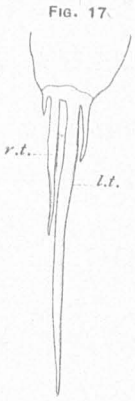

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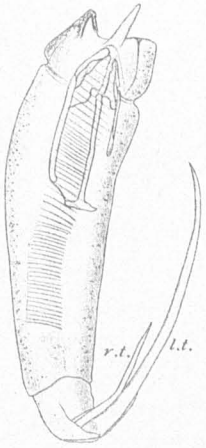


FIG. 22.

FIG. 21.

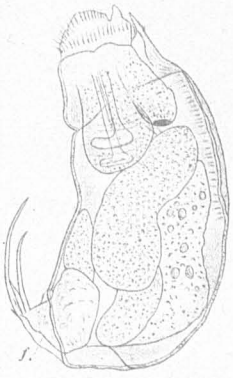
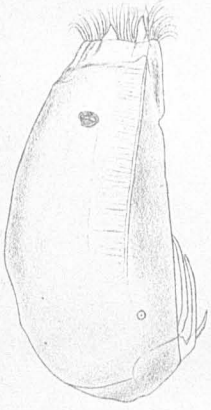


FIG. 23.

FIG. 19.



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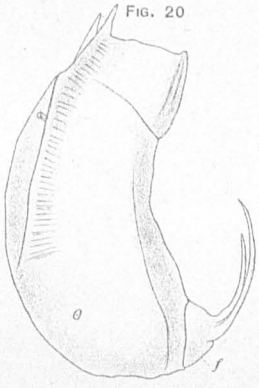

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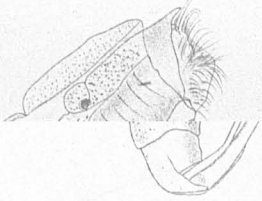
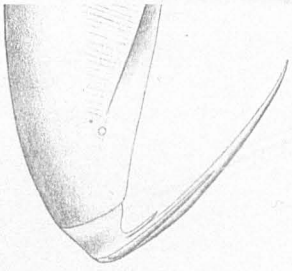


FIG. 26.

m.g.
m.r.



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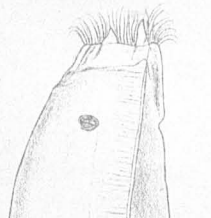

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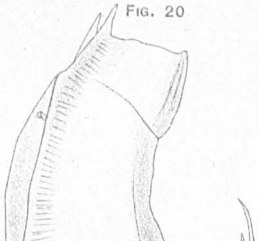

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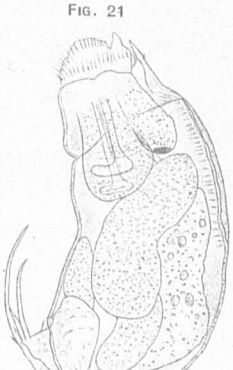
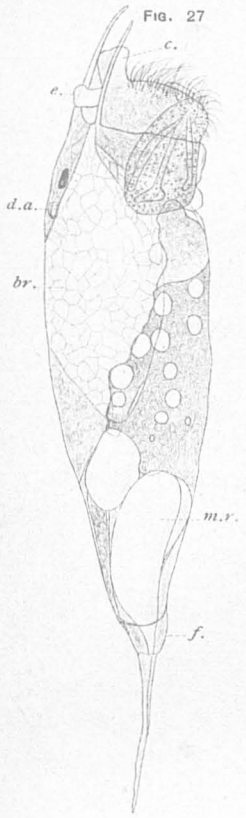


FIG. 23.

FIG. 27



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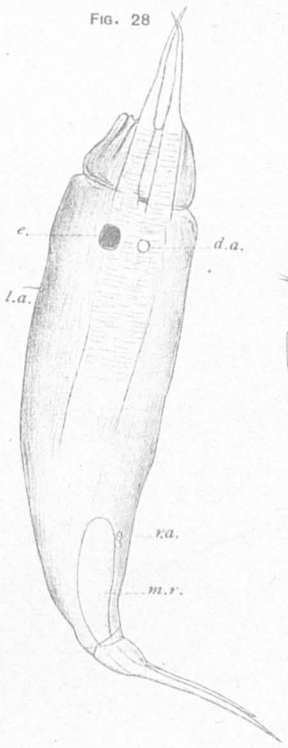

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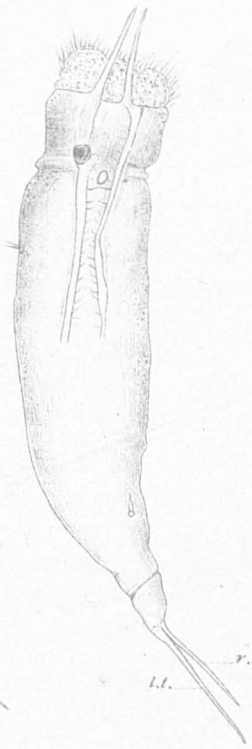

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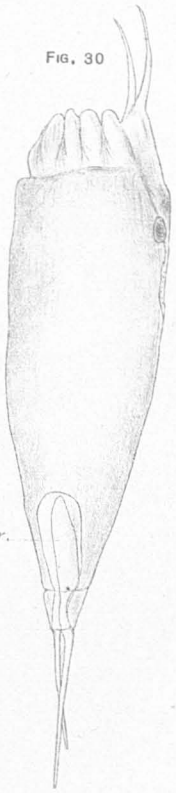

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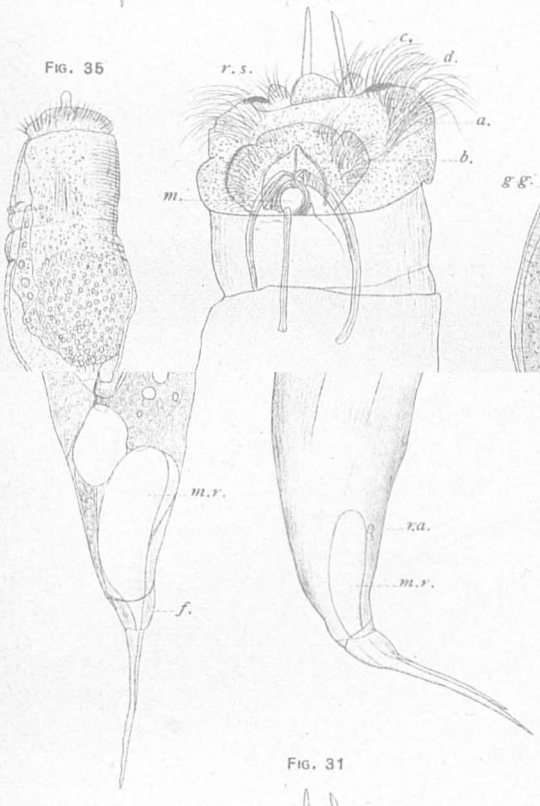

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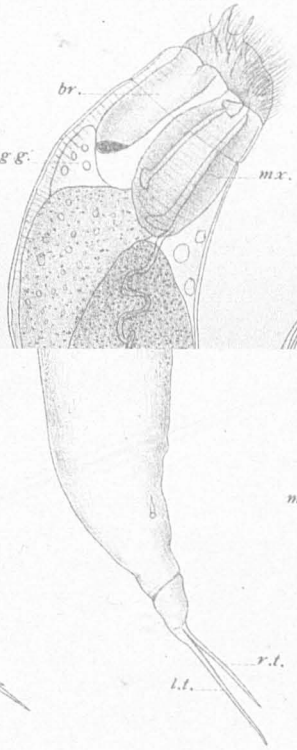

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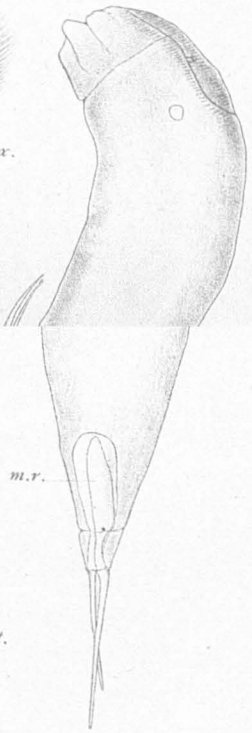


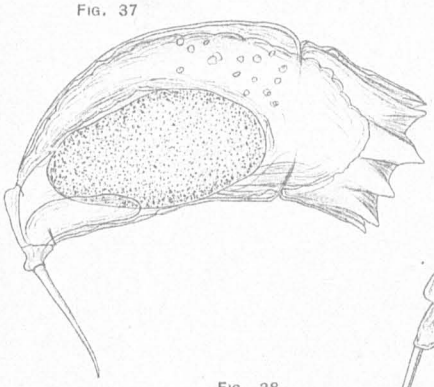
FIG. 35

FIG. 31

FIG. 32

FIG. 33

FIG. 37



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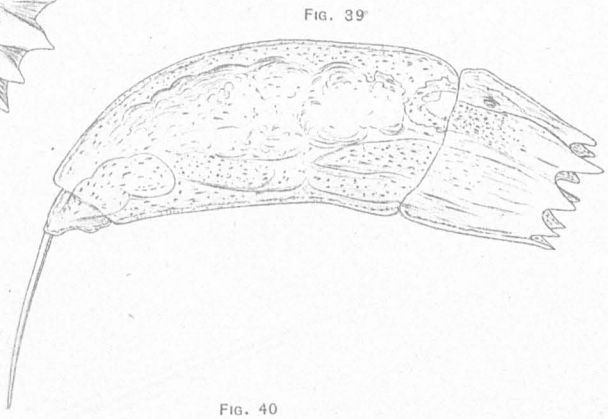
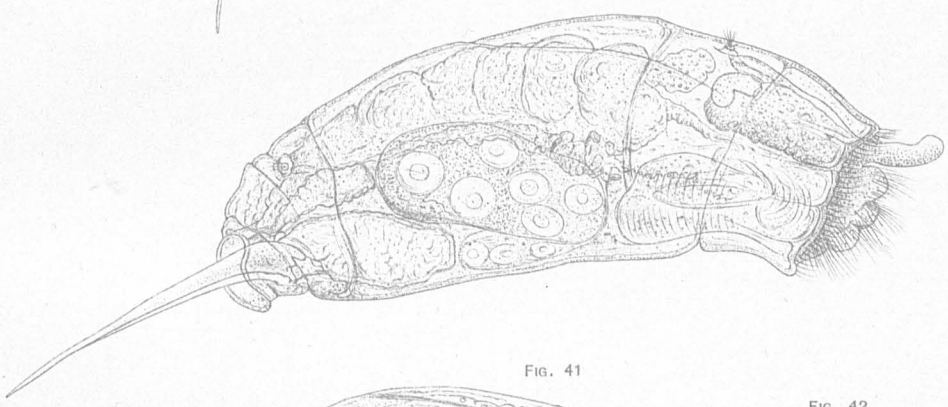


FIG. 38

FIG. 40



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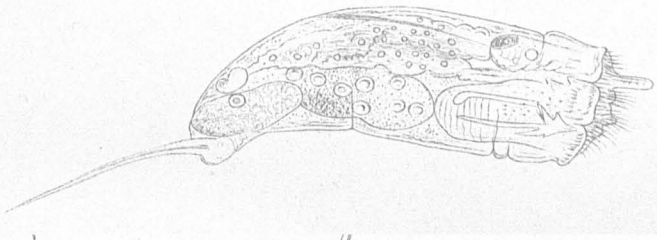


FIG. 42

FIG. 38

FIG. 40

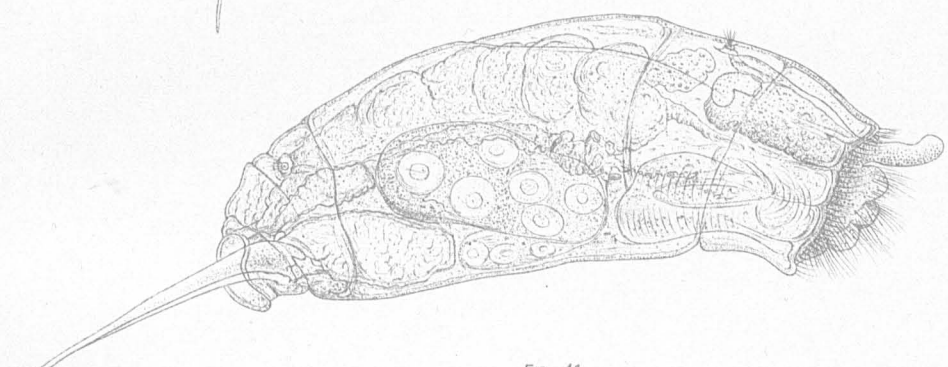
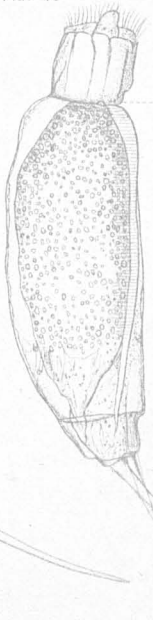


FIG. 41

FIG. 45

FIG. 46



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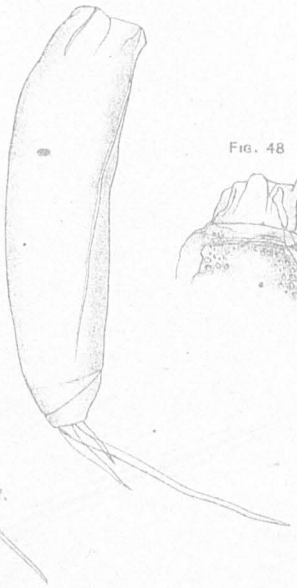


FIG. 48

FIG. 49

FIG. 50

FIG. 51

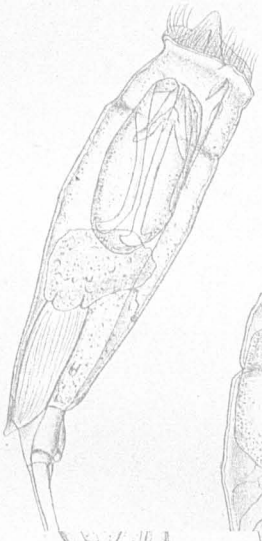


FIG. 52

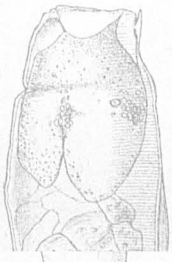


FIG. 53

FIG. 54

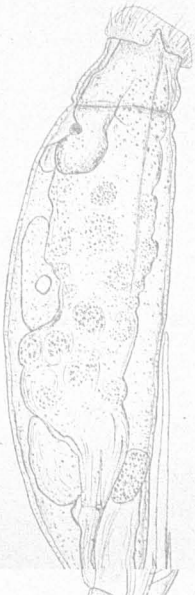


FIG. 50

FIG. 51

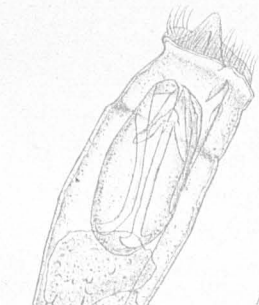


FIG. 52

FIG. 53

FIG. 54

FIG. 55

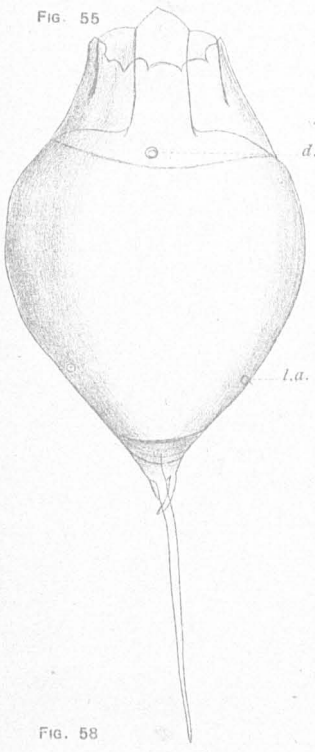


FIG. 56

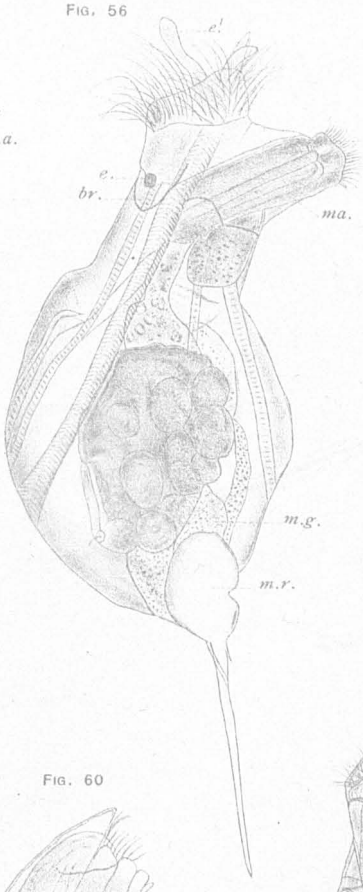
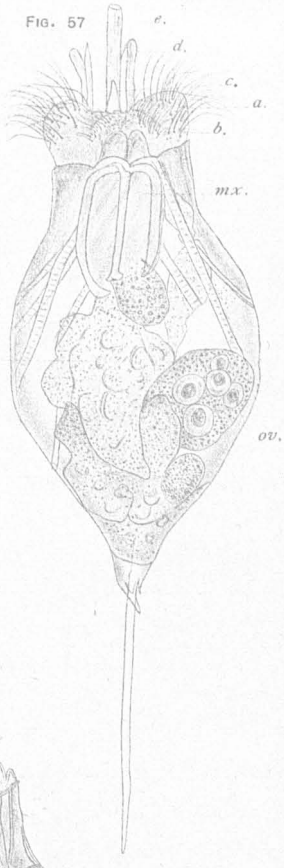


FIG. 57



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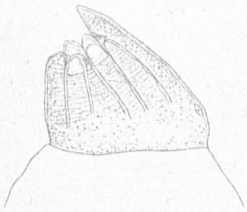
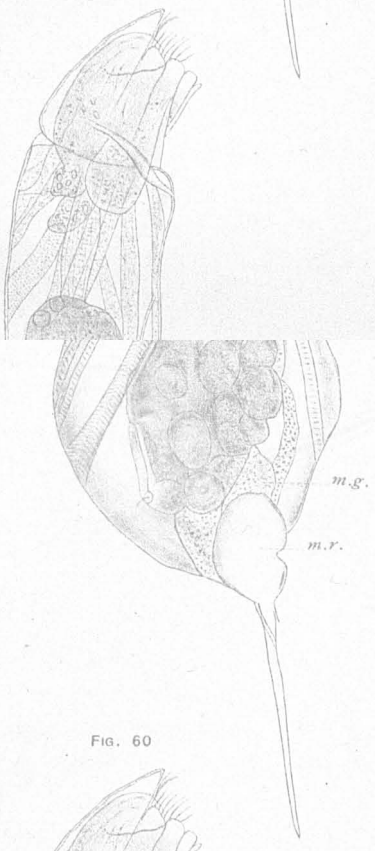


FIG. 59

FIG. 60



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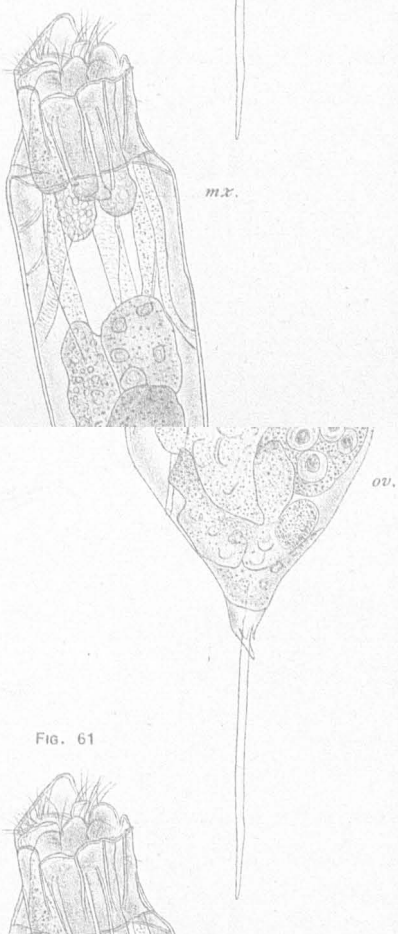

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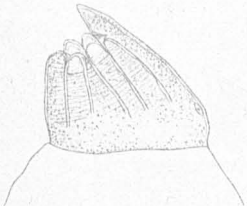


FIG. 60

FIG. 61

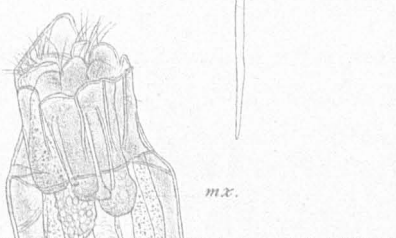


FIG. 62

FIG. 63

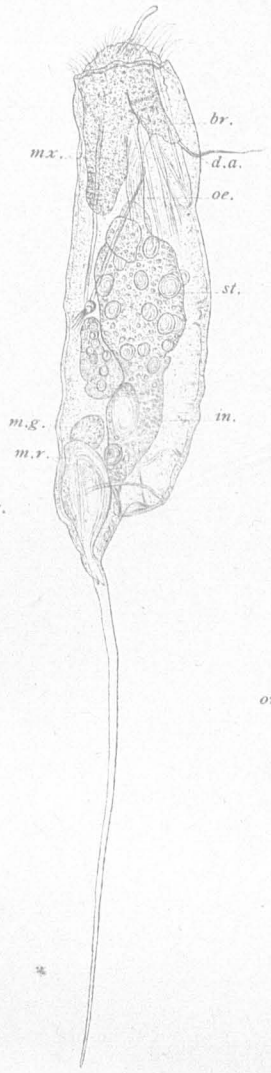


FIG. 65

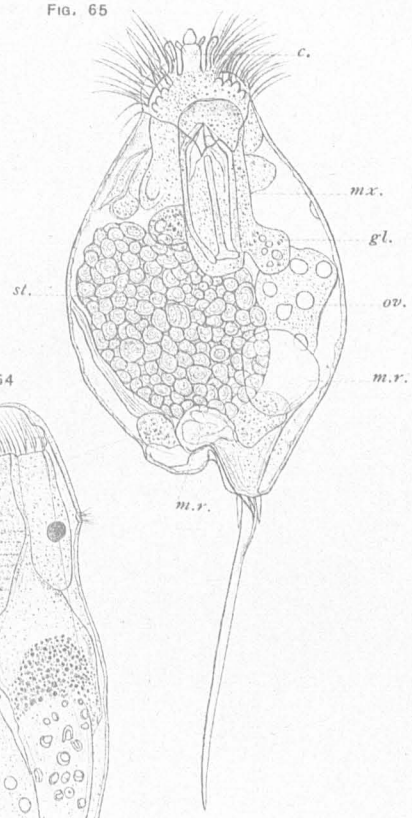


FIG. 64

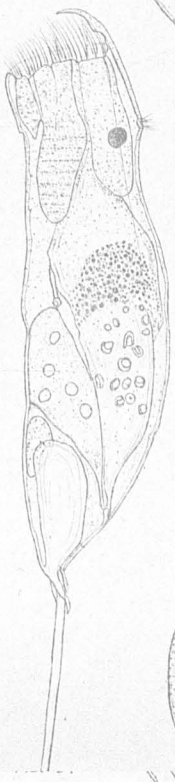
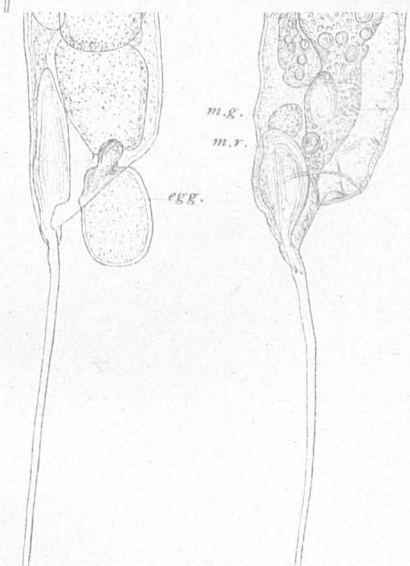


FIG. 66



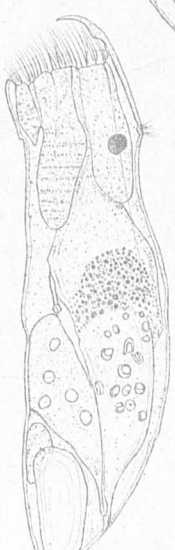


FIG. 66

FIG. 67

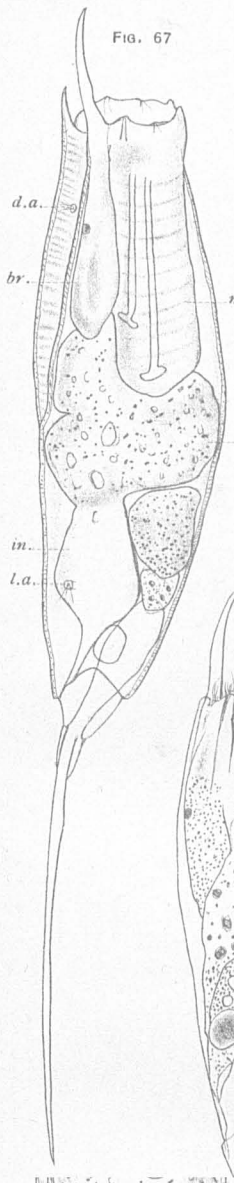


FIG. 68

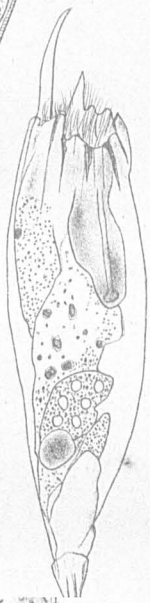


FIG. 69

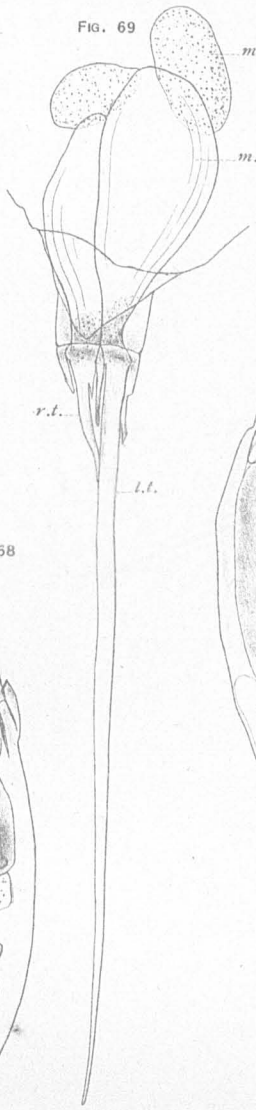


FIG. 70

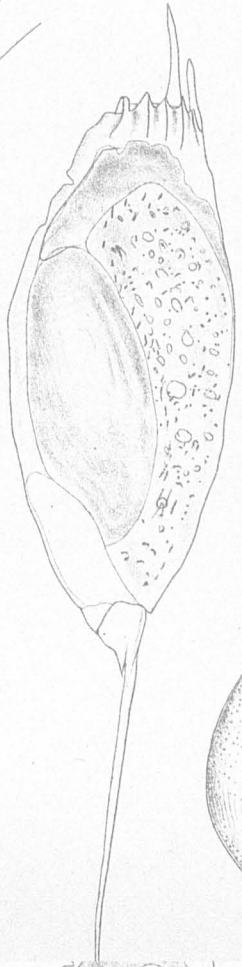


FIG. 73

FIG. 74

FIG. 75

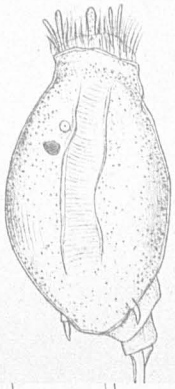


FIG. 72

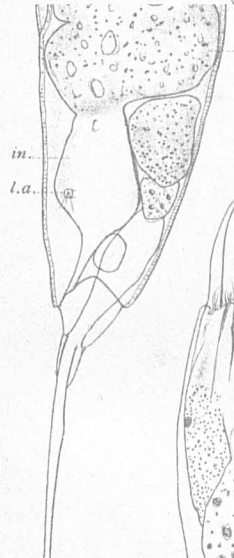


FIG. 68

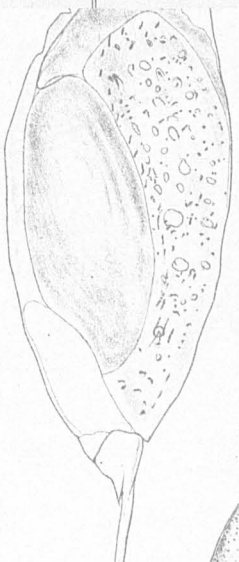
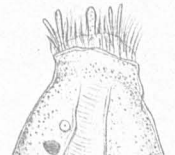


FIG. 74

FIG. 75



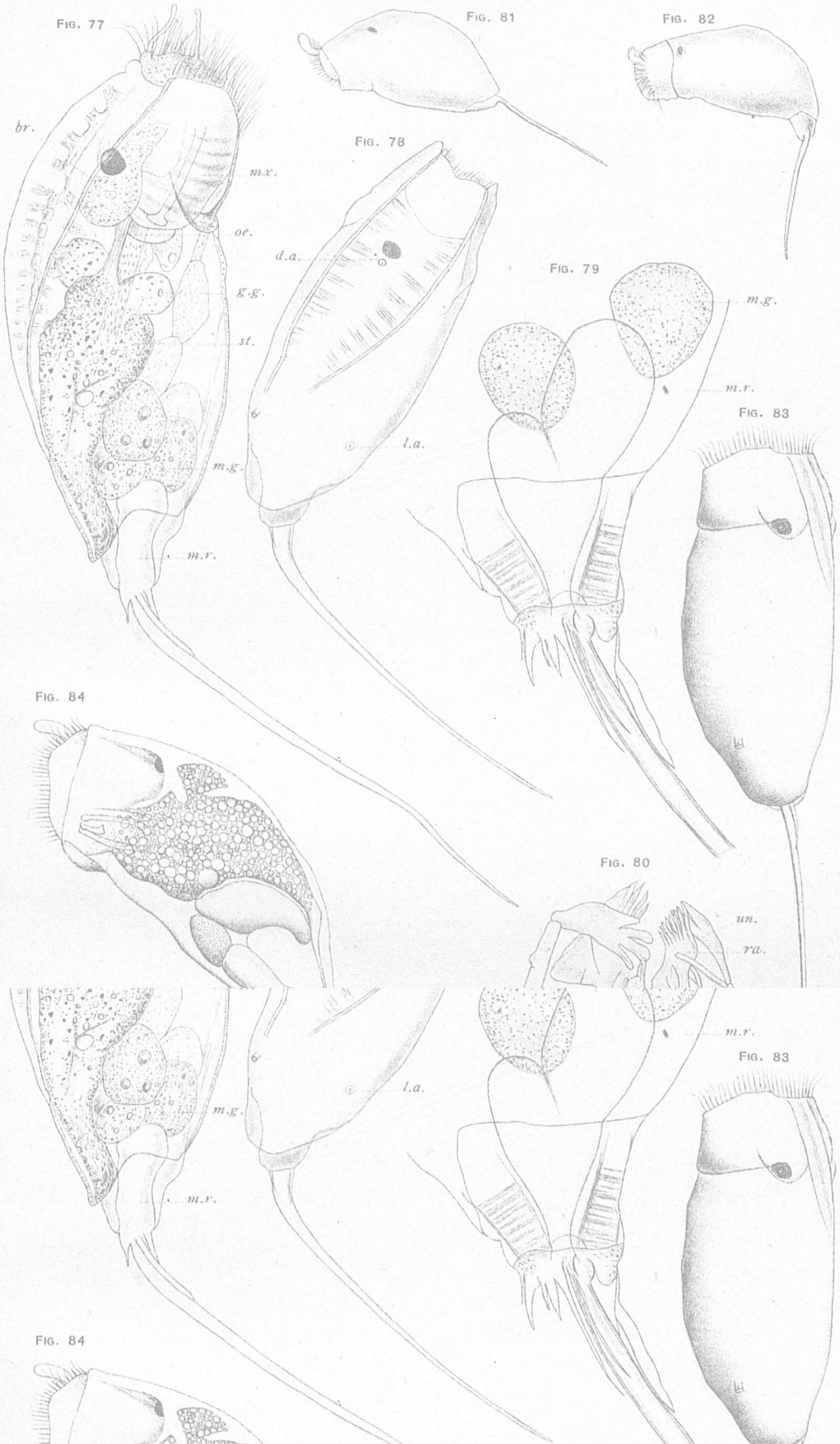


FIG. 77
br.
mx.
oe.
g.g.
st.
m.g.
m.r.
FIG. 81
FIG. 82
FIG. 78
d.a.
l.a.
FIG. 79
m.g.
m.r.
FIG. 83
FIG. 84
FIG. 80
un.
ra.
m.r.
FIG. 83
l.a.
m.g.
m.r.
FIG. 84

FIG. 86

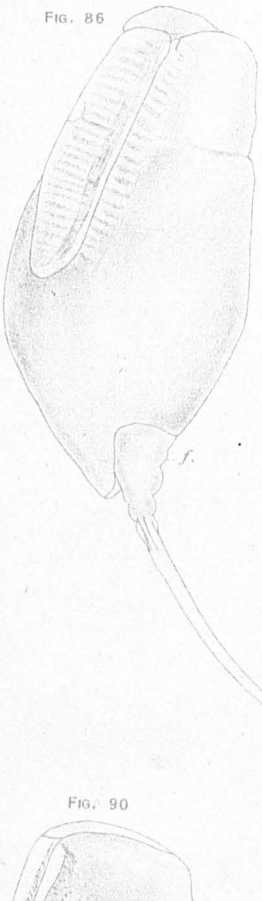


FIG. 87

FIG. 89

FIG. 88

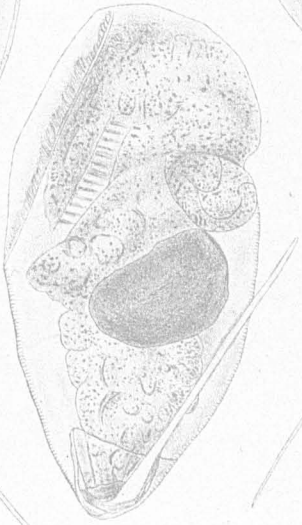


FIG. 90

FIG. 91

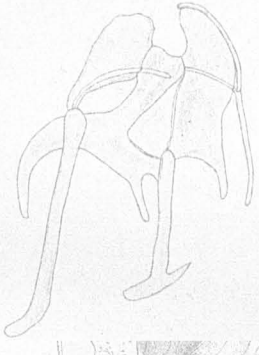


FIG. 92

FIG. 93

FIG. 90

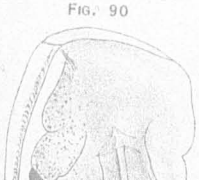


FIG. 91

FIG. 92

FIG. 93

FIG. 95

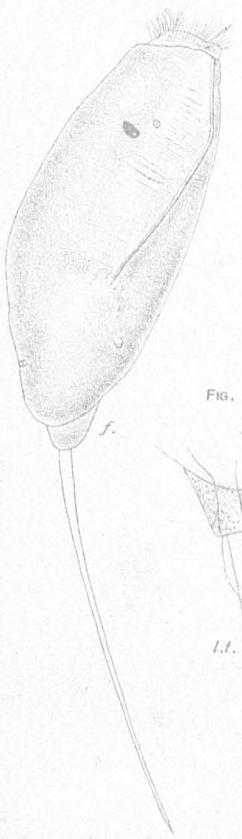


FIG. 97

FIG. 99

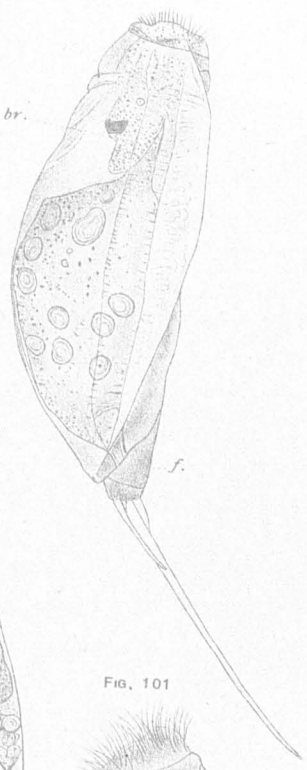


FIG. 96

FIG. 98

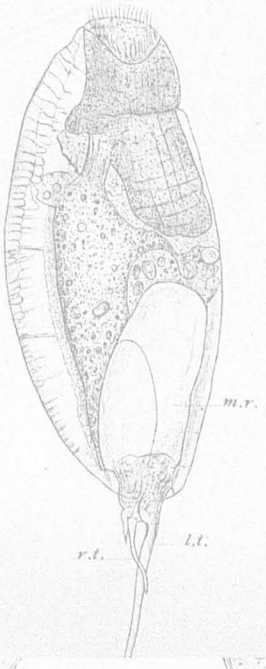


FIG. 101

FIG. 100

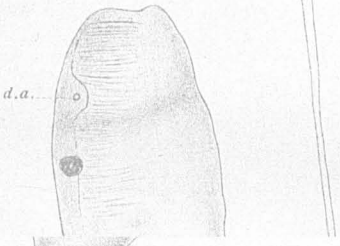


FIG. 96

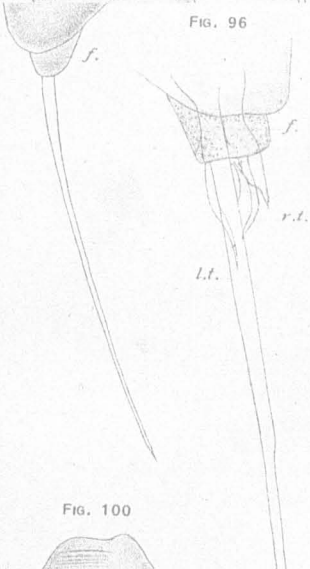


FIG. 98

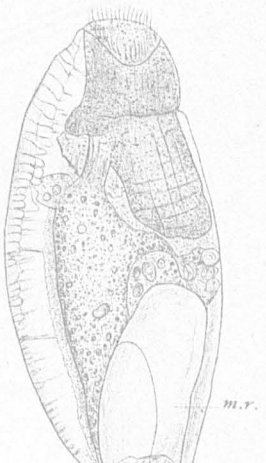


FIG. 101

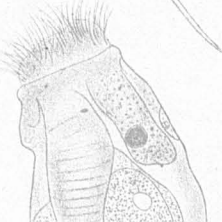


FIG. 100

FIG. 102

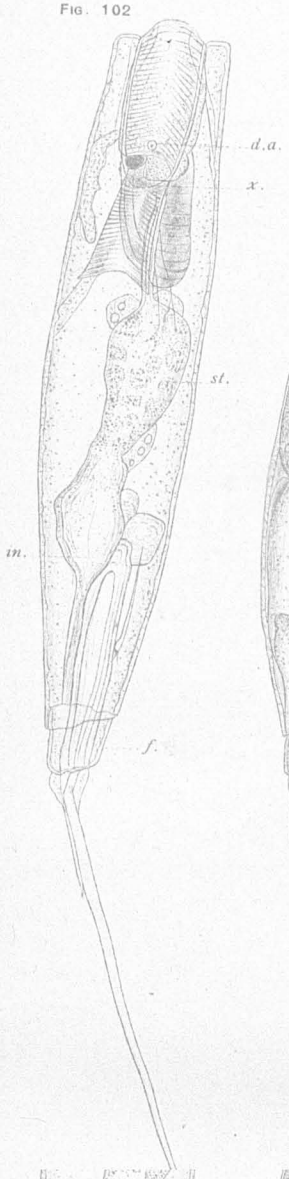


FIG. 103

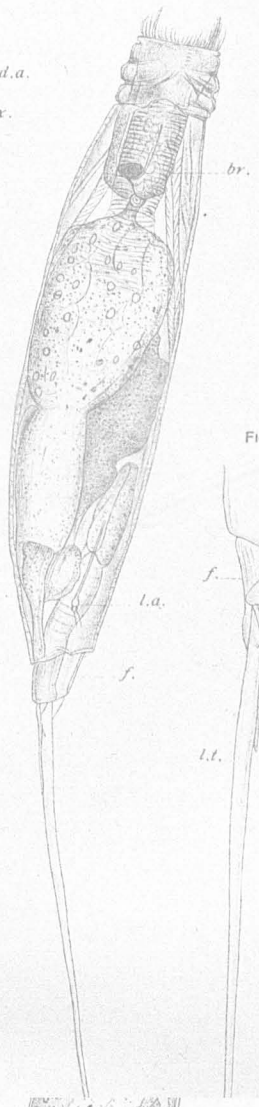


FIG. 104

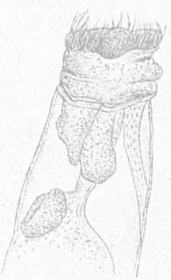


FIG. 105

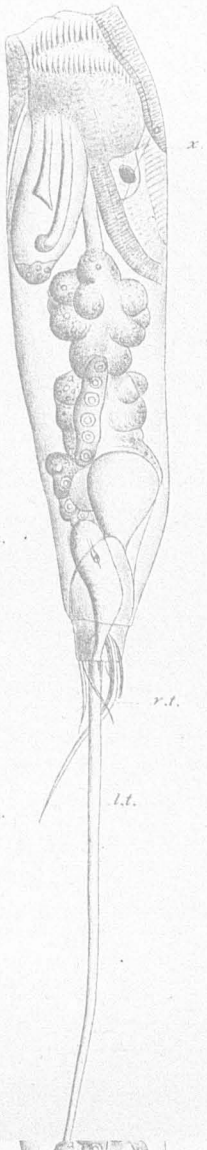
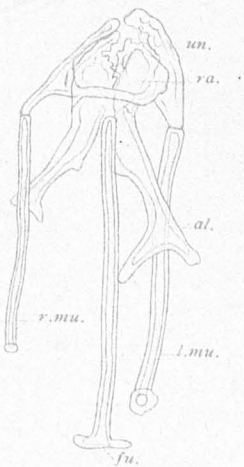


FIG. 106

FIG. 107



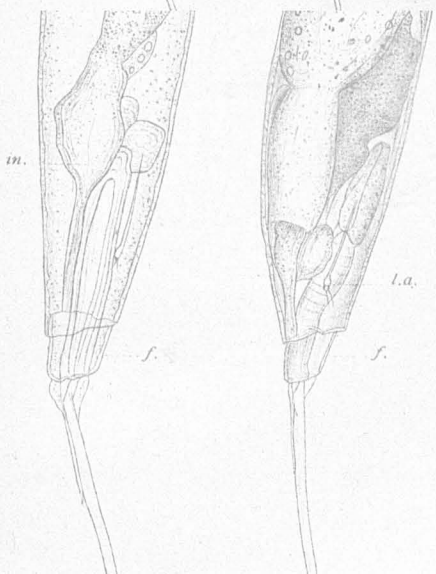
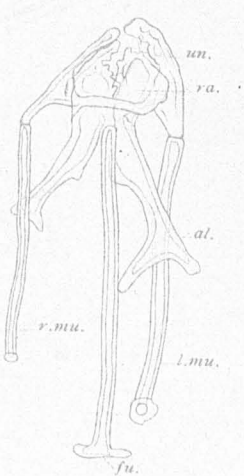


FIG. 106

FIG. 107



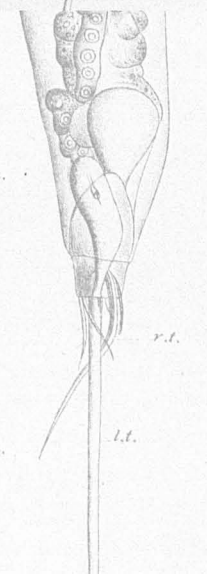


FIG. 108

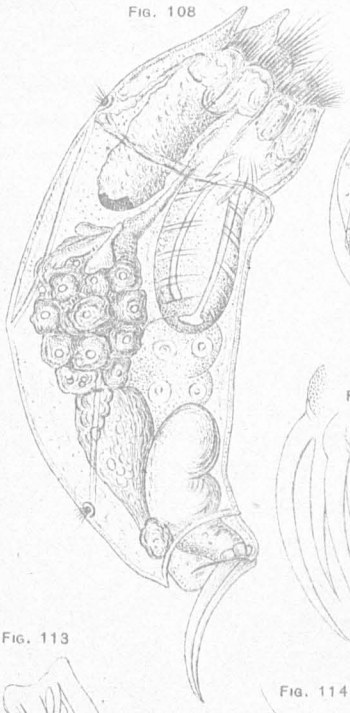


FIG. 109

FIG. 111

FIG. 112

FIG. 110

FIG. 116

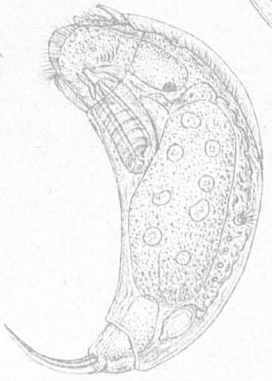


FIG. 113

FIG. 114

FIG. 118

FIG. 115

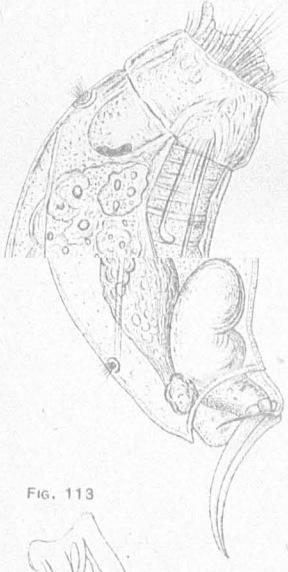


FIG. 117

FIG. 110

FIG. 116

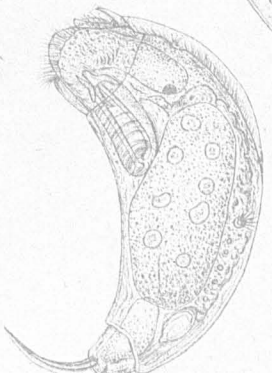


FIG. 113

FIG. 114

FIG. 118

FIG. 115

FIG. 120

FIG. 121

FIG. 122

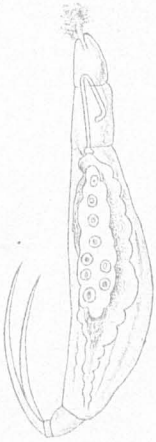


FIG. 123

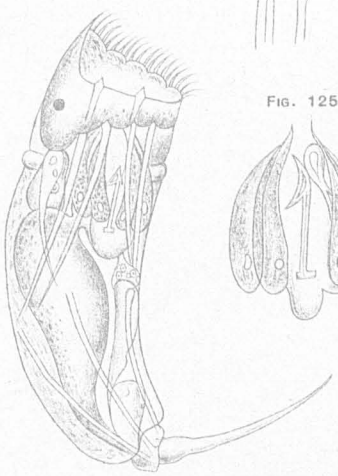


FIG. 124

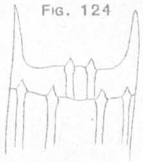


FIG. 125

FIG. 127

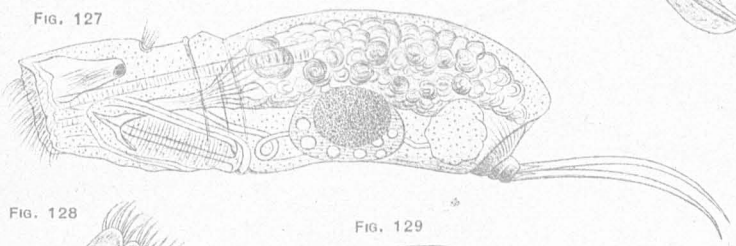


FIG. 126

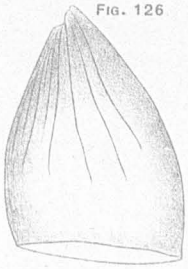


FIG. 128

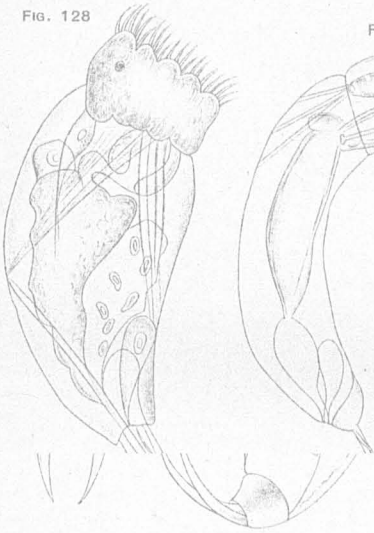


FIG. 129

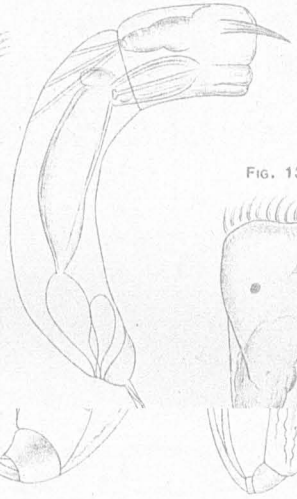


FIG. 131

FIG. 130

FIG. 133

FIG. 132

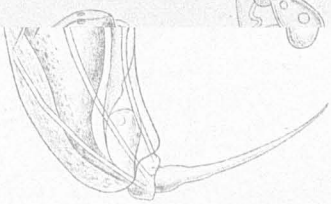


FIG. 127

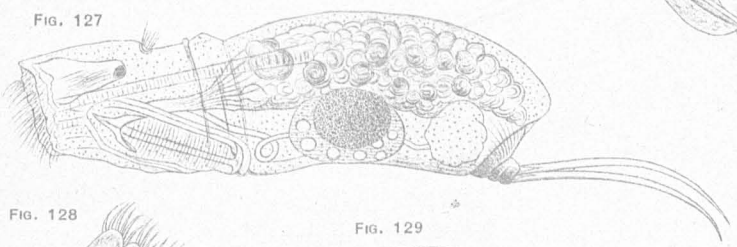


FIG. 126

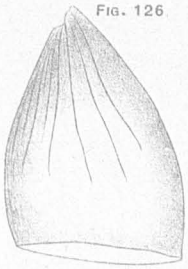


FIG. 128

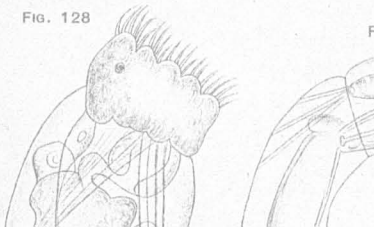


FIG. 129

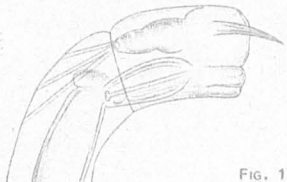


FIG. 131

FIG. 130

FIG. 135

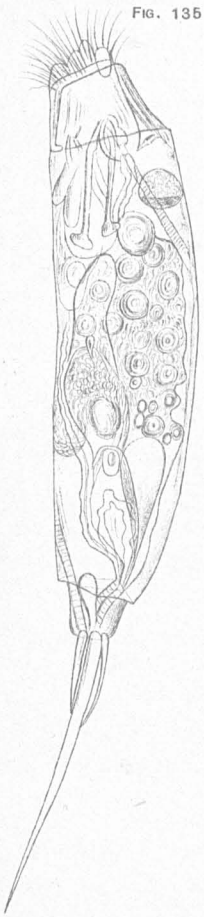


FIG. 136

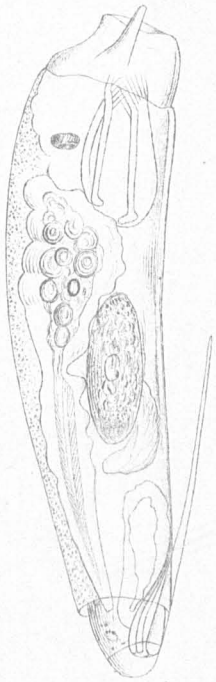


FIG. 137

FIG. 138

FIG. 139

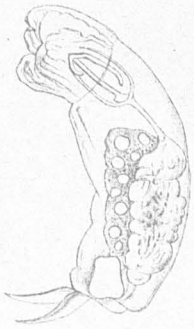


FIG. 140

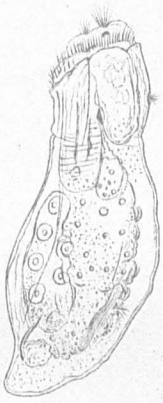


FIG. 141

FIG. 143

FIG. 146

FIG. 142

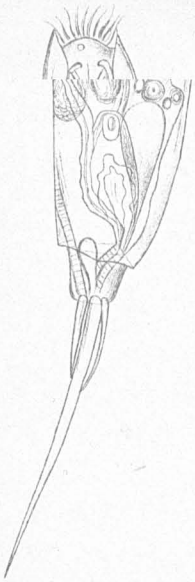


FIG. 144

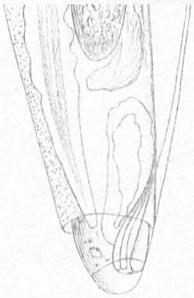


FIG. 145

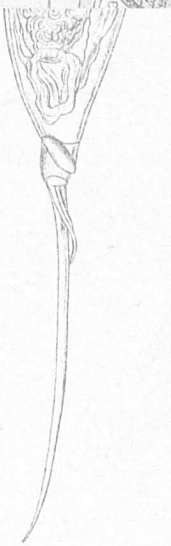


FIG. 139

FIG. 140

FIG. 141