

NORTH AMERICAN PARASITIC COPEPODS BELONGING TO THE FAMILY ERGASILIDÆ.

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INTRODUCTION.

The present is the tenth^a paper in the series based upon the collection of parasitic copepods in the U. S. National Museum, and deals with the family Ergasilidæ.

As in all the preceding papers, the Museum material has been largely supplemented by a study of living forms, developmental stages, and material derived from other sources.

Much of this study has been accomplished while working for the U. S. Bureau of Fisheries at various laboratories situated both upon salt and fresh water. For these valuable opportunities the author is indebted to the courtesy of the Hon. George M. Bowers, U. S. Commissioner of Fish and Fisheries, to whom acknowledgment is gratefully made.

Thanks are also due to Prof. E. A. Birge and Prof. Chauncy Juday, of the University of Wisconsin, for furnishing a generous supply of tow taken from Lake Mendota, Madison, Wisconsin, from which has been obtained an excellent series of specimens of both sexes of *Ergasilus chautauquaënsis*.

The value of this material is enhanced by the fact that it was the first opportunity for a personal examination of an *Ergasilus* male.

To Dr. Andrew Scott, of the Board of Fisheries of Scotland, the author returns sincere thanks for some finely preserved specimens of

^aThe nine preceding papers are 1. The Argulidæ, Proc. U. S. Nat. Mus., vol. 25, pp. 635-742, pls. 8-27. 2. Descriptions of Argulidæ, idem, vol. 27, pp. 627-655, 38 text figures. 3. The Caliginæ, idem, vol. 28, pp. 479-672, pls. 5-29. 4. The Trebinæ and Euryphorinæ, idem, vol. 31, pp. 669-720, pls. 15-20. 5. Additional Notes on the Argulidæ, idem, vol. 32, pp. 411-424, pls. 29-32. 6. The Pandarinæ and Cecropinæ, idem, vol. 33, pp. 323-490, pls. 17-43. 7. New species of Caliginæ, idem, vol. 33, pp. 593-627, pls. 49-56. 8. Parasitic Copepods from the Pacific Coast, idem, vol. 35, pp. 431-481, pls. 66-83. 9. Development of *Achtheres ambloplitis* Kellicott, idem, vol. 39, pp. 189-226, pls. 29-36.

Bomolochus soleæ, taken from the nostrils of the cod common upon the coasts of the British Isles.

These specimens also included both sexes and proved of great value in a comparison of the mouth-parts. The male of this species has never been described, but Doctor Scott has generously given the author permission to include it in the present paper. In private correspondence he has also furnished many notes and suggestions upon the mouth-parts of the genus *Bomolochus*, which have proved exceedingly helpful in coordinating the accounts of different authors, in the effort to establish an accurate and common basis for future use.

This is the smallest of all the families of parasitic copepods, both in number of species and in bodily size.

As here constituted it contains ten genera, three of which are new to science, while a fourth, *Tucca*, has been so changed by the discovery of its mouth-parts and swimming legs as to make of it virtually a new genus. Hesse has described four other genera which in all probability belong to this family. Two of them, *Megabrachinus* and *Macrobrachinus*, would fall in the subfamily Ergasilinæ, since the second antennæ are developed into long and powerful prehensile organs like those of *Ergasilus*. The other two, *Metopocatacoteinus* and *Metoponaphrissontes*, as evidently belong to the Bomolochinæ from the structure of the first antennæ and the mouth-parts. But Hesse's figures and descriptions are so full of flat contradictions and palpable errors as to render it impossible to locate these genera with any certainty, and hence they must be left until future investigation shall furnish the necessary data. For the good of systematic zoology it is to be hoped that at least the last two names may prove to be synonyms; there is no chance that they were preoccupied.

The family separates naturally into three groups or subfamilies, which differ in habits as well as morphology, and thus constitute well-marked divisions. (See key, p. 311.)

The first of these subfamilies, the Ergasilinæ, are typically fresh-water forms, and nearly all the species are found upon the gill filaments of fresh-water fishes. The second subfamily, the Bomolochinæ, are as typically salt-water forms, and no one of them, so far as known, has ever been found in fresh water. The third subfamily, the Taeniacanthinæ, are also salt-water forms, and none of them have thus far been found upon fresh-water fishes.

There are one or two species (*Artacolax cornutus*, *Irodes tetrodontis*, etc.) that reach a length of 3 or 4 mm., but all the remaining species are much smaller, and many of them are under 1 mm. in length. The Ergasilidæ thus compare more closely in size with the free-swimming forms than do any of the other parasitic copepods. This resemblance is increased by the fact that the eggs are multiseriate and are carried in elliptical or pear-shaped pouches almost exactly like those of *Cyclops* and other free-swimmers.

The Corycæidæ, a family of free-swimmers established by Claus in 1863, offer the greatest affinity with the Ergasilidæ. This resemblance has already been stated by Vogt (1879, p. 98), and is especially noticeable in the genera *Corycæus*, *Antaria*, and *Lubbockia*.

In superficial view the genus *Corycæus* looks very much like *Ergasilus*; there is the same bodily structure, the second antennæ are transformed into powerful prehensile organs, the mouth parts are somewhat similar, and even the unpaired eye is small and well concealed in the tissues.

But in spite of this seeming likeness the Ergasilidæ differ radically from the free-swimmers in both habits and morphology, as can be seen from the account which follows.

The present paper includes all the genera belonging to the family which have thus far been found in North American waters. On examining the species which have been referred by various authors to the genus *Bomolochus*, it was soon found that we have among them sufficient differences to warrant the establishing of at least three new genera, *Artacolax*, *Irodes*, and *Phagus*. A diagnosis of *Artacolax* has already been published.^a

A description of the type-species, *A. ardeolæ*, is here added, the diagnoses of the other two genera are given with their distinguishing characteristics, and the different species belonging to each are clearly indicated. There is also presented a comparison of the mouth parts in the two sexes of the three type genera, *Ergasilus*, *Bomolochus*, and *Tæniacanthus*. The mouth parts of the female of each of these genera have already been published, some of them many times, and the large maxillipeds, which are the distinguishing character of the male, have been described and figured.

But these descriptions have all been isolated and nearly every author has changed the nomenclature of one or more of the mouth parts. The result has been a confusion so great as to make intelligent comparison possible only after long and painstaking study of the published accounts and careful examination of both living and preserved material.

To the best of the author's knowledge no collective account of the family as a whole, showing the interrelation of the subfamilies, genera, and species, has hitherto been published.

ECOLOGY.

Habits.—The Ergasilidæ live almost entirely upon the gill filaments or within the gill cavities of fishes, and this habit has occasioned several departures from the conditions found existing in the Caligidæ. There is about the same difference between the sexes in their morphology, but the difference in habit is considerably greater.

^a Proc. U. S. Nat. Mus., vol. 35, p. 433.

While the adult females become more or less fixed upon their host, the males remain free-swimmers during life, and at least in the genus *Ergasilus* do not appear to practice parasitism at all. In consequence of this difference there is always a great scarcity of males, especially among the Ergasilinæ.

Females can be found in abundance upon nearly all our common food fishes, but the males disappear at the close of the mating season and can then be found only in the tow.

We can thus understand how in the great majority of species the female alone is known. In a very few instances the two sexes are found together, as noted by Mr. T. Scott, an excellent investigator and one who has worked upon free-swimming as well as parasitic forms. In a short paper published in the Annals of Scottish Natural History (vol. 9, p. 153) he calls attention to the fact that certain species of *Bomolochus* are habitually found in the nostrils of such fish as the cod (*Gadus callarius*), the lumpsucker (*Cyclopterus lumpus*), and the plaice (*Pleuronectes platessa*). Both sexes and the young live here in the mucus lining of the nostrils, and when removed to an aquarium prove to be lively swimmers.

The mating of the sexes in this family takes place while the female is still very young and in all probability before she seeks out a host. And only at that time would there be any chance of finding the two together.

The evidence for these conclusions is contained in the following facts: The developmental stages of all the Ergasilidæ are free-swimming; none of them are found attached to a host along with the adults, as is the case with the chalimus stage of the Caligidæ. Among the many hundreds of specimens taken by the author from the gills of different fishes in both salt and fresh water no developmental stage has ever been found. Undersized females have been repeatedly obtained, less than half the length of the fully developed adult, and giving unmistakable proof that they had not as yet developed their first pair of egg strings. But they were still sexually mature, the eggs within the ovaries were well advanced, and the spermatophores were already attached to the genital segment.

Again, in all this large number of specimens, as well as among those contained in the National Museum, there have never been found a male and female in union. And there is but a single record of such a find within the author's knowledge, the one given by Bassett-Smith (1898, p. 358) of *Bomolochus megaceros*. If the coming together of the sexes took place upon the gills of the host many more would undoubtedly have been obtained, as among the Caligidæ. That they have not been thus found indicates that mating takes place before the female seeks a host. Fortunately the few males known are well distributed among the genera, and we thus have a good idea of that sex throughout the family.

After the female is once fastened to her host all further incentive to free swimming disappears. She finds on the fish's gills excellent aeration for her eggs and a good position from which to discharge the nauplii when sufficiently matured. There is also an abundance of food so that she remains there in all probability throughout life.

The only instance of a mature female found swimming freely is that of *Ergasilus chautauquaënsis*. Both sexes of this species have been taken in the tow of Lake Chautauqua in New York, and of Lake Mendota in Wisconsin. The females were as abundant as the males, were fully matured, and carried egg cases. As yet neither sex of this species has been found on any host, so that we can not positively affirm that it ever becomes parasitic, but the probability is that it does.

Prehension.—These tiny creatures fasten themselves to the gill filaments, or rarely to the walls of the gill cavity, to the skin or the fins, by means of the second antennæ and the maxillipeds. For this purpose we find both these appendages enlarged and furnished with powerful muscles.

Their terminal joints are in the form of stout and sharp claws, while they are further armed with spines and roughened surfaces to prevent slipping.

The second antennæ are usually the chief organs of prehension and are enlarged in nearly all the species. In the Ergasilinæ they are often as long as the carapace or even the entire body, while the maxillipeds are wanting in the female.

These antennæ are thus long enough to reach around the gill filament and give the parasite a firm hold.

In the Bomolochinæ, however, while the second antennæ are enlarged and well armed with claws, spines, and roughened surfaces, they are not the chief organs of prehension. But this distinction belongs to the maxillipeds whose terminal joint is developed into a stout curved claw, capable of grasping a gill filament or of being driven into the tissue of the wall of the gill cavity, or into a fin.

The Ergasilidæ have no lunules or sucking disks, such as were found among the Caligidæ, and in the majority of the genera this mode of prehension can not be employed.

But in the genus *Bomolochus*, especially those species which frequent the nostrils of the cod and allied fish, and in the Tæniacanthinæ the carapace is so arched as to act like a large sucking disk, its margin being pressed close to the surface of the skin and the contact sealed with mucus and water.

This makes an effective prehensile organ in the quiet of such cavities as the nostrils and often obviates the necessity of setting the claws into the skin.

That the hold maintained by these parasites upon their host is quite secure is realized when one tries to remove them. Long practice

has shown that the best way to accomplish this on the gills is as follows. The body of the parasite is always parallel with the gill filament around which are clasped either the second antennæ or the maxillipeds. The head of the parasite is always toward the base of the filament or the gill arch from which the filament proceeds. If a blunt pointed needle, like a tape needle, be inserted from the base of the filament between the latter and the body of the parasite, the creature may be swept down along the filament and off its end with considerable ease. This method possesses the further advantage of removing as little slime along with the parasite as possible and in particular, by holding the mouth-parts out away from the filament, helps to keep them clean and free from obnoxious matter.

Locomotion.—The two sexes are similar in structure; each possesses four pairs of well-developed swimming legs, which are perfectly capable of functioning during the larval stage of development. But while this power is retained by the adult male, it is usually diminished in the female, and the latter when placed in an aquarium often shows no tendency to swim about, but lies inert upon her back wherever she may be placed. Under sufficient provocation, however, the females can move with considerable rapidity, but never with the agility exhibited by the males.

T. Scott, after noting that *Bomolochus soleæ* is frequently found in the nostrils of the cod, adds (1901, p. 122):

This habit on the part of *B. soleæ* is the more interesting when it is remembered that it is a "free-living" species, and that there appears to be nothing to hinder it from leaving the nostrils of the fish, for it can move freely about amongst the mucus with which the nostrils are usually well supplied, and if the copepods are removed and placed in clean sea water they may be seen swimming or running about with nearly as much agility as the free-swimming species.

Both sexes of *Ergasilus chautauquaënsis* were captured with other crustacea while swimming freely at the surface of Lake Chautauqua in New York. And the males of all the common species of *Ergasilus* are found in the tow of our fresh-water lakes and ponds as has been noted by nearly every observer in recent years who has studied the plankton of such localities at all carefully. These observations all go to prove the close relationship of the present family with the free-swimmers. They show that, in spite of the parasitic habits they have acquired, they still retain to a considerable degree this form of locomotion.

But they have also acquired another method of moving about which has come as a direct result of their parasitism. Vogt has called attention (1877, p. 98) to the fact that the two sexes are never found attached side by side on the same gill filament, but the male is always at some distance from the female. Hence it follows that the males at least must move about in search of the females, and this ability

being recognized for that sex one can not refuse it to the females also. Indeed the present author has repeatedly witnessed it when the gills of some fresh-water fish were placed under the dissecting microscope for the purpose of removing these parasites. On being disturbed they may often be seen to move considerable distances up or down the filament to which they are clinging. This movement is accomplished by alternate motions of the second antennæ and swimming legs, in much the same way as a man uses his arms and legs in climbing a pole.

If there is this freedom of motion on a single filament it is reasonable to believe that they can also move from one filament to another, since the filaments are closely interwoven in the living gill. This belief is strengthened by the fact that the parasites are usually found on those filaments which are nearer the ends of the arches, leaving the ones along the center free. This could hardly happen by chance in so great a majority of the cases, but must be the result of a selective choice, which necessitates the power of moving about over the gills in order to reach these positions. Many species of the genus *Bomolochus* are found in other places upon the fish's body besides the gills. And while in the water they are found capable of moving about over such surfaces with the same scuttling motion shown by *Caligus*, though not with the same rapidity.

This family of copepods therefore possess all the methods of locomotion known in the group.

Because they retain so fully their powers of locomotion the Ergasilidæ do not show as much degeneration as the Caligidæ. Indeed there is but a single genus, *Tucca*, which can be regarded as at all degenerate. The others only exhibit the preparatory stage to degeneration in which the female becomes fixed upon her host and loses her incentive for free swimming.

Hosts.—In general these parasites may be found upon our common food and game fish, often in considerable numbers. Among fresh-water fish the bass, perch, sunfish, pike, and carp are nearly always infested. This is especially true of the red-eye or rock bass, *Ambloplites rupestris*, nearly every specimen of which is sure to yield parasites the number of which from a single fish often reaches the hundreds.

Among salt-water fish the needle fishes (Esocidæ), the gizzard shads (Dorosomidæ), the sauries (Scomberesocidæ), the balaos (Hemirhamphidæ), the soles (Soleidæ), and many members of the large family of Gadidæ are common hosts.

Besides these which may be considered regular hosts, there are of course many others upon which some species of the family may be occasionally found. Owing to the fact that the great majority of them retain so fully their power of free swimming, these Ergasilidæ

are much more widely distributed than the Caligidæ. The latter family contains three or four times as many species as the former, yet only one or two of them are cosmopolitan, while in the Ergasilidæ there are half a dozen or more found in all parts of the world.

Food.—Living as they thus do upon the fish's gills, there can be but little doubt that they feed upon blood.

Such a conclusion is further evidenced by the structure of the mouth-parts, which are so degenerate as to be unfit for biting or chewing but are well suited for piercing such delicate tissues as cover the gill filaments.

MORPHOLOGY.

General body form.—As in the Caligidæ the body of an Ergasilid is made up of four parts or regions, a cephalon or cephalothorax, a free thorax, a genital segment, and an abdomen (fig. 1).

The first thorax segment is generally united with the head to form the cephalothorax, the two being covered with a carapace which in many species is so strongly inflated that it overlaps the following thorax segments to a greater or less degree. In the females of the *Bomolochinæ* and *Tæniacanthinæ* and in the genus *Thersitina* the fusion is complete, and there is no line of demarcation visible between the two. But in the females of the genus *Ergasilus* the fusion is not complete, and there is a well-defined groove or at least a pair of notches in the lateral margins of the carapace to indicate the point of union. In the males of nearly all the genera the first thorax segment is free like the others. This cephalothorax is more strongly arched than in the Caligidæ, and in the genus *Thersitina* it becomes almost hemispherical. This is at

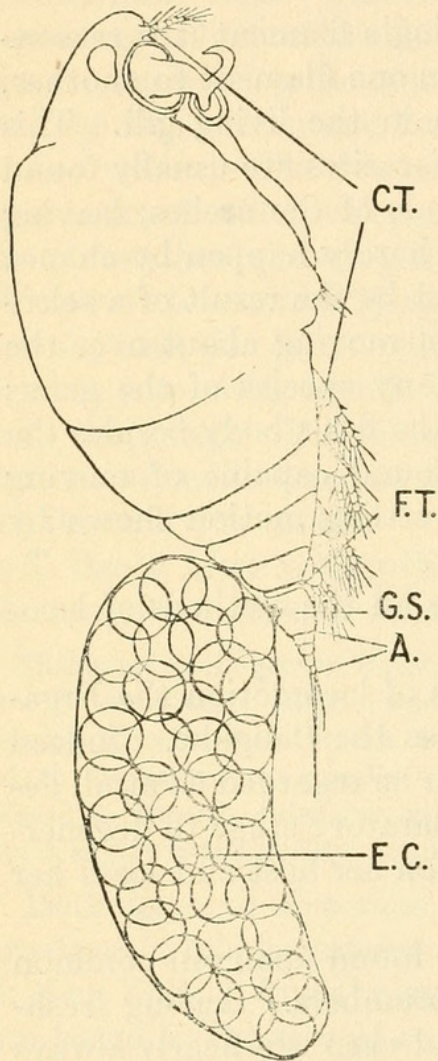


FIG. 1.—SIDE VIEW OF A FEMALE ERGASILUS MANICATUS, SHOWING BODY REGIONS: A, ABDOMEN; C T, CEPHALOTHORAX; E. C., EGG CASES; F. T., FREE THORAX; G. S., GENITAL SEGMENT.

least partly explained by the fact that in the females the ovaries and ovarian diverticula are just beneath the carapace and require considerable space, especially when the eggs are fully developed. The carapace is perfectly plain and without sinuses; the only grooves visible are a horseshoe-shaped groove, which in some species surrounds the cephalon proper, very similar to that in the Argulidæ, and in the genus *Ergasilus* a transverse groove separating from the rest of the

carapace a large anterior shield connected with the bases of the second antennæ (fig. 2). This latter groove does not in any way indicate the limits of the cephalon, since the mouth-parts are situated posterior to it on the ventral surface. Furthermore, in most of the species no groove at all is visible, and consequently it is not feasible to divide the carapace into areas as was done in the Argulidæ and Caligidæ. The cuticles covering the dorsal and ventral surfaces of the cephalothorax are fused along the margins, but they do not form a flexible border as in the Caligidæ. In those species of the Bomolochinæ and Tæniacanthinæ in which the carapace forms a sucking disk for prehension the edges of this disk are formed of the ventral cuticle rather than of a fusion of the two cuticles.

The eyes are situated close to the anterior margin of the carapace and are fused on the mid-line near the ventral surface. Their inner margins, in contact with each other, are heavily pigmented, while the outer portions are clear and transparent. No definite lens is visible. In most of the species of the Bomolochinæ and Tæniacanthinæ the eyes are invisible, but this is probably due to the inflated condition of the cephalothorax and the opacity of its contents. They are certainly present in the genus *Ergasilus* and in some species of *Bomolochus* (*teres*), *Artacolax* (*cornutus*), and *Thersitina* (*biuncinata*). They do not change their position during development as in the Caligidæ, but appear in the same place in the youngest nauplius stage as in the adult.

Free thorax and genital segment.—The thorax is composed of six segments, the first of which is usually joined with the head, while the sixth constitutes the genital segment, thus leaving four free segments, each of which bears a pair of swimming legs. In such males and immature females as have been found the genital segment also bears a pair of rudimentary legs, but these can not be seen in most of the adult females (see pl. 58, fig. 200). The thorax segments usually diminish regularly in size from in front backwards; the fifth is rudimentary and very short, and is often so overhung by the preceding segments as to be invisible in dorsal view. The legs which it bears are also rudimentary, uniramous, and one or two jointed. They are sometimes reduced to mere papillæ, each bearing one or more short spines, or even to simple spines without any papillæ. In the Caligidæ evidence was found that the so-called genital segment is really a fusion of two segments, the anterior of which, the fifth segment, is the larger.

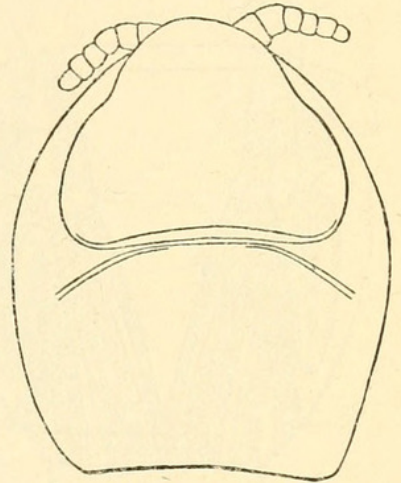


FIG. 2.—DORSAL SURFACE OF CARAPACE IN *ERGASILUS CENTRARCHIDARUM*, SHOWING THE LARGE ANTERIOR SHIELD CONNECTED WITH THE BASES OF THE SECOND ANTENNÆ. FIG. 11 (P. 286) SHOWS THE POWERFUL MUSCLES ATTACHED TO THIS SHIELD.

In the present family the fifth segment is considerably the smaller and is usually well separated from the sixth. But in a few species the two are thoroughly fused, yet even here the fusion is still indicated by the presence of the fifth legs attached to either side of the compound segment near its anterior margin.

The sixth segment is less worthy of bearing the name "genital" than it was in the Caligidæ.

In that family it contains the convolutions of the oviduct within which most of the development of the eggs takes place, the large cement glands which furnish the material for the external egg cases, and the sperm receptacles from which the eggs are fertilized as they pass out into the cases.

Here in the Ergasilidæ it apparently contains nothing but the posterior portion of the sperm receptacles and a somewhat complicated musculature which controls the openings of the oviducts.

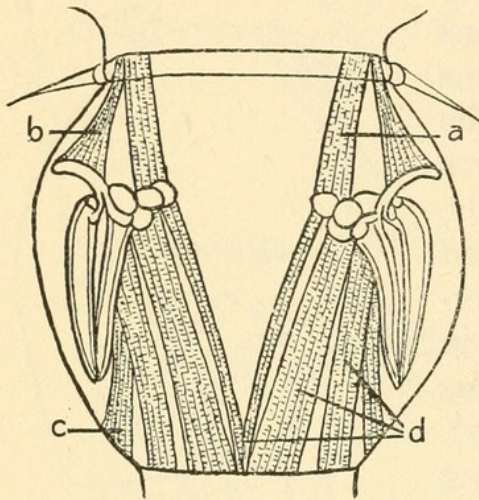


FIG. 3.—DORSAL SURFACE OF THE GENITAL SEGMENT OF *ERGASILUS CENTRARCHIDARUM*, SHOWING THE COMPLEX MUSCULATURE. *a* AND *c*, CLOSING MUSCLES; *b* AND *d*, OPENING MUSCLES.

The convolutions of the oviducts and the cement glands are situated farther forward in the free thorax and cephalon. There the eggs are matured, and when ripe they simply pass out through the genital segment one by one, without remaining in it for any length of time. And yet, understanding this, it is better to retain the old name and thus avoid confusion. In this family, therefore, the genital segment approaches more nearly to the structure of the other thorax segments and varies but little more than they in

shape and size in the two sexes and in different species.

It is somewhat enlarged, to be sure, but never as much as in the Caligidæ, and is fairly uniform in shape throughout the group. It is relatively smaller in the males and immature females, but the difference in size is only trifling.

Accordingly, there is not much danger that the careful systematist will mistake an immature female for a male, as has frequently been done when dealing with the Caligidæ.

And there is not as rigid a demand for absolute precision as to the stage of development or the degree of maturation when comparing different specimens for purposes of classification. The eggs are arranged in several longitudinal rows, the number varying in different species. The length of the rows and the shape of the sacks also varies, but in general the sacks are club-shaped, larger at the posterior end, and are very similar to those of *Cyclops*.

The abdomen is always narrower and nearly always longer than the genital segment, and is three-jointed in the great majority of species. In the genera *Irodes* and *Phagus*, however, it is four-jointed, while in the genus *Tucca* it has but a single joint.

In adult females segmentation is usually indistinct, being indicated only by notches along the lateral margins without a continuous groove. In the males and in the females of a few species the grooving is more distinct.

The anal laminae are long and narrow, and the setae with which they are armed are usually much longer than the entire abdomen. We have thus in the general body form a cephalon bearing six pairs of appendages, a thorax of six segments, each bearing a pair of swimming legs, the sixth pair often lacking in the adult female, and an abdomen of one, three, or four segments, the last of which bears the anal laminae.

The appendages.—There are 12 pairs of appendages, namely, two pairs of antennae, one pair of mandibles, two pairs of maxillae, one pair of maxillipeds, and six pairs of swimming legs. These are all on the ventral surface with the exception of the first antennae, which arise from the frontal margin and curve upward toward the dorsal surface.

There is no one genus, however, in which all these appendages are present and normally developed. One or more pairs are often lacking, such as the maxillipeds, or the sixth pair of swimming legs. Again, the first maxillae and the fifth pair of legs, which are always present, are also always more or less rudimentary (fig. 4).

The *antennules* or first antennae are attached to the frontal margin, a little

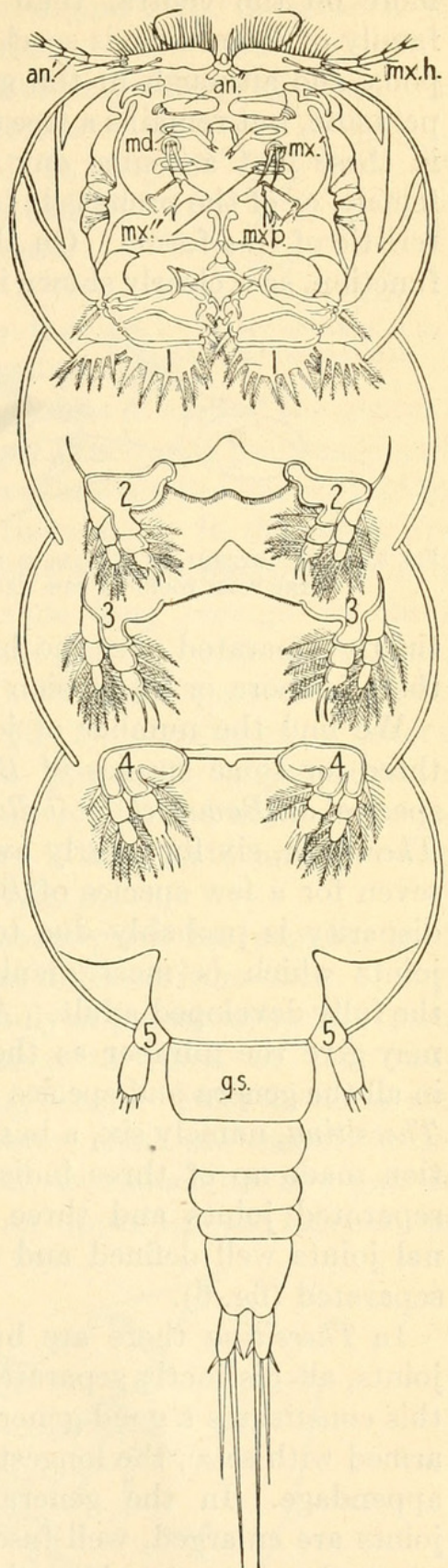


FIG. 4.—VENTRAL SURFACE OF *TENUICANTHUS CARCHARIAE*, SHOWING APPENDAGES (AFTER SUMPFF). *an'*, FIRST ANTENNA; *an''*, SECOND ANTENNA; *gs.*, GENITAL SEGMENT; *md*, MANDIBLE; *mx. h.*, MAXILLARY HOOK; *mx'*, FIRST MAXILLA; *mx''*, SECOND MAXILLA; *mxp*, MAXILLIPED; 1 TO 5, SWIMMING LEGS.

more on the ventral than on the dorsal surface. Although this family of Ergasilidæ is so closely related to the free swimming copepods, and although in the genus *Ergasilus* the male never becomes parasitic, but remains a free swimmer throughout life, yet there is not in these first antennæ any trace of the locomotor function in the female, or of the prehensile function in the male, which are so characteristic of free forms. On the contrary, they are entirely sensory in function, as is clearly shown in their armature and innervation. They

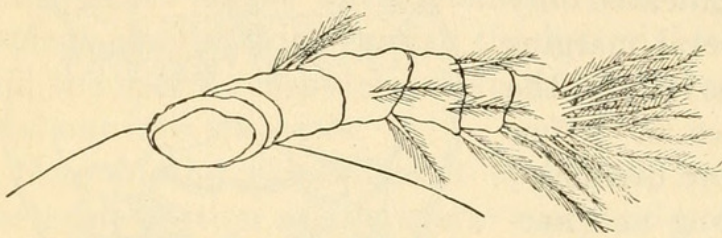


FIG. 5.—FIRST ANTENNA OF *ERGASILUS MANICATUS*, SHOWING THE FORM FOUND IN THE *ERGASILINÆ*.

are curved abruptly near the base in two directions, upward and outward, so that nearly the entire appendage is visible in dorsal view.

They are made up of joints which are indistinctly separated near the base of the antenna, and in most species there is more or less fusion here as a result (fig. 5).

We find the number of joints in these antennæ variously given, three for some species of *Bomolochus* (*denticulatus*), four for other species of *Bomolochus* (*bellones* and *parvulus*), five for the genus *Thersitina*, six for nearly every species of the genus *Ergasilus*, and seven for a few species of *Bomolochus* (*onosi*, *soleæ*, etc.). But this disparity is probably due to the indistinct separation of the basal joints which is most manifest in the fully developed adult. And we may give the number as the same in all the genera and species except *Thersitina*, namely six, a basal portion made up of three indistinctly separated joints and three terminal joints well defined and clearly separated (fig. 6).

In *Thersitina* there are but five joints, all distinctly separated, and this constitutes a good generic character (see p. 349). Each joint is armed with setæ, the longest of which are often as long as the entire appendage. In the genera *Bomolochus* and *Artacolax* the basal joints are enlarged, well fused and furnished with a heavy fringe of stout plumose setæ along their anterior margin. Interspersed with these setæ are tactile hairs without plumes, which are often as long as the entire antenna. In some species (*Bomolochus triceros*, *Artacolax scomberesocis*, etc.) a process is given off from the ventral surface of the basal joint which terminates in two or three large

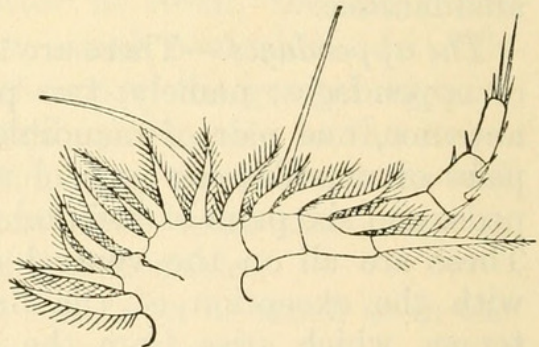


FIG. 6.—FIRST ANTENNA OF *BOMOLOCHUS EMMENS*, SHOWING THE FORM FOUND IN THE *BOMOLOCHINÆ* AND *TENIACANTHINÆ*.

tactile setæ. These are sensory in function and if the innervation is any criterion they must be highly sensitive.

These heavily armed first antennæ, curving around the anterior margin of the carapace, give the parasites a peculiar bristling front. And they stand out so prominently in most species that they can be plainly seen with the naked eye despite the small size of the creatures.

The *second antennæ* are attached to the ventral surface just posterior to the bases of the first pair. They are made up of four joints in each of the genera, but vary greatly in size and shape. Their function is prehensile and they terminate in one or more stout claws, or even become chelate in

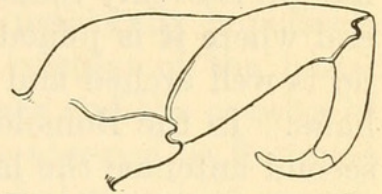


FIG. 7.—SECOND ANTENNA OF ERGASILUS CENTRARCHIDARUM.

some of the males. In the genus *Ergasilus* they are enormously enlarged and become long enough to clasp around the gill filaments of the host, thereby holding the parasite securely in place (fig. 7). In the other genera they are plentifully supplied with spines and roughened surfaces so as to secure a firm hold and prevent slipping (fig. 8).

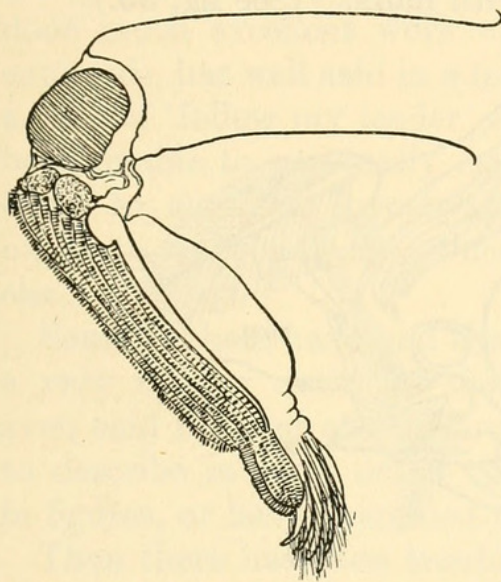


FIG. 8.—SECOND ANTENNA OF BOMOLOCHUS NITIDUS.

The *mouth-parts* are peculiar and altogether different from those of any other family of parasites, having more resemblance to those of the free-swimming forms. Most of them are rudimentary, some are usually lacking, and at least in the females of the Bomolochinæ one pair is abortive in position. They consist of an upper lip, the labrum, an

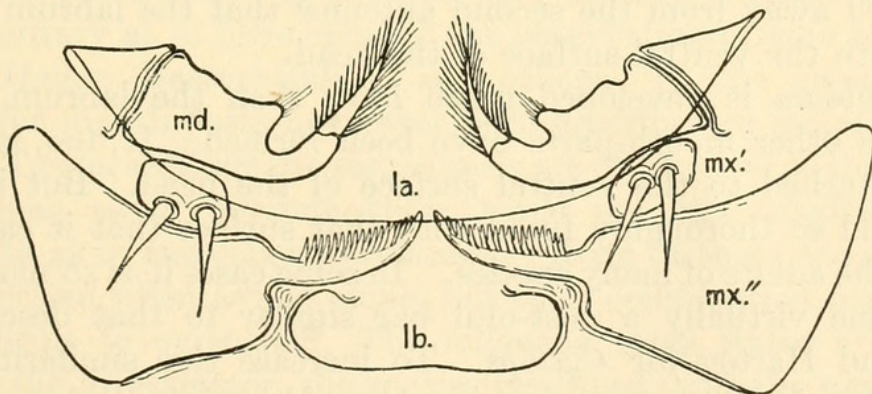


FIG. 9.—MOUTH-PARTS OF ERGASILUS MUGILIS. *la*, LABRUM; *lb*, LABIUM; *md*, MANDIBLE; *mx'*, FIRST MAXILLA; *mx''*, SECOND MAXILLA.

under lip, the labium, a pair of mandibles, a pair of maxillary hooks, two pairs of maxillæ, and one of maxillipeds.

The *labrum* is a chitin plate, usually somewhat obcordate or obovate in shape, often wider than long, and situated between and mostly posterior to, the bases of the second antennæ. Its posterior margin is evenly rounded and often has a large circular flap at either end where it is joined to the ventral surface of the carapace. The lip is well arched and covered in most species with short bristles or hairs. In the Bomolochinæ where the mouth-parts are close to the second antennæ the labrum is prominent and well defined, while in the Ergasilinæ where there is a considerable interval between the second antennæ and the mouth-parts, the labrum is fused with the ventral surface of the carapace and often difficult to distinguish. But in the early development stages of this latter family the upper lip is prominent and occupies a position similar to that in the Bomolochinæ, and is also sparsely covered with hairs. (See fig. 35.)

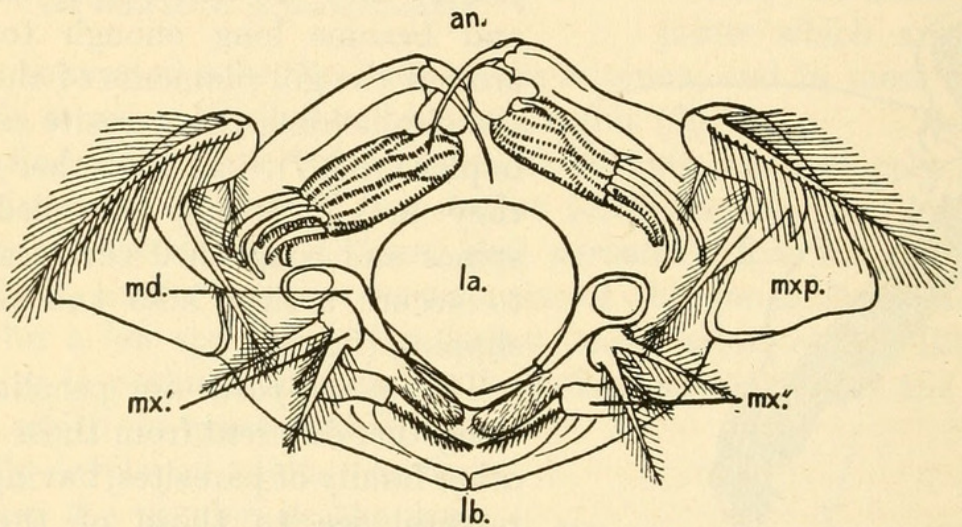


FIG. 10.—MOUTH-PARTS OF BOMOLOCHUS EXILIPES. *an*, SECOND ANTENNÆ; *la*, LABRUM; *lb*, LABIUM; *md*, MANDIBLE; *mx'*, FIRST MAXILLA; *mx''*, SECOND MAXILLA; *mxp*, MAXILLIPED. BETWEEN THE TERMINAL JOINTS OF THE MANDIBLE AND SECOND MAXILLA CAN BE SEEN A HAIRY STRUCTURE SIMILAR TO THE PARAGNATHS IN FREE-SWIMMING FORMS.

It must be therefore during the migration of the mouth-parts backward away from the second antennæ that the labrum becomes fused with the ventral surface of the head.

The *labium* is developed much later than the labrum, in fact, after the other mouth-parts have been formed. It, too, is a chitin plate attached to the ventral surface of the head. But it is flattened and so thoroughly fused with that surface that it can not be seen in the adults of many species. In some cases it is so narrowed as to become virtually a post-oral bar similar to that described by Claus and Hartog for *Cyclops*. To increase this similarity in the genus *Bomolochus* a process runs forward and inward from either end of the post-oral bar and below the shafts of the mandibles, thus resembling the processes called paragnaths in *Cyclops*. These processes are usually covered with short stiff hairs.

In the interpretation of the other mouth-parts the literature dealing with this family has shown a wide divergence of opinion, due to a variety of causes. We may first mention the excessive minuteness of these appendages and the accompanying opacity of the cephalon. They are so small that it is practically impossible to make any dissection that will reveal the relation of the parts. One is compelled to study them actually in place and the opacity of the cephalon proves a serious obstacle. If the copepod be flattened sufficiently to push out the contents of the cephalon and let enough light through to render the mouth-parts visible, the latter are practically certain to be twisted or folded out of their natural shape. Furthermore most of the investigators have worked with preserved material in which such methods were impossible. Again, as Mr. Andrew Scott, esq., of the Fisheries Board of Scotland, who has done much excellent work upon both parasitic and free-swimming copepods, has well said in a letter to the author: "It has simply been a case of 'follow my leader' with many writers." They have either been unable to personally examine these mouth-parts, or they have come to such an investigation with preconceived ideas of what ought to be found, and of course have been unable to see anything else.

Some of them have had the good sense to content themselves with a very meager notice of the mouth-parts thus examined, or have even said nothing at all about them. But others have felt obliged to describe in some detail these organs which they have seen only in figures, or have examined through "colored spectacles."

Then there has been trouble arising from the degeneration of the mouth-parts, and the consequent abortion or disappearance of some of them. In the Ergasilinæ the maxillipeds have entirely disappeared in the female, while the first maxillæ are so rudimentary as to require careful search to detect them. In the Bomolochinæ the maxillipeds are abortive in position, and the first maxillæ are again so rudimentary as to have escaped the observation of such investigators as Heller, Bassett-Smith, and others. In the genus *Tucca* none of the mouth-parts have ever been described or figured.

In the Tæniacanthinæ the maxillipeds are often fused so thoroughly to the head as to be immovable, while the first maxillæ are as degenerate as in the other subfamilies. None of these causes ought to be effective when acting alone, but their combination has proved very difficult to overcome. The following table states briefly the name of the investigator, the species described, and the name given to each of the appendages; a blank indicates that the author made no mention of the appendage in question.

Author.	Species described.	Mandible.	Maxillary hook.	1° maxilla.	2° maxilla.	Maxilliped.
Burmeister, 1833.	<i>Bomolochus bellones</i>	Tooth.....	Wanting.....	Tooth.....	Tooth.....	2° maxilliped.
Claus, 1864.	<i>Eucanthus batistæ</i>	Mandible.....	Haken.....	Maxilla.....	1° maxilliped.....	Hornhaken.
Heller, 1865.	<i>Bomolochus megaceros</i>	1° maxilliped.....	Wanting.....	.....	2° maxilliped.....	2° maxilliped.
Heller, 1865.	<i>Bomolochus gracilis</i>	Mandible.....	H a k e r Seitenan- hang.	.....	1° maxilliped.....	.....
Hartmann, 1870.	<i>Bomolochus belones</i>	Mandible.....	Wanting.....	Mandibular palp.	1° maxilliped.....	2° maxilliped.
Sumpf, 1871.	<i>Tæniacanthus carchariæ</i>	Mandible.....	Chitenhaken.....	Maxilla.....	1° maxilliped.....	2° maxilliped.
Claus, 1875.	<i>Ergasilus sieboldii</i>	Mandible.....	Wanting.....	Maxilla.....	1° maxilliped.....	Wanting in ♀.
Wright, 1882.	<i>Ergasilus centrarchidarum</i>	Mandible and maxilliped.	Wanting.....	.....	1° maxilliped.....	Wanting in ♀.
Fellows, 1888.	<i>Ergasilus chautauquaënsis</i>	Mandible and maxilliped.	Wanting.....	.....	1° maxilliped.....	2° maxilliped in ♂.
Bassett-Smith, 1898.	<i>Bomolochus triceros</i>	Mandible.....	Wanting.....	.....	.....	Hamulus.
Bassett-Smith, 1898.	<i>Bomolochus tetradomis</i>	Mandible.....	Hamulus.....	.....	1° maxilliped.....	2° maxilliped.
T. Scott, 1902.	<i>Bomolochus soleæ</i>	Mandible.....	Wanting.....	Maxilla.....	1° maxilliped.....	2° maxilliped.
Gadd, 1904.	<i>Ergasilus sieboldii</i>	Maxilla.....	Wanting.....	M a x i l l a r y palp.	Maxilliped.....	Wanting in ♀.
Brian, 1906.	<i>Pseudoencanthus alosæ</i>	Mandible.....	Wanting.....	.....	1° maxilliped.....	2° maxilliped.
Brian, 1906.	<i>Bomolochus murængæ</i>	Mandible.....	Wanting.....	Maxilla.....	1° maxilliped.....	2° maxilliped.
Brian, 1906.	<i>Anchistrotos gobii</i>	Mandible.....	H a m u l u s lateralis.	Maxilla.....	1° maxilliped.....	2° maxilliped.

From this list it can be seen that each mouth-part has borne at least three different names, while the first maxillæ in the genus *Ergasilus*, and in many species of the genus *Bomolochus* have been overlooked by every author except Claus and Gadd. Both of these investigators describe the same species, *Ergasilus sieboldii*, but give very different names to the mouth parts, as can be seen.

Such being the conditions it remains to determine the correct names for the various appendages, and to state the reasons for the decisions made.

The mandibles.—Most of the authors are agreed that the first pair should be called mandibles. Heller designates them thus in his *Bomolochus (Irodes) gracilis*, but calls the same organs in *B. megaceros* first maxillipeds. In the latter case he claims to have found the mandibles entirely inside of the mouth. If this be true it is the only instance in the entire family, and would at least be worthy of a generic distinction. This, and the fact that Heller wholly overlooked the first maxillæ, while he contends that the maxillipeds correspond to the first maxillæ in *Caligus* and *Lepeophtheirus*, enable us to dismiss his objection as a case of mistaken identity. (See p. 384.)

Wright (1882) and Fellows (1888) call the first pair of appendages mandibles, but the palps attached to them they call maxillæ. This is easily explained from the fact that neither of them found the true maxillæ, and hence they were forced to substitute something for them.

Gadd (1904) describes and figures the mouth-parts of *Ergasilus sieboldii* and claims that the first pair of appendages are maxillæ, and that the true maxillæ are their palps.

As reasons for his belief, he declares (a) that the latter are attached to the former in the manner of palps; (b) that some forms like the genus *Lichomolgus* (which he includes in the Ergasilidæ) possess a rudimentary sucking mouth with inclosed mandibles. Hence if there were any mandibles in *Ergasilus* they would be inside the mouth, where Heller claimed to have found them for *Bomolochus*. And the fact that there are none there means that they have degenerated enough to have disappeared. This sounds plausible, but any assurances the text may have given us are quickly dispelled when we come to examine Gadd's figures.

After all an author's illustrations give us the best idea of what he has really seen; the text may contain much that is imaginary in the way of interpretation.

Gadd figures the mouth-parts of two species which he refers to the genus *Ergasilus*. The first, which he calls *E. biuncinatus*, apparently belongs to the genus *Thersitina*, but however that may be, he has figured the mouth-parts *upside down* (pl. 1, fig. 19). That is to say, the "maxilliped" is placed above (in front of) the "maxilla" on

the plate, and both appendages are inverted. If the figure be turned so as to bring the appendages into their proper positions, then the "maxillary palp," as Gadd designates it, is in front of (anterior to) the maxilla, which is not where such a palp belongs. The second figure (pl. 1, fig. 23) represents the mouth-parts of a female of *E. sieboldii*.

This figure is turned down on its side, and must represent the left side of the mouth parts, as seen in a somewhat diagonal view, partly ventral and partly lateral. Here the "maxillary palp" is behind (posterior to) the "maxilla," and there are two "first maxillipeds," exactly alike and attached one behind the other, which is rather difficult to explain.

Moreover the basal joint of the true mandible (which Gadd calls a maxilla) is not represented at all, but in the figure the appendage looks as if it were attached directly to the upper lip. In the face of such radical mistakes we can only conclude that Gadd's observations were inaccurate, and hence his arguments lose their power.

That this first pair of appendages are true mandibles is evidenced by the following facts:

1. They are the first or anterior pair, are situated in just the right position with reference to the upper lip, and correspond exactly in all the genera belonging to the Ergasilidæ.

2. If they are maxillæ, then the mandibles are lacking, a condition occurring nowhere else among the parasitic copepods and contrary to the facts established by degeneration.

3. In the great majority of species they project into the mouth under the upper lip (see figs. 9 and 10). They are thus partially, and in some species almost wholly, inclosed, a condition which would be anomalous for the maxillæ, but just what we should look for in mandibles.

4. Comparison with free-swimming forms shows that the organs under discussion are analogous in structure and position with the mandibles of the latter.

5. In genera like *Taeniacanthus* and *Anchistrotos*, where all the mouth-parts are present, we are certain that this first pair must be mandibles. If so, they are also mandibles in the other genera.

The maxillary hooks.—These are present only in the genera belonging to the subfamily Taeniacanthinæ, where they have been described by Claus (1864), Heller (1865), Sumpf (1871), Bassett-Smith (1898), and Brian (1906). Each of these authors has given them a different name, although the general meaning of the names is the same. (See table, p. 278.)

Heller and Brian state positively that these appendages correspond to the ones found in *Caligus* and *Lepeophtheirus*, and the other authors tacitly agree to this by giving them the same name that each

bestows upon the corresponding organ in the Caligidæ. But A. Scott (1901, pp. 10 and 25) has shown by a careful study of the innervation that these organs in *Lepeophtheirus* are probably the first maxillæ, or some portion of them, migrated from their normal position beside the mouth and transformed into prehensile organs.

• He called them the first maxillæ, and the other pair close to the mouth the second maxillæ. The present author, confirming Scott's observations by an examination of other species of *Lepeophtheirus* (*edwardsi* and *salmonis*) and also certain species of *Caligus* (*rapax* and *bonito*), adopted the same nomenclature in dealing with the Caligidæ (1905, p. 499).

But in both instances these names were given upon the assumption, put forward by Claus and others, that the two posterior pairs of mouth-parts were the exopod and endopod of one and the same appendage. Hansen, however, discovered in the larvæ of certain marine copepoda (*Eucalanus*, *Pontella*, etc.), whose body is more elongated than usual, that the two appendages are entirely distinct. Furthermore the posterior pair arise behind the suture line which separates the head from the first thorax segment. Hence they belong to the latter segment and are true maxillipeds, while the anterior pair become maxillæ. These observations have been confirmed by Giesbrecht and by Claus himself upon the same or similar long bodied larvæ. They are also confirmed in the present paper upon the larvæ of *Ergasilus centrarchidarum* (p. 323). But this definite proof that the posterior mouth-parts are thoracic, while the pair just in front of them are cephalic, makes one of two things necessary. Either there are three pairs of maxillæ in some copepod genera, or the first two pairs are different portions of the same pair. The latter seems much the more probable for several reasons: 1. When completely developed (Calanidæ, Pontellidæ, etc.) the first maxillæ are made up of a distinct endopodite, exopodite, and epipodite, while the protopodite is produced internally into a large masticatory lobe. 2. In all those genera possessing these lateral hooks, the first maxillæ consist of but a single one of these parts, or at the most two of them, and are very rudimentary. The lateral hooks might well be one of the other parts, say the exopodite, migrated outward a little toward the lateral margin of the carapace, while the endopod has remained in close proximity to the mouth. In the Caligidæ the two parts are opposite each other, while here in the Ergasilidæ the outer one remains where it first appears in the metanauplius stage and the inner one migrates backward with the other mouth-parts. 3. The two nerves which supply these appendages are distinct to their very origin in *Lepeophtheirus pectoralis* according to Scott. In *Lepeophtheirus edwardsi* they are united for a short distance from their origin, while in some *Caligus* species they are distinctly branches from a common trunk.

This furnishes a strong argument in favor of the community of origin of the appendages themselves.

This question can be definitely settled only in the same manner as was the origin of the two posterior pairs of appendages. Some species possessing these lateral hooks will give us a larva on whose body the two appendages in question can be traced to their origin. In the meantime we can only say that the hooks in the Ergasilidæ certainly correspond to the similar appendages in the Caligidæ.

They appear to be situated farther forward, but this is largely due to the backward migration of the mouth-parts. For the present, then, we are justified in calling them maxillary hooks and in regarding them as closely related to the first maxillæ.

The first maxillæ.—These were first described for the genera *Bomolochus* and *Eucanthus* (*Anchistrotos*) by Claus in 1864 who designated them correctly as maxillæ, and they have been thus recognized in these genera by all subsequent investigators. In 1875 Claus described the corresponding appendages in the genus *Ergasilus* and called them also maxillæ.

But in this latter genus they have been either overlooked by other authors, or when seen (Gadd, 1904) have been regarded as palps of the mandibles. That they are distinct appendages, although very rudimentary, appears certain from the following considerations:

1. In the genera *Tucca* and *Taeniacanthus* this pair of mouth-parts is separated by a considerable interval from those on either side of them. The space is wide enough to show that they are not attached to any other pair. But the fact that they are distinctly separate appendages here furnishes a strong argument that they are also separate in the other genera. Their juxtaposition is the result of a crowding together of the appendages during their backward migration, and does not indicate actual union.

2. Again, there is altogether too close an agreement in size, shape, position, and armature between these organs in the different genera, and in the two sexes of the same genus, to allow us to consider them as palps. Palps vary greatly in different species, to say nothing of different genera, and they usually show marked sexual variations. These appendages are not only present, but are practically identical in every species throughout the entire family, and thus furnish good proof of their disconnection.

3. Among the Caligidæ this pair of maxillæ show marked degeneration; the exopod is reduced in size and much simplified, while the endopod has degenerated in some species to a mere knob, armed with one or two setæ. Here in the Ergasilidæ the exopod has entirely disappeared from all the species if it is not to be found in the maxillary hooks, as just suggested, and the endopod has degenerated into a knob armed with setæ. The structure therefore is exactly what

we should look for as a result of degeneration in the maxillæ, but it is radically different from anything that can be found in the way of mandibular palps among either the parasitic or free-swimming forms.

4. Finally the mandibles in the genera *Tucca* and *Ergasilus* and in some species of *Bomolochus* already possess well-defined palps attached where one would expect to find them, at the tips of the basal joints and entirely distinct from these maxillæ. Hence the latter, if regarded as palps, would form a second pair on the same appendages and attached at the very base of the basal joints—an untenable supposition.

The second maxillæ.—Burmeister and Heller are the only two authors who have not agreed in calling this pair of appendages the first maxillipeds. But the following considerations identify them as maxillæ and not maxillipeds.

1. From the close relationship between the Ergasilidæ and free-swimming forms we should naturally expect the mouth-parts to correspond in origin and development. By reference to figures 34 and 37 it will be seen that this penultimate pair of mouth-parts arises in front of the suture which separates the head from the thorax, while the last pair arises behind it. The latter appendages therefore are thoracic in origin, and must be regarded as maxillipeds, while the former are cephalic and are just as surely maxillæ.

2. The correspondence of this third pair of mouth-parts with the second maxillæ in free-swimmers is further shown by their relation to the paragnaths in certain species (*Bomolochus soleæ*, *Artacolax sætiger*, etc.). The proximity of the base of the appendages to the paragnaths shows them to be identical with the second maxillæ of free-swimmers.

The maxillipeds.—Two facts have contributed to the confusion in regard to these mouth-parts. In the females of the genus *Ergasilus* they are entirely wanting, while in those of the genus *Bomolochus* they are abortive in position, being attached outside, and partly in front, of the other mouth-parts.

These two discrepancies have bothered many observers and have led to curious blunders. Burmeister failed to find them at all; Heller states plainly that they correspond to the maxillary hooks in *Caligus* and *Lepeophtheirus*; Bassett-Smith implies as much by designating them as "hamuli" and then applying the same term to the true maxillary hooks of *Bomolochus (Irodes) tetrodonis*.

That they are really maxillipeds, as Claus, T. Scott, Brian, and others have named them, seems conclusively proved by the following considerations.

1. Their position: The terminal hooks are situated far forward in the Bomolochinæ, even perhaps in front of the other mouth-parts, but we can not regard the appendage as attached there. Its posi-

tion must be determined by the basal end of the basal joint, even though that joint be fused with the ventral surface of the head for its entire length.

In the mature adult the second joint is usually called basal, but the proximal end of this joint is distinctly posterior to the other mouth-parts. Heller and Bassett-Smith both represent this correctly in their figures, but evidently failed to see its significance.

2. Their development: If we examine a half-grown female we find that these maxillipeds are really three-jointed, made up of two basal joints and a terminal claw. (See pl. 54, fig. 159.) In the mature female, carrying fully developed egg-strings, of the new species, *Bomolochus eminens*, both basal joints are still distinctly visible. (See pl. 53, fig. 151.)

Even the proximal end of the second joint, therefore, is not the true base of the appendage, but this is still farther back and directly behind the second maxillæ, in a position corresponding exactly to that in the male. To be sure, the appendage is turned outward instead of inward, and the second joint is turned forward outside of the other mouth-parts. But there can be no question that the basal joint is posterior to the second maxilla, and therefore this must be the maxilliped.

3. The analogy presented by the genera *Anchistrotos* Brian (*Eucanthus* Claus) and *Tæniacanthus* Sumpf. In each of these genera both pairs of maxillæ and the maxillipeds are present and in their normal position in the female as well as in the male. In *Anchistrotos* the second joint is free, but in *Tæniacanthus* it is fused solidly to the head.

Moreover, in the latter genus it is almost the exact counterpart of that found in the Bomolochinæ, a large triangular second joint and a terminal claw curved into an S-shape, but tipped with setæ. The similarity in shape and structure is sufficient to establish the identity of the appendages. In these two genera, therefore, they are unquestionably maxillipeds, and hence must be so regarded in the Bomolochinæ.

4. The analogy presented by the appendages of the male: This sex was discovered by Claus for the genus *Bomolochus* in 1864, and was found to possess large and powerful three-jointed maxillipeds, which were normally placed behind the other mouth-parts. The structure and position of these organs in the male are so typical that no one would think of calling them anything but maxillipeds. But when we come to examine them we find that their basal joints are attached considerably outside the other mouth-parts, in a position corresponding to that of the proximal end of the second joint of the same appendages in the female.

The one appendage is manifestly the homologue of the other; if we call it a maxilliped in the male, as its position, structure, and function plainly indicate, we must also call it a maxilliped in the female, even though it be degenerate, fused with the head, and considerably changed in form and apparent position.

Having determined here the names and relation of the several mouth parts, brief diagnoses will be given of them as actually found in the two sexes of a selected type under each of the three sub-families (see pp. 311, 350, and 382).

The swimming legs.—The first four pairs of swimming legs are biramose in each of the genera. The rami of the first pair vary greatly; in *Thersitina* and *Ergasilus* alone are they cylindrical and three jointed like those of the other legs.

In all the other genera they are flattened into lamellæ, obscurely jointed if at all, and with a fringe of large plumose setæ around the entire margin. The rami of the second, third, and fourth legs are alike in all the genera, slightly flattened, three or four jointed, and well armed with plumose setæ. The fifth legs are uniramous, rudimentary, and usually two jointed, with setæ only at the tips. A sixth pair of legs is present in most genera upon the genital segment, and are like those found in the same position in the Caligidæ, simple knobs, armed with spines or setæ.

The *Anal laminæ* are slender, cylindrical or flattened, and armed with the usual plumose setæ, one or more of which are greatly elongated, sometimes to half the length of the entire body.

THE MUSCULAR SYSTEM.

The Ergasilidæ have bodies which are much thickened in proportion to their breadth; furthermore, both the ovaries and oviducts are developed inside the cephalothorax.

Hence these copepods are not as transparent as the Caligidæ, and the musculature is usually obscure, especially in the sexually matured female. But in the young of both sexes the body remains flattened and the muscles can be determined with comparative ease. The general arrangement of muscles is very simple as will be seen from figure 11, and their function is the flexion or extension of one part of the body or appendage upon another.

There are no frontal plates like those in the Caligidæ, but there are corresponding flexor muscles. It was suggested under that family that the frontal plates were really the basal joints of the first antennæ, fused more or less completely with the frontal margin of the carapace.

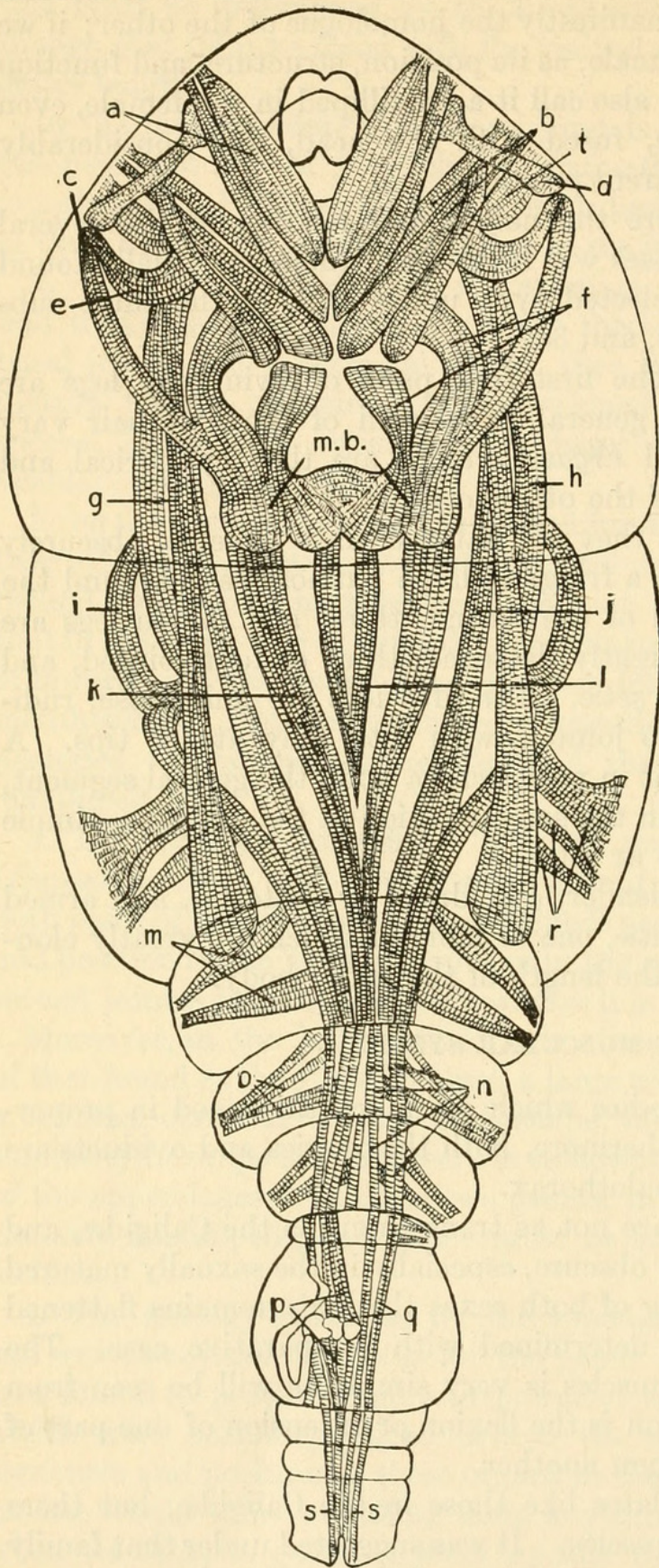


FIG. 11.—MUSCULAR SYSTEM OF *ERGASILUS VERSICOLOR* IN DORSAL VIEW. *a*, MUSCLES MOVING FIRST ANTENNA; *b* TO *f*, MUSCLES OF ENLARGED SECOND ANTENNAE; *g* TO *l*, FLEXORS OF HEAD AND FIRST TWO THORAX SEGMENTS; *m*, *o*, AND *r*, MUSCLES MOVING SWIMMING LEGS; *m. b.*, TRANSVERSE MUSCLE BAND; *n*, FLEXOR MUSCLES OF THIRD AND FOURTH THORAX SEGMENTS; *p*, MUSCLES CONTROLLING THE OPENING OF THE OVIDUCT; *q*, FLEXOR MUSCLES OF FIFTH AND GENITAL SEGMENTS; *s*, FLEXOR MUSCLES OF ABDOMEN. *t*, ACCESSORY MUSCLE OF SECOND ANTENNA.

Here in the Ergasilidæ these plates are free and are very manifestly a part of the antennæ. They still perform the same functions, being partly tactile and partly prehensile. And we find them operated by a pair of powerful muscles (*a*) on either side, corresponding in position and function with those which operate the frontal plates of the Caligidæ. These muscles are particularly well developed in the Bomolochinæ, where the basal joints of the antennæ are considerably enlarged, and even in the opaque cephalothorax of the mature female they show up prominently in dorsal view. (Pl. 52, fig. 138.)

Behind these and parallel with them are three pairs of strong muscles (*b*), extending from the mid-line diagonally outward to the very edge of the carapace. These produce flexion of the margin of the carapace similar to that produced by the corresponding muscles in the Caligidæ. But there is not the same freedom of motion here, since there are no grooves between the cephalon and the lateral areas, and

so but little flexion. The chief use of these muscles is to act as shoulder flexors in moving the large second antennæ, and in accomplishing this they are assisted by four other muscles on either side. One of these (*c*) is parallel with them and removed some distance farther back. It extends from a point near the mid line diagonally outward and strikes the lateral margin a little behind the three just mentioned.

The second (*d*) starts from this marginal end of the first and runs forward and inward, nearly parallel with the carapace margin. The third (*e*) and fourth (*t*) are curved and extend from the junction of the first and second downward and inward to the base of the second antennæ. These seven muscles on either side thus form an armature sufficiently powerful to manipulate the large second antennæ.

The diagonal muscle (*c*) is united at its posterior end with a pair of broad and ribbon-like curved muscles (*f*), which occupy the center of the head on either side of the mid line, and form a dorsal muscular band (*m. b.*), which serves as a basis of support and attachment for the muscles already described. Just outside this band there is a single muscle (*g*) on either side, which is the longest in the body. It reaches from the base of the second antennæ back through the head and first thorax segment, and into the second thorax segment, to whose dorsal surface its enlarged posterior end is attached. This powerful muscle aids in controlling the second antennæ, and also produces flexion between the head and thorax. Exterior to this long muscle and parallel to it is a much shorter one (*h*), extending from the base of the second antennæ back nearly to the center of the first thorax segment. This muscle produces flexion of the head upon the first thorax segment, and is assisted in this by a curved muscle (*i*), which arises much farther back on the dorsal surface of the head and runs through the first two thorax segments. This last muscle is divided near the center of the first segment and attached to the dorsal surface of the latter. It thus produces flexion not merely between the head and first segment, but also between the first segment and the three which follow it.

The remaining dorsal muscles consist of three on either side of the mid-line, which originate some little distance apart at about the middle of the head and beneath the transverse muscle band, and which converge rapidly backwards.

The outer one (*j*) is narrow in front and widens a little posteriorly, reaching to the posterior border of the second thorax segment. The middle one (*k*) is wider in front and narrows posteriorly, and also stops at the posterior border of the second thorax segment. The inner one (*l*) is the same diameter throughout, but only reaches a little beyond the center of the first segment. These muscles all produce flexion between the head, the first and the second thorax segments.

They are followed by other similar muscles (*n*), approximately parallel to the median line and close to it on either side. These are arranged in series, three pairs extending from each segment of the thorax forward into the preceding segment, from whose dorsal surface they originate. They produce flexion of one segment upon another.

There is a single set of similar muscles (*s*) in the abdomen, extending from the anus forward into the genital segment, where they are attached to the dorsal surface of the latter.

This indicates that while the abdomen may be divided into segments by grooves, it nevertheless operates as a single joint, and there is no flexion between its parts.

For moving the swimming legs there is a set of two muscles, or rather two bundles of muscles, (*m*) extending out from the median line to the basal joint of each leg. The posterior bundle extends outward from the median line itself and nearly at right angles to it. The anterior one is more inclined to the body axis and seldom reaches the center of the segment.

In the case of the first pair of legs both muscles are diagonal (*r*), and extend in but a very little ways toward the center of the segment.

There are finally in the genital segment the muscles which control the genital openings (fig. 3). These openings are irregular in shape and are situated on the dorsal or partly on the lateral surface of the segment, near its posterior end. Each is surrounded by a thickened and somewhat chitinous border, which has the shape of a much twisted letter V. The point of the V is close to the posterior corner of the segment, while the arms extend forward. Each arm is bent inward near its center toward the median line and the inner ends are enlarged. The posterior arm extends farther forward before bending and is bent almost at a right angle, whose terminal branch is considerably shorter than the basal. The anterior arm is bent at an angle of 45° ; its two portions are nearly equal, and the tip is prolonged anteriorly and posteriorly into a T shape. The muscles are attached to the ends of the V and are six in number in each half of

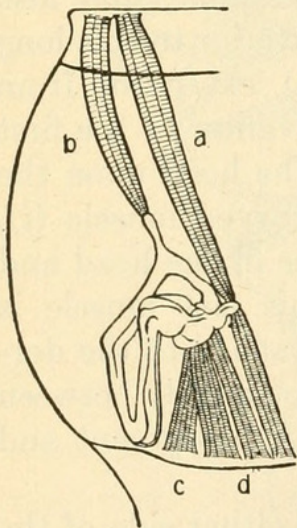


FIG. 12.—MUSCLES CONTROLLING OPENING OF OVIDUCT IN *ERGASILUS VERSICOLOR*. *a* AND *c*, CLOSING MUSCLES; *b* AND *d*, OPENING MUSCLES.

the segment, two extending anteriorly and four posteriorly. The two anterior muscles start from the outer anterior corner of the fifth segment and run diagonally backward and inward side by side. The outer shorter one (*b*) connects with the anterior horn of the T at the end of the anterior arm of the V. The inner and longer one (*a*) connects with the tip of the posterior arm of the V. Of the four pos-

terior muscles the first (*c*) runs from the posterior horn of the T backward and outward to the posterior corner of the segment. The other three muscles are attached to the end of the posterior arm of the V and run backward and inward side by side to the posterior margin of the segment. The working of these muscles to control the genital openings is simple; when muscles *a* and *c* contract the two arms of the V are pulled together and the opening is closed. When *b* and *d* contract the two arms are pulled apart and the opening is widened (fig. 12). In this manner the passage of the eggs outward into the external sacks is controlled.

If this muscular system be compared with that found in the Caligidæ, several conclusions may be drawn from the differences noted.

1. The lack of dorsal grooves on the carapace in the Ergasilidæ is emphasized by the entire absence of those internal muscles which in the Caligidæ produced more or less flexion between the different areas. There the carapace was made up of definite areas put together in such a way as to allow some motion between them. Here it is just as definitely one solid piece, with no possibility of motion between the various parts.

2. The fusion between the three anterior thoracic segments and the head in the Caligidæ is not as complete as is the fusion between the first segment and the head here in the Ergasilidæ. There the flexor muscles all stopped at the groove separating the head and first segment; here they all run past that groove without being changed in the least.

3. These facts magnify the value of the ability possessed by the Caligidæ to arch or depress the carapace and thus make of it an organ of prehension in the form of a large sucking disk. The subfamily Ergasilinæ can not use the carapace in this way at all. To compensate for this loss, witness the grouping of large and powerful muscles in the dorsal portion of the cephalon to control the enlarged second antennæ. These form a notable contrast to the comparatively weak set found in corresponding position in the Caligidæ.

4. The grouping of powerful locomotor muscles over the second and third legs in the Caligidæ show that these two pairs are the chief organs of propulsion. Here the locomotor muscles are distributed equally to the first four pairs of legs. Hence the latter must share equally in the propulsion of the copepod.

THE CÆLOM AND ITS CONNECTIVE AND MUSCULAR TISSUES.

The connective tissues within the cœlom loosely fill the entire cavity, leaving numerous irregular and scattered lacunæ. Being connected with the integument of the body wall, as well as with that which covers the various internal organs, they act as mesenteries to support the alimentary canal and reproductive organs (fig. 15).

In none of the specimens thus far examined do they show any structure. In many cases, especially in the youngest females found attached to the fish's gills and in nearly all the adults that are loaded with Vorticellidæ, these connective tissues are filled with oil globules, which are especially abundant between the stomach and the dorsal wall of the carapace. These globules vary in color from orange to rusty brown, but thus far they have never been found symmetrically arranged, as Hertog has noted in the morphology of *Cyclops* (1888, p. 21).

The muscles are all well striated and are made up exclusively of contractile substance without any nuclei or sarcolemma. The circular muscles which produce the peristaltic movements of the stomach and intestines are inserted in the outer layer of connective tissue surrounding those organs. The muscles which cross more or less of the cœlomic space are inserted directly in the epidermis, and so far as observed there are no tendons.

The cœlomic fluid is colorless and the corpuscles are amœbiform as in the free-swimming copepods. No heart is present, but the circulation of the cœlomic fluid is accomplished by the digestive system, as will be described under the latter.

THE DIGESTIVE SYSTEM.

The alimentary canal begins in a sort of mouth or oral cavity, bounded by the mouth parts and projecting lips. From this a narrow gullet passes upward and backward and opens into the stomach on the ventral surface of the latter a little in front of its center. The stomach is separated by a well-defined constriction at the posterior border of the second thoracic segment from the intestine, which in the abdomen passes insensibly into a rectum and ends at the anus, situated between the anal laminæ and nearer the ventral than the dorsal surface.

The mouth is bounded by the labrum in front and by the labium behind, both of which project from the ventral surface of the head, thereby increasing the size of the oral cavity.

Laterally the mouth is bounded by the sockets and bases of the mandibles and maxillæ; these mouth parts are described under each of the subfamilies.

The gullet leads directly from the mouth cavity upward and backward to the stomach; it is not bent at an angle as in *Cyclops*, but is evenly curved. It enters the stomach on the ventral surface of the latter, some distance behind the anterior end (fig. 15).

The stomach is a long and pear-shaped sac, extending back to the second (first free) thorax segment. The anterior end is considerably larger than the posterior, and from it rounded processes or lobes extend forward and sidewise, in all five in number (fig. 13). From the

center near the dorsal surface an unpaired lobe, nearly spherical in shape, extends forward and slightly upward (*a*). On either side of this and just below it an elliptical lobe extends downward and outward diagonally (*b*). From the ventral surface behind the bases of these paired lobes, another lobe (*c*), spherical or somewhat pointed, extends diagonally downward and outward on either side at right angles to the long axis of the stomach. These lateral lobes are firmly attached by a broad mesentery to the dorsal wall of the head, and do not move during the protraction and retraction of the stomach. Hence their shape remains practically unaltered and they can be discerned at all times.

The anterior end of the unpaired median lobe is attached by a pair of long narrow muscles to the dorsal wall of the head near its frontal margin. By these muscles during protraction the lobe is pulled forward almost to a level with the eye and narrowed accordingly (see fig. 15). The oblique lobes do not appear to be attached at all, or at the most very loosely, and during protraction they are obliterated, leaving only the median and the two lateral lobes in evidence. But during retraction they show distinctly.

In addition to these lobes at the anterior end, the dorsal surface of the stomach is also raised for its entire width in two rounded elevations, of which the anterior is about twice the size of the posterior.

The esophagus enters the stomach behind the base of the unpaired lobe, and between the bases of the first paired lobes.

At the posterior margin of the second thorax segment the stomach is differentiated from the intestine by a well-defined constriction. The whole of the median unpaired lobe, the first set of paired lobes, and the bulk of the second set project into the head, but the remainder of the stomach is within the first two thorax segments.

Two narrow anterior levator muscles run from the upper surface of the stomach forward and upward and are inserted in the dorsal wall of the carapace, just in front of the line of demarcation between the head and first thorax segment.

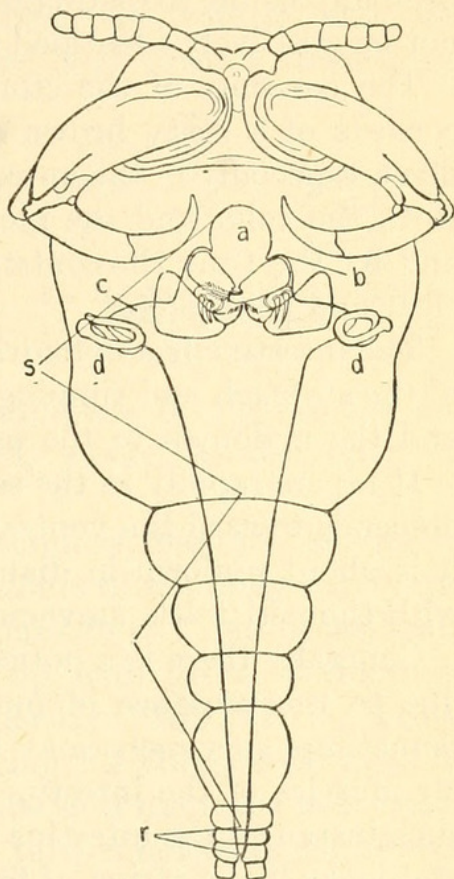


FIG. 13.—VENTRAL SURFACE OF FEMALE ERGASILUS CENTRARCHIDARUM. *a*, MEDIAN LOBE OF STOMACH; *b*, DIAGONAL LOBE; *c*, LATERAL LOBE; *d*, EXCRETORY TUBES; *i*, INTESTINE; *r*, RECTUM, *s*, STOMACH.

Two posterior levators run from the posterior dorsal wall of the stomach backward close together on either side of the mid-line, and are inserted in the dorsal wall of the third thorax segment. The movements of the stomach and intestine show clearly that there must be depressor muscles, anterior and posterior, connected with the ventral walls, and similar to those found by Hertog in *Cyclops*.

But owing to the opacity of the ventral portion of the body it has been impossible to distinguish them in a living *Ergasilus*, and they can not be positively identified in any of the sections thus far examined.

The contents of the stomach just after the parasites have eaten consists of a rusty brown granular mass, usually quite opaque and filled, especially in the anterior portion, with small spherical globules. Both the color and the globules diminish toward the posterior end, and by the time the contents have reached the intestine they become clear and transparent.

The intestine is a cylindrical tube starting from the ventral surface of the stomach and running backward through the rest of the thorax and the abdomen to the anus.

It tapers rapidly in the second and third thorax segments and also descends toward the ventral body wall. For the rest of the distance it is about uniform in diameter, but the relative size varies greatly with the peristaltic movements.

Generally there is a noticeable enlargement in the genital segment, due to the presence of food that has not yet been fully digested. Sometimes specimens may be found which have died with the circular muscles of the intestine wall in a state of rigid contraction. In such instances the intestine appears of the same diameter throughout, and looks like a string of flattened beads.

At or near the posterior end of the second abdominal segment the intestine passes insensibly into the rectum. The latter is a very short and thin walled tube, connected with the walls of the abdomen by stout retractor and protractor muscles. These produce the opening and closing of the rectum which is concerned in anal respiration, as has been repeatedly observed in living specimens under the microscope, and prove that this form of respiration obtains in the *Ergasilidæ* as well as in the *Argulidæ*, *Caligidæ*, and all the free swimmers.

There is apparently only one anal valve in the dorsal wall of the rectum near the anterior margin of the second abdomen segment, instead of the two noted by Hertog in *Cyclops*.

By means of the levator and depressor muscles already described the stomach and intestine are moved backward and forward in regular rhythm, the anal valve opening and closing in unison. In this way the coelomic fluid is moved forward in the dorsal chamber and backward in the ventral chamber, constituting the only circulation perceptible.

The kidneys.—There are two excretory organs (*d*, fig. 13), one on either side, lying near the lateral margins of the carapace and just above the lateral lobes of the anterior end of the stomach, and partially concealed by them. Each is a simple tube, coiled once into a horseshoe shape, the long diameter of the coil at right angles to the body axis. The coils differ somewhat in different specimens as can be seen in figure 14, *a* and *b*. The blind end (posterior) of the tube is a little enlarged; the other end is usually coiled once, in some individuals around the blind end, in others free from it, and then passes into the duct which leads forward and inward toward the maxilliped, and apparently opens just behind the base of the latter. This organ was first described by Zenker as opening near the mouth and probably a poison gland; it was identified by Claus and Leydig with the "schalendruse" of Phyllopod, and Claus showed that it opened on the base of the second maxillipeds in Phyllopod and behind the single maxilla in Cladocera, where it also opens in *Ergasilus*.

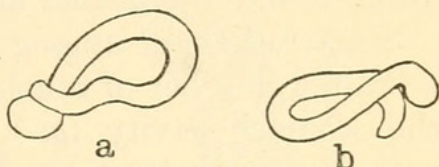


FIG. 14.—EXCRETORY TUBES OF ERGASILUS CENTRARCHIDARUM. *a* AND *b*, FROM DIFFERENT INDIVIDUALS.

These tubes can be seen in living specimens, but are usually indistinct, owing to the opacity of the contents of the body cavity and the stomach. Often they can not be discerned at all, but occasionally in freshly killed specimens they show up with great distinctness, this being largely a matter of chance rather than skill. In such cases the coiled tube and the duct leading from its anterior end can be easily followed. The contents of the tube and duct are both colorless and structureless. Furthermore the tube is not fastened in place very securely, and frequently becomes displaced under pressure, turning either backward or forward indiscriminately. On the bursting of the body wall under continued pressure this kidney tube passes out of the body with the first loose material that escapes.

Accessory glands.—The only accessory glands to the alimentary canal are what may be called the salivary glands, which surround the esophagus for its entire length (fig. 15). These are made up of elongated pear-shaped cells, the larger rounded ends lying nearest the esophagus and the smaller pointed ends extending away from it. The nuclei are large and spherical and stain deeply with hæmatoxylin. They lie in the larger ends of the cells, close to the esophagus. The cells which are dorsal and ventral to the large nerve ganglia are considerably increased in size; those which lie between the nerve ganglia and the esophagus are smaller.

There is apparently no arrangement into paired masses with a distinct duct, but the cells are thrown together loosely and irregularly. From their structure and staining, however, there can be no doubt they are glandular in nature and that they contribute to digestion.

As can be seen in figure 15, the stomach wall is made up of an outer muscular coat composed of fine muscle fibers arranged in a thin connective tissue. This is lined by an endothelium of large nucleated cells, which covers the entire inner surface of the stomach and extends into all the lobes.

There is no differentiation of the anterior third of the stomach by a thin chitinous cuticle, thrown up into longitudinal folds, and corresponding to the chitinized gizzard found in other crustacea. The only noticeable difference is that the cells toward the posterior end of the stomach are larger and more columnar, while those at the anterior end are smaller and more of a pavement epithelium.

Scattered about among the columnar cells at the posterior end are a limited number of much larger vacuolated cells which project into the stomach cavity (*gc.*). Their free ends are rounded and filled with large spherical or ellipsoidal masses which stain deeply with eosin. This suggests that they probably correspond with the so-called fat globules found by Hartog in the cells of the posterior portion of the stomach of *Cyclops*.

THE NERVOUS SYSTEM AND SENSE ORGANS.

General structure.—The nervous system is made up, as usual, of two ganglia connected by a commissure around the esophagus, and a ventral cord which reaches to about the center of the genital segment. But the structure and arrangement of these different parts presents many striking peculiarities (fig. 15). In the first place, the backward migration of the mouth and esophagus has carried the two ganglia and the connecting commissure along the ventral surface to the extreme posterior margin of the cephalon. This, coupled with the fact that the eye is in actual contact with the ventral surface, has removed every portion of the nervous system from the dorsal part of the body. Ganglia, nerve cord, commissures, and sense organs are as completely ventral as they are dorsal in any vertebrate. The ordinary terms supra and infra are hence rather out of place when applied to the respective ganglia; præ and post become far more appropriate.

Furthermore, as a result of this backward migration, or from other causes, each of the ganglia is enormously elongated, so that together they extend practically the entire length of the cephalothorax. They thus become more markedly the ventral counterpart of the dorsal nerve cord in vertebrates.

Præesophageal ganglion.—This is a long and club-shaped mass, extending from the esophagus to the anterior end of the stomach. It is strongly flattened dorso-ventrally, of about the same width for the posterior two-thirds of its length, then tapers rapidly into the comparatively long optic nerves, which lie side by side and partially

fused, and extend to the eye, striking the latter at the level of the ventral surface of the two dorsal ocelli. The cellular elements form a thick superficial layer over the posterior two-thirds of the ganglion, then become abruptly scanty, the optic nerves being composed almost wholly of fibers, with only a very few scattered nuclei among them. The whole center of the ganglion is a broad ribbon-like mass of fibers. The nuclei are also absent from the lateral and dorsal surfaces at the posterior end where the ganglion passes into the commissures, and this portion shows exclusively a fibrous structure. Some of the fibers can be seen to cross from one commissure to the other, or from the commissure on one side diagonally to the ganglion on the opposite side, but there is apparently no definite grouping of either the fibers or the nuclei. From the anterior end of the ganglion, on either side of the optic nerves, are given off the nerves to the first antennæ, which run forward just outside of the lateral ocelli. At the point of their origin the ganglion is somewhat swollen laterally and contains a number of nuclei.

From the dorsal surface of the ganglion, just in front of the stomach, arise the two short frontal nerves which supply the anterior portion of the head, the so-called frontal region.

From either side of the ganglion, a little posterior to the

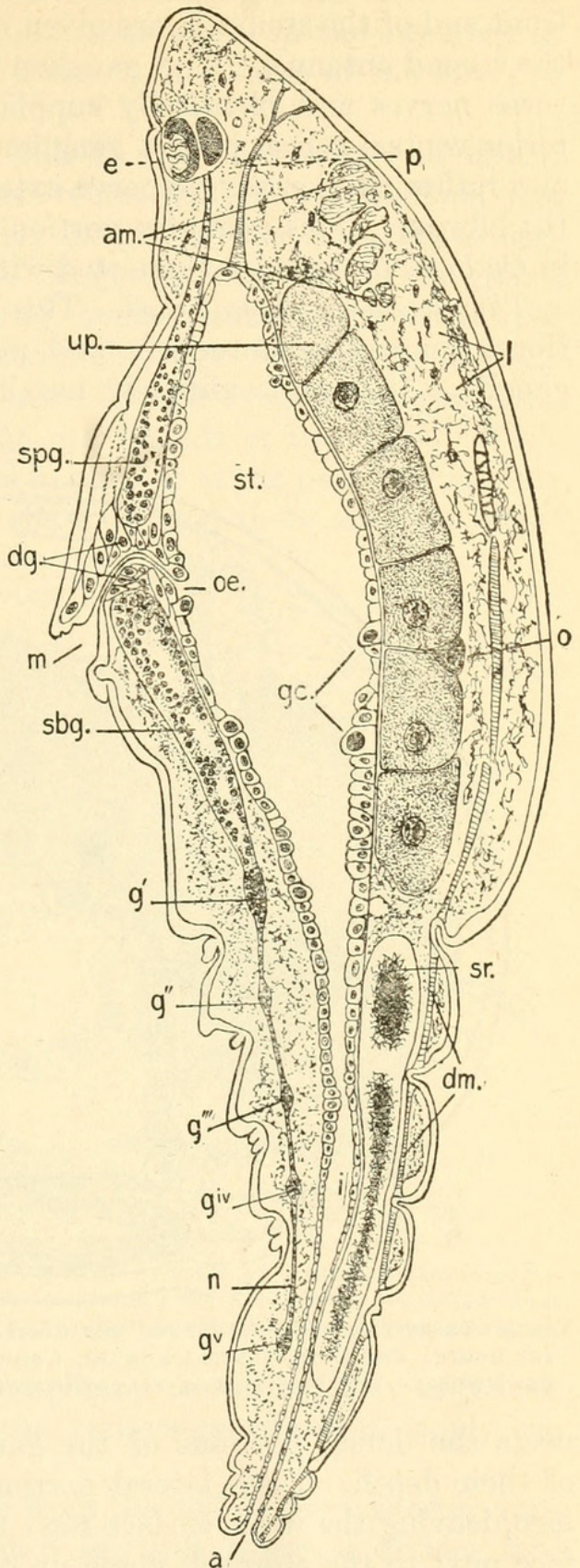


FIG. 15.—MEDIAN LONGITUDINAL SECTION OF ERGASILUS CENTRARCHIDARUM. *a*, ANUS; *am*, MUSCLES OF SECOND ANTENNÆ; *dg*, DIGESTIVE GLAND; *dm*, DORSAL MUSCLES; *e*, EYE; *g'* TO *g^v*, GANGLIA OF THORACIC AND GENITAL SEGMENTS; *gc*, GLAND CELLS; *i*, INTESTINE; *l*, LACUNÆ; *m*, MOUTH; *n*, VENTRAL NERVE CORD; *o*, ANTERIOR END OF OVARY; *æ*, ESOPHAGUS; *p*, PROTRACTOR MUSCLES OF STOMACH; *sbg*, POST (SUB) ESOPHAGEAL GANGLION; *spg*, PRÆ (SUPRA) ESOPHAGEAL GANGLION; *sr*, SEMEN RECEPTACLE; *st*, STOMACH; *up*, UTERINE PROCESS OF OVARY.

front end of the stomach, are given off the large nerves which supply the second antennæ. The ganglion is much swollen at the bases of these nerves and plentifully supplied with nuclei. From the posterior ventral corner of the ganglion close to the esophagus a short and rather swollen azygos nerve extends downward and backward to the labrum. This posterior portion of the ganglion is perforated, as in *Cyclops*, by muscles connected with the mouth-parts.

The circumesophageal cord.—This is made up of two lateral portions, connecting anteriorly and posteriorly with the ends of the ganglia. It is approximately parallel with the body axis and con-

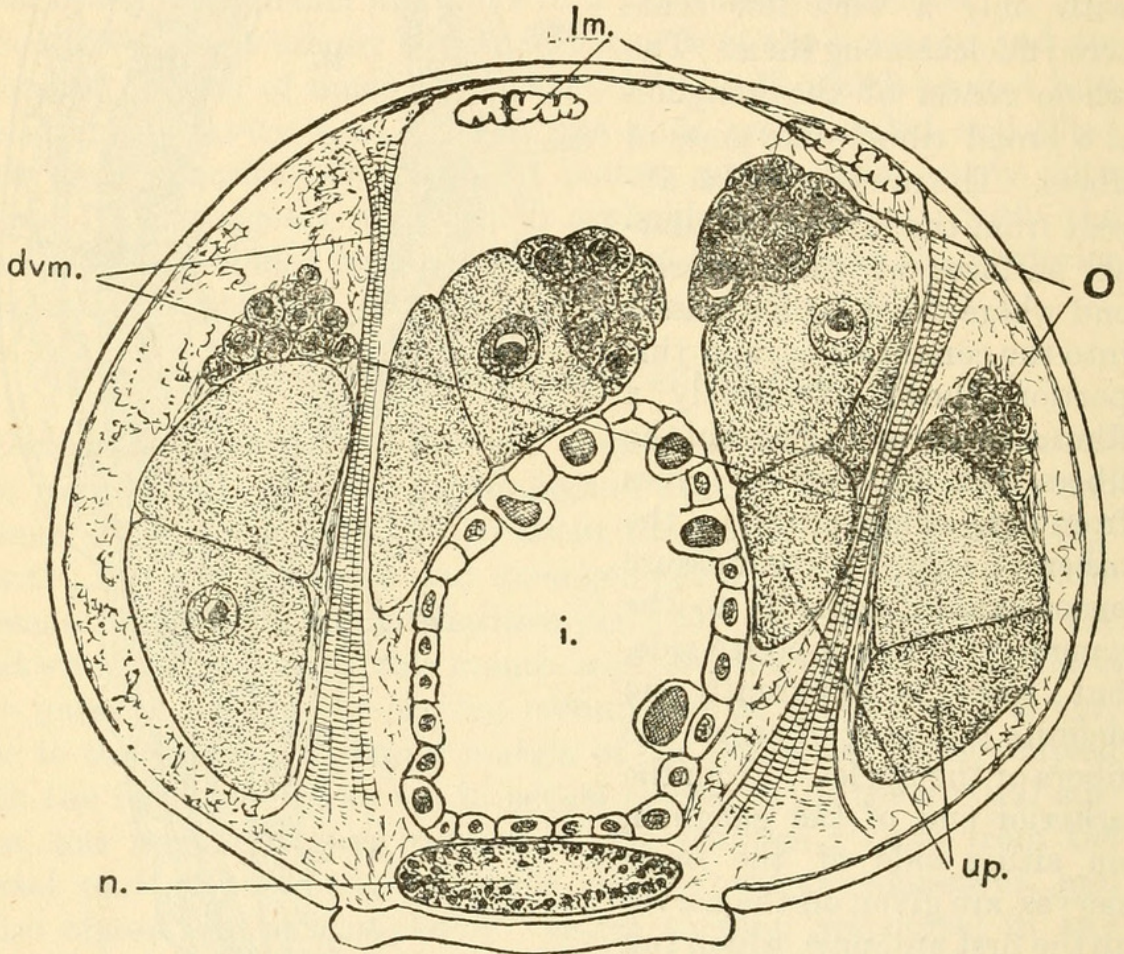


FIG. 16.—TRANSVERSE SECTION THROUGH THE CARAPACE OF *ERGASILUS CENTRARCHIDARUM* BEHIND THE MOUTH. *dvm*, DORSO-VENTRAL MUSCLES; *i*, STOMACH; *lm*, LONGITUDINAL MUSCLES; *n*, VENTRAL NERVE CORD; *o*, UNDEVELOPED EGG CELLS OF OVARY; *up*, UTERINE PROCESSES.

nects the dorsal portions of the ganglia only for about two-thirds of their depth. Each lateral portion is nucleated on its outer surface, leaving the inner surface next to the gullet and the dorsal surface next to the stomach made up of fibers only. It thus possesses the same elements as the ganglia and has been given the name of cord, as suggested by Hartog. Since it has been moved so far back by the migration of the mouth-parts, it could not be expected to give immediate origin to the nerves that supply the second antennæ. Whether any of the fibers of those nerves can be traced backward along the ganglion to the commissure can not be determined with

the material at hand. But the numerous nuclei in the swellings at the bases of those nerves would indicate that some of the fibers at least originate there.

The postesophageal ganglion.—This is also club-shaped in lateral view, but strongly flattened dorso-ventrally. It extends from just behind the gullet to the posterior margin of the first thorax segment, and is made up exactly like the ganglion in front of the gullet. There is a swelling at its posterior smaller end from whence arise the nerves that go to the first swimming legs. From the anterior end of the ganglion are given off nerves which supply the mandibles, the two pairs of maxillæ and the maxillipeds in the male. While the nuclei are noticeably increased in number at the posterior swelling that gives rise to the nerves of the first legs, there are only slight

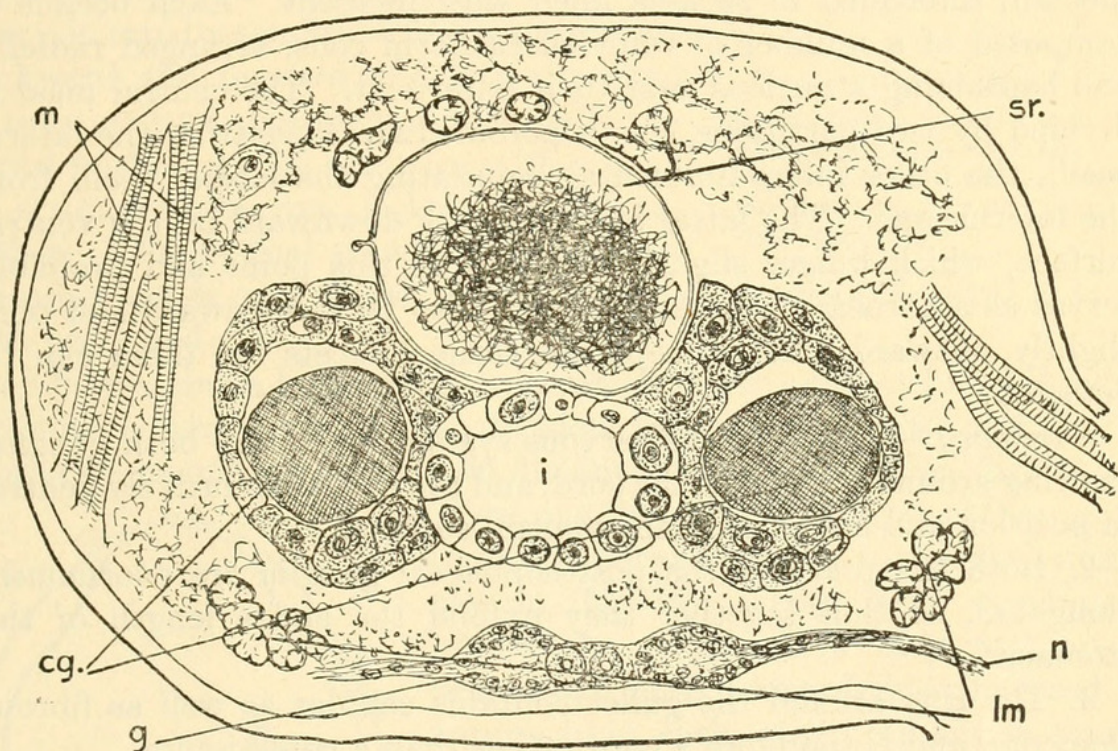


FIG. 17.—TRANSVERSE SECTION THROUGH THIRD THORACIC SEGMENT OF ERGASILUS CENTRARCHIDARIUM. *cg*, CEMENT GLAND; *g*, GANGLION OF THIRD SWIMMING LEGS; *i*, INTESTINE; *lm*, LONGITUDINAL MUSCLES; *m*, DORSO-VENTRAL MUSCLES OF THIRD LEGS; *n*, NERVE OF THIRD LEG; *sr*, SEMEN RECEPTACLE.

differences in other parts of the ganglion. Accordingly we may look upon it as a complete fusion of the various ganglia that supply the mouth-parts (*n*, fig. 16).

The ventral cord.—This extends from the end of the posterior ganglion back into the sixth or genital segment, where it divides into two branches which finally end in the anal laminae.

For the entire distance through the thorax it is evidently made up of two cords lying side by side and partially fused. This is most evident at the ganglionic swellings which occur at the origin of the nerves going to the swimming legs (fig. 17). Here there is plainly a separate ganglion on either side (*g*), the two being connected by a

fibrous band in which a pair of giant fibers are visible. The nuclei are practically confined to these ganglia, and even in them they diminish greatly in number from in front backward, so that in the sixth segment it is often impossible to distinguish them. After dividing in the sixth segment the rami run alongside the intestine, giving off branches to the trunk muscles. Toward the posterior end of the abdomen each ramus divides into a dorsal branch going to the anus and a ventral one going to the anal lamina. In each segment of the thorax a pair of nerves is given off to the trunk muscles in addition to those going to the swimming legs.

The eye.—The eye of *Ergasilus* is situated far forward in the frontal region and in immediate contact with the ventral surface (fig. 15). It consists of three hemispherical ocelli, two lateral and one infero-median, imbedded in sockets lined with pigment. Each ocellus is composed of a number of rounded fusiform cells, arranged radially and containing a nucleus near their outer end. The central mass is divided by two partitions, one superomedian, separating the lateral ocelli, the other infero-horizontal, separating the lateral ocelli from the inferior one. The latter looks directly downward on the ventral surface, which bulges slightly outward at this point and probably serves as a cornea. The lateral ocelli also face downward and only slightly outward, and no separate corneal facets for them can be detected.

Summary.—1. The entire nervous system, including both ganglia, the ring around the gullet, the cord, and the eye, is exclusively ventral in position and lies close to the ventral surface.

2. Both the præ and the postesophageal ganglia are enormously elongated, so that together they extend the entire length of the stomach.

3. The ring around the gullet contains cellular as well as fibrous elements, and is therefore a cord rather than a commissure.

4. The nerves supplying the second antennæ originate from the anterior end of the præesophageal ganglion.

5. The ventral cord is really a pair of cords lying side by side and connected by a fibrous band with two giant fibers.

6. Both ganglia are perforated in the vicinity of the gullet by muscles extending to the mouth-parts.

REPRODUCTIVE ORGANS.

In the female the reproductive organs consist of a paired ovary, convoluted oviducts, and a pair of shell glands; the oviducts lead backward on either side to the vulva, which opens on the dorsal surface of the genital segment, while the shell glands extend forward from the genital segment into the free thorax (fig. 21).

The ovaries are small egg-shaped bodies situated on either side of the anterior portion of the dorsal surface of the stomach. Each consists of a mass of small nucleated cells, the ova, which are formed by kariokinetic division at the posterior, free end of the ovary, and gradually pass out into the oviduct which is given off at the wider anterior end. The body of the ovum accumulates yolk granules and increases greatly in size as it passes into the oviduct. The latter seems to be an outgrowth from the ovary as in free-swimming forms. At first it is a simple tube without convolutions, extending backward to the genital segment.

But as the ova issue into it out of the ovary it rapidly sends out uterine processes backward and forward and laterally until in fully mature specimens it fills the entire dorsal portion of the carapace with a mass of opaque white ova tightly packed together. The gradual growth of these uterine processes is well shown in the series of figures (18 to 24) here-with presented.

At first a single large ovum appears in either oviduct just behind the suture which marks the division between the head and first thorax segment, and some little distance from the mid-line (fig. 18).

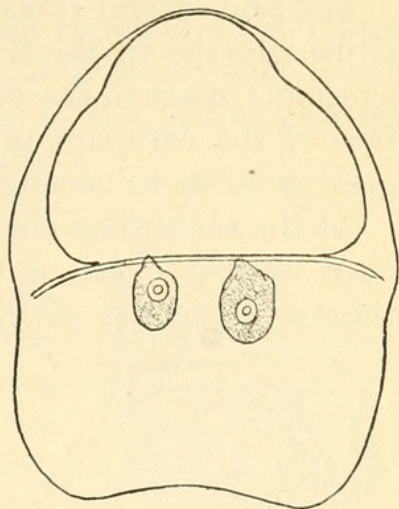


FIG. 18.—DORSAL VIEW OF CARAPACE OF ERGASILUS CENTRARCHIDARUM, SHOWING POSITION OF FIRST TWO EGG CELLS THAT ISSUE FROM THE OVARY.

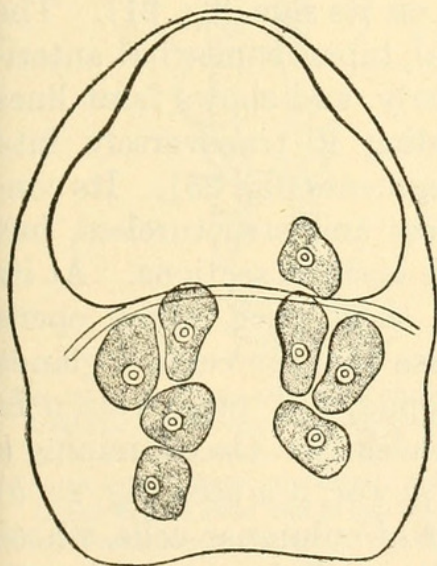


FIG. 19.—THE FIRST UTERINE PROCESSES FORMING POSTERIORLY THROUGH THE FIRST THORAX SEGMENT.

These ova then extend backward through the first thorax segment to its posterior margin (fig. 19). They next accumulate at the point where they first appeared and push forward into the head, approaching each other on either side of the mid-line (fig. 20). Again accumulating at the same point, each oviduct sends out a lateral process which extends obliquely forward and downward toward the base of the second antenna (fig. 21). The entire portion within the first thorax segment now thickens, approaching close to the mid-line, and another lateral process is sent out in the posterior portion of the segment and

nearly at right angles to the body axis. This process also curves over ventrally and eventually approaches close to the ventral wall of the body (fig. 24). Each of these processes thickens laterally as well as increases in length (fig. 22), until eventually the space in the

cœlom at the top and sides and in front of the stomach is completely filled, the processes almost touching one another and those along either side of the mid-line approaching till they come in actual contact (fig. 23).

The first lateral process is the longest, while the last one given off is usually the thickest. These gravid processes not only fill all the available space in the cœlom, but their growth arches the dorsal surface of the carapace until it is strongly curved (fig. 24); indeed, it goes so far as to become practically spherical in *Thersitina*.

At the same time they push back the posterior margin of the carapace until it overlaps the second and sometimes part of the third thorax segments, giving the fully mature female very much the appearance of a tadpole, except of course for the egg-strings.

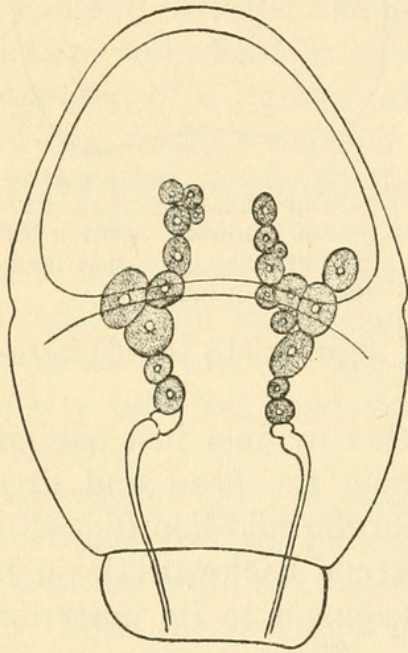


FIG. 20.—THE SECOND UTERINE PROCESSES FORMING ANTERIORLY IN THE HEAD; POSTERIORLY CAN BE SEEN THE OVIDUCTS CONNECTED WITH THE FIRST UTERINE PROCESSES.

Cement glands.—Unlike the free copepods, in which, according to Claus, Gruber, and Hertog, the cement or “Kittsubstanz” is contained in the posterior portion of the oviduct, *Ergasilus* possesses a pair of cement glands similar to those of the Caligidæ. These are situated in the posterior portion of the thorax on either side. Each consists of a long and narrow tube somewhat curved, the one facing the other like two parentheses marks, and each lying below the oviduct on its side (fig. 21). The tube is cylindrical, tapers somewhat anteriorly and posteriorly, and shows faint lines or grooves dividing it transversely into about a dozen segments (fig. 25). Its contents are colorless and structureless, but stain deeply with eosin in sections. At its

posterior end it narrows abruptly into a short duct, which opens into the oviduct close to the vulva. These shell or cement glands are difficult to discern in the living copepod, but preservation in weak formalin often brings them out quite clearly. On examining a section of one of these glands under a high power, it is seen (fig. 25, *b*) that the wall is composed of a single layer of columnar cells, whose nuclei are situated near the inner ends. These cells increase in length from the proximal toward the distal end of the gland.

There is a second increase at about the center of the gland, where the cells from opposite sides approach each other until only a narrow neck-like lumen is left between their inner ends. This probably represents the mouth of the really glandular portion of the organ, the remaining proximal portion being more of a duct. The entire

substance of these cells, and especially the nuclei, stain deeply with hæmatoxylin in strong contrast to the red secretion which fills the lumen of the gland.

Semen receptacle.—It is impossible to distinguish the semen receptacle in the living copepod, since it lies directly above the intestine, is of about the same width as the latter, and its walls are structureless and as transparent as glass.

In both transverse and longitudinal sections, however, it stands out prominently. It consists of a long cylindrical bag (fig. 15), extending from the middle of the genital segment forward through the free thorax to the posterior border of the first segment.

This bag occupies the entire body cavity between the intestine and the dorsal wall of the thorax. It is somewhat narrowed at the center, where it passes the groove between the third and fourth thorax segments, and is enlarged at either end, more in front than posteriorly. It is very nearly the same diameter as the intestine, being wider anteriorly (fig. 17). At the posterior end it di-

vides, or, rather, sends out a tube on either side, which extends around the intestine ventrally and posterior to the genital openings. Each tube then turns forward and opens into the oviduct just before the latter reaches the os uterus or external opening. This extraordinarily large receptacle is entirely filled with spermatozoa in the living female, but they cling together and shrink away from the wall somewhat in preserved mate-

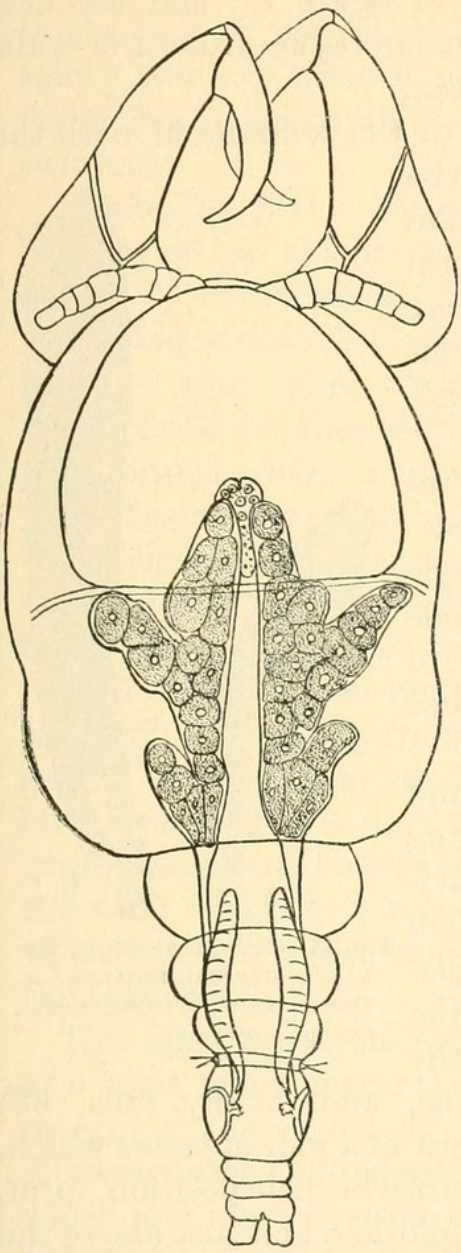


FIG. 21.—THE THIRD AND FOURTH OBLIQUE UTERINE PROCESSES, EXTENDING FORWARD AND DOWNWARD FROM THE OUTER SIDES OF THE FIRST PROCESSES. ANTERIORLY CAN BE SEEN THE FUSED OVARY AND POSTERIORLY THE CEMENT GLANDS.

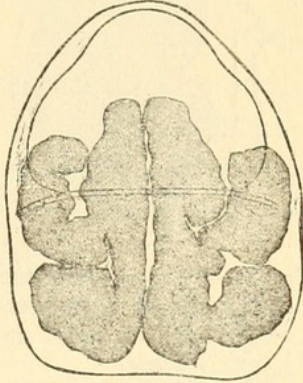


FIG. 22.—FULLY MATURED FEMALE OF ERGASILUSCENTRARCHIDARUM, SHOWING RELATIVE SIZE AND SHAPE OF COMPLETED PROCESSES IN DORSAL VIEW.

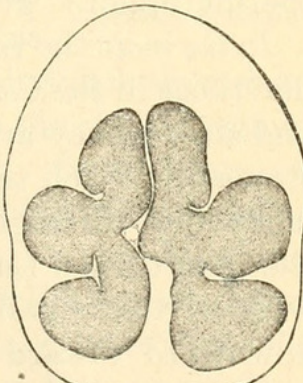


FIG. 23.—THE RELATIVE SIZE AND SHAPE OF COMPLETED PROCESSES AS SEEN IN VENTRAL VIEW.

vides, or, rather, sends out a tube on either side, which extends around the intestine ventrally and posterior to the genital openings. Each tube then turns forward and opens into the oviduct just before the latter reaches the os uterus or external opening. This extraordinarily large receptacle is entirely filled with spermatozoa in the living female, but they cling together and shrink away from the wall somewhat in preserved mate-

rial. Each spermatozoan has the general shape shown in figure 59, Plate 42.

The semen receptacle, the cement glands, and the intestine are firmly bound together by connective tissue in the position shown in figure 17, and are also suspended by the same tissue from the walls and sides of the thorax.

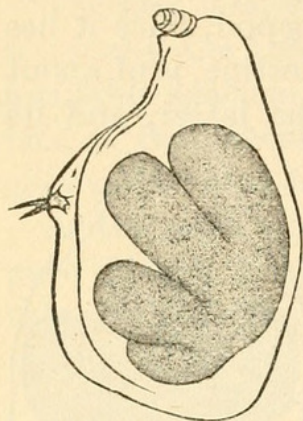


FIG. 24.—THE RELATIVE SIZE AND SHAPE OF COMPLETED PROCESSES AS SEEN IN LATERAL VIEW.

For the discharge of the contents of both the receptacle and the glands the contraction of the dorso-ventral muscles in each thorax segment may well contribute material assistance.

The size of this receptacle renders it practically certain that there is but a single union between the sexes, and that the female derives from this a sufficient quantity of sperm to fertilize all the eggs she can produce during her entire life.

Spermatophores can occasionally be found in position upon the bodies of very young females, but they soon disappear. Evidently they are full of spermatozoa when first attached, these spermatozoa are discharged into the semen receptacle of the female, and then the old shell of the spermatophore gradually decays, loosens, and finally falls off.

In the male the reproductive organs consist of a pair of testes which, like those in the Caligidæ, resemble the ovaries in their position, form, and size. They are situated close to the mid-line and just above the stomach. Each testis is somewhat ovate in form, the long diameter inclined at an angle of about 60° to the body axis, the small end of the oval turned forward.

From this small end is given off the vas deferens, which turns downward toward the ventral body wall and then backward and upward approximately parallel with the body axis to the posterior margin of the fourth thorax segment, where it empties into the semen receptacle (fig. 26).

In each segment of the thorax the vasa deferentia are convoluted or curved in toward each other at the anterior and posterior margins and away from each other at the center of the segment. They are

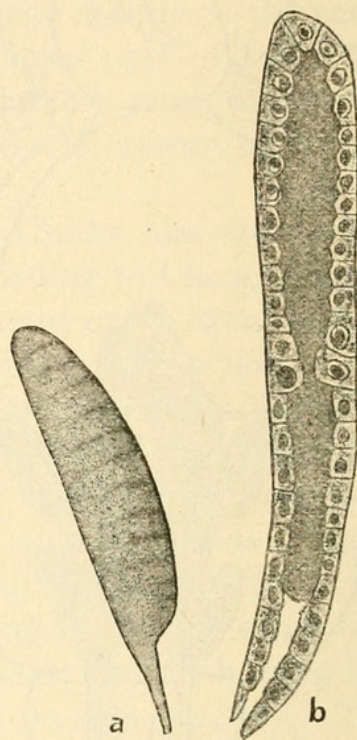


FIG. 25.—CEMENT GLAND OF ERGASILUS CENTRARCHIDARUM. *a*, DORSAL VIEW; *b*, LONGITUDINAL VERTICAL SECTION.

also somewhat enlarged in diameter at the center, which gives them a peculiar crenulated appearance. This structure shows more distinctly in the *Ergasilus* male (*E. chautauquaënsis*) than in *Bomolochus* (*B. soleæ*), but this seems to be the result of the greater transparency of the former rather than of any marked structural difference. Owing to the lack of material it has been impossible to determine with certainty whether there is any loop (epididymis, Hertog) in the vasa deferentia corresponding to that found in *Cyclops* and other free swimmers.

The bodies of the limited number of males examined by the author have been too opaque to show up the internal anatomy with any degree of distinctness. The testes could be located because they were opaque enough to show as dark spots, but the transparent ducts leading from them were so nearly invisible for much of the distance as to leave it in doubt whether they formed a loop or not.

In *Bomolochus soleæ* the semen receptacle is somewhat cigar-shaped, and occupies practically the whole of one side of the fifth segment and the anterior seven-eighths of the genital segment. The posterior end of the receptacle is evenly rounded and projects strongly from the lateral margin of the genital segment near its distal end. The diameter of the receptacle is about uniform throughout the genital segment, but when it passes forward into the fifth segment it narrows rapidly into a cone whose apex falls just behind the anterior margin of the segment.

This apex passes insensibly into the vas deferens at a point much nearer the mid-line than the lateral margin of the segment. In the male of *Ergasilus chautauquaënsis* the semen receptacles are relatively much shorter and wider, and more ovate in shape. They occupy in the genital segment only the anterior three-fifths, and on passing into the fifth segment taper rapidly down to the diameter of the vasa deferentia (fig. 26).

Each semen receptacle contains one or more spermatophores, ready to be extruded and fastened to the body of the female. Each spermatophore consists of an enlarged body, ovate or ellipsoidal in shape, and a long narrow duct or tube leading from it, very similar to those described by Gruber and others for free-swimming forms. So far as observed each spermatophore is fastened to its own side of the genital segment of the female and there is no crossing of the tubes as in many of the other parasitic forms. Furthermore it is only rarely that a female is found with these spermatophores in position. Out of considerably over five hundred specimens of females belonging to

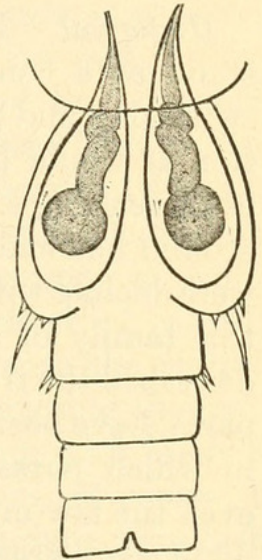


FIG. 26.—GENITAL SEGMENT OF MALE ERGASILUS CHAUTAUQUAËNSIS, SHOWING SPERM RECEPTACLES.

this family only one or two could be found with spermatophores. We thus have another link in the chain of evidence which goes to prove that the union of the sexes takes place while they are still swimming freely at the surface and before they have sought out a host. Or rather before the female has sought one out, for the male remains a free swimmer throughout life.

It also furnishes strong proof that a single union supplies the female with enough spermatozoa to fertilize many broods of eggs, if indeed it is not enough for all she will ever lay.

Furthermore, it explains incidentally the fact that no males are found with the females at any season of the year, upon the host which the female may have selected.

Family ERGASILIDÆ.

Historical.—In spite of the fact that the present family of copepods stand as a connecting link between the two great groups of free-swimming and parasitic forms, they have not received as much attention as would be expected from authors who have dealt with either of these groups. Perhaps the fact that they do thus occupy a middle ground has had some influence in causing the neglect. Authors who were dealing with the free-swimming forms would not naturally include this family of parasites. And on the other hand, those who have described the true parasitic forms, degenerate or with modified mouth parts, have been satisfied with merely mentioning these tiny creatures, in which parasitism has as yet produced but little change. And even the few investigators who have taken up especially the intermediate semiparasitic families have almost without exception neglected the Ergasilidæ. Possibly this is due to the fact that they are fish parasites, while all the others live on invertebrate hosts.

The family was founded in 1832 by Nordmann, who established the two type genera, *Ergasilus* and *Bomolochus*, the former with three species and the latter with one. Nordmann gave an excellent digest of the genus *Ergasilus* after a comparison of his three species, and included even some of the development stages. For the genus *Bomolochus* he had but a single species and contented himself with a description of that, making no attempt at a genus diagnosis. But he found no males of either genus, and while he inferred that there would be a difference between the sexes similar to that in *Cyclops*, there was no direct proof. He recognized the close relationship of the two genera, but left them without creating any new family for their reception. This was done in the following year by Burmeister in his work on the parasitic copepods (1833), who placed the new family, Ergasilina, between the Caligina and the Lernæoda. He included in the family not only Nordmann's genera *Ergasilus* and *Bomolochus*, but also the *Lamproglena* of the same author, Audouin's *Nicothoë*,

Leach's *Anthosoma*, Hermann's *Dichelestium*, and Risso's *Nemesis*. Naturally the family diagnosis which he gave was made broad enough to include all these genera, and was not of much value for *Ergasilus* and *Bomolochus*.

Seven years later Milne Edwards in his great work on the Crustacea retained this family but changed its name to "Pachycephala," and subdivided it into two tribes or subfamilies, the Dichelestiens and the Ergasiliens, including in the latter but three genera, *Ergasilus*, *Bomolochus*, and *Nicotohö*.

This was a manifest improvement, and his grouping forms the basis of that accepted at the present time, the difference being that his subfamilies or tribes have become separate families.

In 1859 the Swedish naturalist, Thorell, published an excellent paper on the copepods, which live in Ascidians.

While these did not properly include any species belonging to the Ergasilidæ, yet Thorell's contribution is of special interest for two reasons. He introduces a general systematization of the copepods, both free-swimming and parasitic, dividing them into three groups. The first of these he called the Gnathostoma, and described them as having a pair of free mandibles and three pairs of maxillæ without any siphon. The second group were the Pæcilostoma, in which there were no mandibles or siphon, while the number of maxillæ varied from three pairs to none. The third group were the Siphonostoma, whose mouth was produced into a siphon inclosing the mandibles. He placed the Ergasilidæ in the second group with many of the new Ascidian semiparasites, which was equivalent, of course, to declaring that in this family both mandibles and siphon were lacking. To confirm this, in describing his new genus *Lichomolgus*, a near relative of the Ergasilidæ, he introduced figures of *Ergasilus sieboldii* on plates 11 and 12 and tried to show that in this species there are no mandibles.

On this point, however, he was evidently mistaken, as has been clearly shown by many subsequent writers, notably Claus (1864).

Kröyer in 1863 added four new species of *Bomolochus* and four of *Ergasilus*, and he professed to include both sexes of two species of the latter genus.

He made no attempt at a general classification, and so the value of his contribution would lie chiefly in the discovery of the males of *Ergasilus* and in a broadening of our knowledge of the two genera by descriptions and figures of new species were it not for some serious blunders.

The species which he named *Ergasilus gasterostei*, one of the two for which he gave both sexes, had been described by Pagenstecher in 1861 as *Thersites gasterostei*. Kröyer had not seen this description,

for he states in so many words that the species was "hitherto undescribed" (hidtil ubeskrevne Art).

Pagenstecher's generic distinction seems to be a valid one (see p. 349), and hence this species does not belong to the genus *Ergasilus* at all.

The other species for which the male is given, *E. sieboldii* Nordmann, is of course valid, since it is the type of the genus.

But here Kröyer has made the same mistake as in several other instances of designating a young female without egg strings as a male. The true male differs from the female in the presence of well-developed second maxillipeds, and Kröyer's figures distinctly show that these are lacking in the specimen which he calls a male.

Furthermore, it will be seen from the systematic discussion given on page 367 that three of the species which he assigns to the genus *Bomolochus* really belong to other genera.

His contribution, therefore, serves chiefly as a source of material for subsequent correction.

In the next year (1864) Claus gave a detailed account of two new species of *Bomolochus* (*soleæ* and *cornutus*) and a new and closely allied genus which he called *Eucanthus*, with the species *E. balistæ*. He discovered also and described the true males of both these genera. And finally he gave a systematic review of the genus *Bomolochus* and its relatives, bringing out clearly the position of the family and its relation to both the free-swimming and parasitic forms. With this end in view he made a thorough revision of the mouth parts, locating and naming the different appendages around the mouth, which Burmeister had not understood and which Thorell and Kröyer had interpreted incorrectly. He concluded that the mouth parts in the Ergasilidæ are half-way between those of the Corycaeidæ and the Chondracanthidæ. In particular he contended that mandibles are present in all the Ergasilidæ, and that, therefore, they could not be included in Thorell's group of Pœcilostoma. But while thus destroying in a measure the classification Thorell had made, he offered no substitute in its place.

Even in the fifth edition of his *Lehrbuch der Zoologie* (1891) he makes no mention of a single genus belonging to the Ergasilidæ or the Dichelestiidæ, nor is there any place for them in the classification of the copepods which he gives.

In 1870 Claparède published a *Note sur les Crustacés copépodes parasites des Annelides et Description du Sabelliphilus sarsii*, in which he gave his views upon these troublesome semiparasites. He declared that Claus's statement in regard to the presence of mandibles is correct. But he believed that when the details of the mouth-parts have been fully investigated, it will be found that in *Lichomolgus* and other genera, as well as in his genus of *Sabelliphilus*, the

mandibles can be reduced so much as to be unserviceable for chewing. He gave preference to Thorell's classification, yet admitted that the facts upon which it was founded are not reliable. But, like most of the critics, he contented himself with picking the old classification in pieces and made no effort to modify or improve it.

In the following year (1871) Sumpf described another new genus, *Tæniacanthus*, belonging to this family of Ergasilidæ, and also gave a second thorough revision of the mouth-parts, comparing them carefully with those in the genera *Corycæus*, *Sapphirina*, and *Lichomolgus*. He agreed with Claus that both mandibles and maxillæ are present, and hence declared himself against Thorell's classification.

He showed that Claparède, by some unaccountable error, mistook the upper lip for a pair of fused mandibles, while the structure designated as the maxillary plate was manifestly the true mandibles. He then endeavored to show that the Chondracanthidæ, which Thorell had included in his group of Pœcilostoma, really belong with the Siphonostoma by reason of their limited development, the fixed parasitism of both sexes as well as their sexual dimorphism, and by their degenerate body form and mode of life.

Sumpf thus completed the tearing in pieces of Thorell's classification which Claus had begun and Claparède had continued. But, like those authors, he offered nothing in its place, so that, as far as the Ergasilidæ are concerned, we are left without any arrangement at all.

In 1877 Carl Vogt published his "Recherches Côtitières;" the second section of the second memoir is devoted to the family Chondracanthidæ. In it he described a species of *Ergasilus*, which he named *E. mugilis*, but he believed it to be identical with Hesse's *Mega-brachinus suboculatus*, in which case the latter specific name would take precedence (see p. 346). He then called attention to the close resemblance between the free-swimming family Corycæidæ and the Ergasilidæ. After a very clear cut and logical comparison of these two families with the Chondracanthidæ, he closes with these words:

All these facts authorize us to conclude that the Corycæidæ are the free forms corresponding to the parasitic Ergasilidæ, and are less degenerate, while the retrograde metamorphosis has reached its maximum in the Chondracanthidæ, especially in the females. In this manner these three families, well distinguished by secondary characters, constitute in reality but a single series, which reflects in its successive transformations the analogous phases which the ancestral copepods must have passed through in their passage from a free life to one of parasitism (pp. 99 and 100).

Thus Vogt does not agree with Sumpf that the Chondracanthidæ really belong with the Siphonostoma. He takes the more logical view that they bear the same relation to the Ergasilidæ and Corycæidæ that is borne by the Lernæidæ to the Dichelestiidæ and Caligidæ. This seems to be by far the most sensible statement made with

reference to these parasites, and it proves to be one which is fully substantiated by a careful study and comparison of the mouth-parts.

Three or four years later Gerstaecker published (1881) that portion of Bronn's Thierreich which includes the copepoda. Like his predecessors, he also carefully reviewed and criticised the various systems which had been proposed. But unlike them, he went a step farther and made an earnest effort to combine the good points of all the systems and eliminate as far as possible their errors.

As a result he has given us a thoroughly revised classification, in which we find the Ergasilidæ placed among the tenants and half parasites, between the Corycæidæ and the Ascomyzontidæ. But he has included in the Ergasilidæ all the genera referred by other authors to a separate family, the Lichomolgidæ. These latter are only semi-parasites, and hence Gerstaecker was obliged to place the Ergasilidæ where he did. It seems far better to separate these two families and to include in the Ergasilidæ only those forms which live on the gills or the bodies of fish, and thus are as completely parasitic as the Caligidæ.

Moreover, Gerstaecker has placed the Chondracanthidæ among the true parasites, at the very end next to the Lernæopodidæ. And these last two families are separated from all the others with no marks of lineage to connect them, as though he were uncertain where they really belonged.

In 1892 Canu published a work entitled *Les Copépodes du Boulonnais*, in which he presents another revised classification of the copepods, including both the free-swimming and parasitic forms. He adopted the general arrangement of Thorell and Claus, with certain modifications.

His first division was based upon the number of sexual openings in the body of the female; those having but a single opening he called *Monoporodelphya*, and they correspond exactly to the *Gnathostomata* of Thorell and Claus. All the rest of the copepods belong to the group *Diporodelphya*, which is then divided into three subgroups. Recognizing the fact that the Ergasilidæ and their near relatives really do possess mandibles and maxillæ, he changed the name which Thorell had given (*Pœcilostoma*) and called the first of his subgroups *Monochila*. It corresponds exactly to Thorell's *Pœcilostoma* except in name.

In this same year (1892) Giesbrecht, including only pelagic forms, based his first division upon the position of the movable articulation between the fore and hind body, and the structure of the fifth thoracic legs. His second divisions were made with reference to the structure of the first antennæ.

In 1903 Prof. G. O. Sars published volume 4 of his great work on the Crustacea of Norway. This dealt with the Copepoda Calanoida,

and has been followed by other volumes embracing some of the remaining Copepoda, the publication being not yet finished. He separated the Copepoda into seven divisions: (1) The Calanoida, free-living and pelagic; (2) the Harpacticoida, free-living but demersal; (3) the Cyclopoida, partly free-living and fresh-water species, partly commensals and messmates with other animals; (4) the Notodelphyoida, semiparasitic and living upon ascidians; (5) the Monstriloida, partly parasitic and partly free; (6) the Caligoida, parasitic upon fishes, moderately degenerate, and with some freedom of motion; (7) the Lernæoida, fish parasites, strongly degenerate, fixed in position, and with marked sexual dimorphism.

In this scheme the Ergasilidæ are in the third division, along with the Lichomolgidæ and Corycæidæ, while the Chondracanthidæ are in the seventh division. This is a scheme based upon habits and mode of life, though of course substantiated by morphological differences, and is by far the best one yet devised along those lines. It differs from that adopted by Brady in his *Monograph of the Free and Semiparasitic Copepoda of the British Islands* (1880), only in the arrangement of the Cyclopidæ and Notodelphydæ, and has been adopted by the distinguished Scottish investigators, T. and A. Scott.

The two most recent works upon the Crustacea, that in the *Cambridge Natural History*, by Geoffrey Smith, and that in *Lankester's Treatise on Zoology*, by W. T. Colman, both bearing the date of 1909, adopt Giesbrecht's classification.

These different schemes have been fully discussed elsewhere by the present author.^a It is sufficient here to state that there are very serious objections to all of them except that proposed by Sars.

But from a careful comparison of these various schemes of classification we are enabled to draw certain definite conclusions:

1. The free-swimming copepods have mouth-parts suited for biting and chewing, and are to be grouped by themselves at the head of the classification scheme, as is done by every one of the authors quoted.

2. The parasitic copepods have mouth-parts suited for piercing or tearing, the mandibles being inclosed in a tube or siphon, and are to be grouped by themselves at the opposite end of the classification scheme, as is also done by every one of the authors quoted.

3. Between these two groups is a large middle class, including free-swimmers, messmates, commensals, semiparasites, and complete parasites. In these forms the mouth-parts are in the process of transition, but there is no mouth-tube or siphon. Here belongs the family now under discussion, and nearly every author has placed it in a different position with relation to its immediate neighbors. This is the debatable ground, and the conflict is chiefly due to the fact that the

^a *Zool. Anzeiger*, vol. 35, no. 20, pp. 609-620.

members of this middle class are not as yet well enough known to be located with precision. Much more work must be done upon the ecology, morphology, and especially upon the ontogeny of the various families, before any lasting suggestions can be made in the systematization.

The present paper is intended as a contribution toward this end, and if it succeeds in placing the family Ergasilidæ upon a solid basis of morphological and ontogenetic facts it will have accomplished its purpose. With reference to the systematization the author has at present only three suggestions:

1. The Lichomolgidæ should not be included in the same family with the Ergasilidæ, as is done by Thorell and Gerstaecker, but the two should constitute separate families, as given by Sars and T. Scott. The family Ergasilidæ as thus constituted includes only those forms which are parasitic on fish.

2. The Ergasilidæ are closely related to the Corycæidæ and Lichomolgidæ on the one side and to the Chondracanthidæ on the other, the four families forming a series from a free-swimming condition through the various stages of commensalism, semiparasitism, and parasitism to the degeneration and modification which always result from extreme parasitism. These four families ought therefore to be kept close together in the classification scheme.

3. The Ergasilinæ, the Bomolochinæ, and the Tæniacanthinæ are so closely related and form such a natural series that they should be grouped together rather than separated into distinct families. The nature of this relationship appears clearly in the following discussion.

FAMILY DIAGNOSIS.

Body with cyclops form, segmentation perfect or nearly so, first segment fused with head, other segments free or fused among themselves, genital segment enlarged but little, abdomen narrow, anal laminae with very long setæ. First antennæ tactile, never prehensile or locomotor, and alike in both sexes; second pair strongly developed, prehensile, and armed with stout claws. Mouth-parts degenerate, better suited for piercing or tearing, but with no trace of a siphon; maxillary hooks present in some species and like those in the Caliginæ. First four pairs of legs biramose, rami distinctly jointed; fifth pair uniramose, with indistinct joints.

Sex organs paired and situated in the cephalothorax; egg-sacks like those of *Cyclops*, eggs multiseriate and numerous.

Females becoming more or less fixed parasites, males remaining free-swimmers throughout life.

KEY TO SUBFAMILIES.

- a. Second antennæ much elongated, forming stout clasping organs, ending in a single strong claw; maxillipeds entirely wanting in the female. ERGASILINÆ, p. 311.
- a. Second antennæ normal size, terminal joint roughened and ending in several claws; maxillipeds present in both sexes. b.
- b. Maxillipeds turned forward outside, and partly in front, of the other mouth-parts; maxillary hooks not present. BOMOLOCHINÆ, p. 350.
- b. Maxillipeds in their normal position behind the other mouth-parts; maxillary hooks present. TENIACANTHINÆ, p. 381.

Subfamily ERGASILINÆ.

Body cylindrical and elongate, the ventral surface of the carapace projecting so that its edges can not be flattened down upon any surface to act as a prehensile disk.

First antenna small, the basal joints neither enlarged nor flattened, and moderately armed with slender setæ. Second antenna elongated into a powerful clasping organ, often half or even three-quarters as long as the entire body, and ending in a single stout claw. Mouth nearly in the center of the cephalothorax and projecting somewhat from the ventral surface. First swimming legs like the other pairs; fifth pair simple and one-jointed except in *Thersitina*.

Species minute, from 0.6 to 1 millimeter in length.

DESCRIPTION OF THE MOUTH-PARTS.

Female (fig. 27).—Mouth-parts removed some distance from the second antennæ. Labrum transversely elliptical or nearly orbicular,

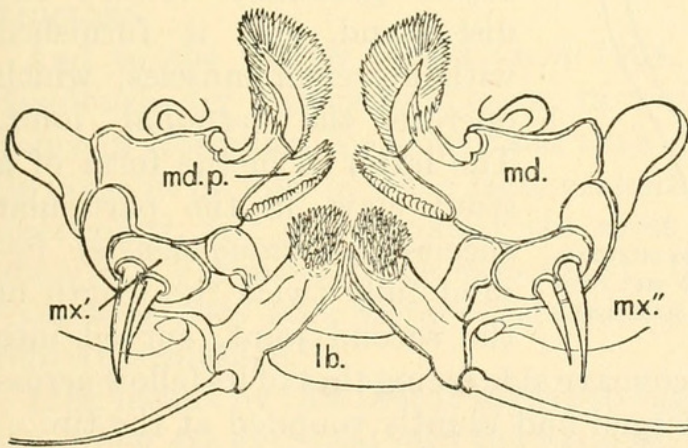


FIG. 27.—MOUTH-PARTS OF FEMALE ERGASILUS CENTRARCHIDARUM. lb, LABIUM; md, MANDIBLE; md. p., MANDIBULAR PALP; mx', FIRST MAXILLA; mx'', SECOND MAXILLA.

often so fused with the head in the adult as to be indistinguishable. Labium flattened or even depressed, and without hairs or spines; semicircular or U-shaped, the convex side pointing backward. In the short space between the labium and labrum are found the mandibles and first maxillæ. The mandible consists of a stout basal joint, armed with

a palp on its posterior margin, and a terminal joint, curved sharply forward and heavily fringed with short setæ around its entire margin. The palp is also fringed with similar setæ along its posterior margin and at its tip.

The two mandibles turn forward beneath the upper lip and overlap each other across the mid-line. The maxillary hooks are lacking; the

first maxillæ are in the form of stout knobs, each bearing two nearly straight setæ with or without plumes, which point backward and outward, and can be seen projecting from the ventral surface of the head in a lateral view. The second maxillæ are made up of a stout basal joint and a short terminal joint, curved forward similar to the mandible and armed with a thick tuft of setæ at its tip.

The chief difference between different species lies in the shape and armature of the terminal joints of the mandibles and maxillæ; the maxillipeds are lacking.

Male (fig. 28).—Mouth-parts in the same position as those of the female, and the first three pairs similar in all respects. The mandibles are perhaps turned a little more sharply forward, and the first

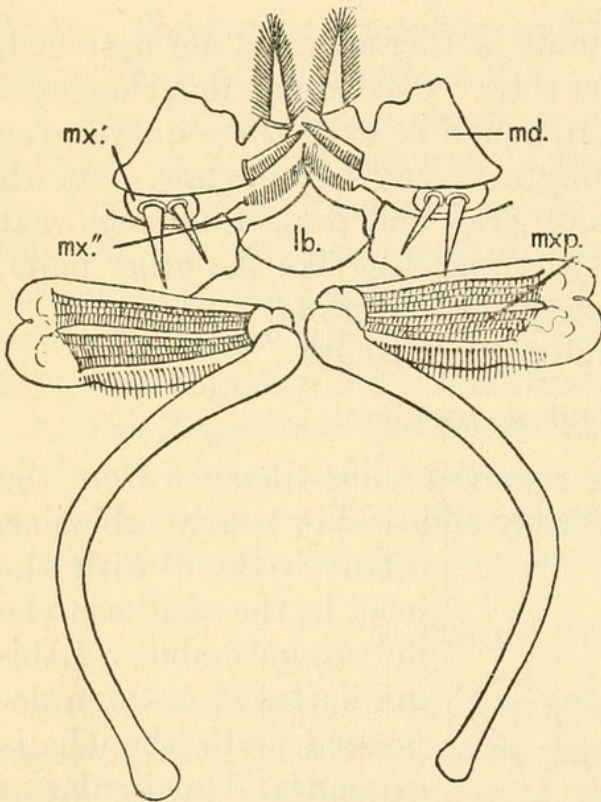


FIG. 28.—MOUTH-PARTS OF MALE *ERGASILUS CHAUTAUQUAENSIS*. *lb*, LABIUM; *md*, MANDIBLE; *mx'*, FIRST MAXILLA; *mx''*, SECOND MAXILLA; *mxp*, MAXILLIPED.

maxillæ are a trifle smaller than in the other sex. But the distinguishing characteristic is the presence of a pair of powerful maxillipeds in normal position behind the other mouth-parts. These are three-jointed and both the terminal joints are entirely free from the head. The basal joint is very short and merely serves to attach the appendages; the second joint is oblong, not much swollen, tapers gradually toward the distal end, and is furnished with powerful muscles, which operate the terminal joint. The latter is in the form of a stout claw, in the particular species (*chautauquaensis*) figured fully twice the length of the second joint, curved into

nearly a semicircle, with the concave side facing that of its fellow across the midline, and slightly enlarged and bluntly rounded at the tip.

In their natural position these large maxillipeds are turned forward and cover the other mouth-parts. The latter are also bunched together, the tips of the mandibles being underneath the tips of the second maxillæ, and the first maxillæ being partially or wholly covered by the basal joints of the same appendages. In the figure here given the distal portions of the mouth-parts have been separated in order to show as much as possible the exact shape of each.

Their bases, however, are in their proper position.

ARTIFICIAL KEY TO THE GENERA.

- a. Body somewhat flattened, considerably wider than thick; second antennæ slender and nearly as long as the entire body; first and second thorax segments free from the head but fused together.....*Macrobrachinus* Hesse, 1871, p. 264.
- a. Body cylindrical or spherical; second antennæ stout and no longer than the cephalothorax; first thorax segment fused with the head, the others free.....b.
- b. Carapace inflated into a sphere; first and second antennæ about the same length, short and stout; maxillipeds in the male with several strong apical spines, but without a claw.....*Thersitina* Norman, 1906, p. 347.
- b. Carapace cylindrical or flattened, much longer than wide; second antennæ four or five times as long as the first pair; maxillipeds in the male with a single terminal claw and no spines.....*Ergasilus* Nordmann, 1832, p. 326.

ONTOGENY.

Historical.—Nordmann, who founded this family, gave also a figure of the newly hatched nauplius of *Ergasilus sieboldii*, his type-species. In his text he presents an account of the development of the genus and a description of the nauplius, which were remarkably good when we consider the date of his work (1832) and the fact that he was dealing with a family previously unknown. His account, however, stopped with the nauplius and included none of the stages which intervene between that form and the fully developed adult.

Subsequent investigators have added practically nothing to our knowledge of this development. One or two of them, like Hesse and Beneden, have given us figures of the nauplius larvæ of other species. But these have not been supplemented by any text description, and the figures themselves have been far too small to give the details of structure.

And so the matter rested until 1904, when Hofer published his *Handbuch der Fischkrankheiten*, in which he embodies the substance of Nordmann's account and adds many statements of his own. He gives us no idea how the facts presented in these statements were ascertained, and unfortunately the most of them are at least questionable. For instance, he says (p. 8) "Die jungen Tiere, welche die Naupliusgestalt aller Copepoden haben, brauchen ca 1 Woche bis zum Ausschlüpfen."

If he means by this that it takes the eggs a week to ripen and hatch after they are extruded into the external sacs, he is probably wrong, for it requires a much longer period in every species observed by the present author.

If, on the other hand, he means that after the eggs are fully ripe and have begun to hatch it requires a week for them all to get out of the envelopes, he is undoubtedly again mistaken, for all the eggs in both strings have repeatedly hatched out under observation within a few hours.

Furthermore, his statement that these nauplii "suchen sich sofort einen neuen Wirt oder eine neue Stelle, an den Kiemen, des alten

Parasitenträgers, wo sie ihre Metamorphose bis zur definitiven Gestalt des erwachsenen Tieres durchmachen" (p. 9) can hardly stand in view of the fact that all copepod nauplii, as well those of parasitic forms as of the free-swimmers, seek the surface of the water and there swim about freely.

Indeed, so far is Hofer's statement from being true that in the Ergasilidæ all the stages in the metamorphosis take place while the larva is still a free-swimmer. No developmental stage of any member of this family has ever yet been recorded as found upon any host.

Later in the same year (1904) Gadd published an account of the Parasitic Copepods of Finland, in which he gives another figure of the nauplius of *Ergasilus sieboldii*, by far the best that has appeared. He also gives the first detailed account of the appendages, but states that he is not fully satisfied as to the number of segments they contain.

He notes the account given by Hofer and takes exception to the same statements that have been discussed above. But he was compelled to stop with the nauplius larva like Nordmann, though he made repeated trials to carry the development farther with water at different temperatures and different degrees of salinity. As will be seen, these accounts all describe the nauplius of *E. sieboldii* and that species alone. The following description includes all the facts thus presented and much additional material, based upon original observations made by the author upon two additional species of *Ergasilus* (*centrarchidarum* and *versicolor*).

Both of these are American species and the first of them was carried successfully through two molts subsequent to the nauplius stage, that is, up to the first copepodid stage. As all these accounts agree in every particular where exact comparison is possible, the development of the genus *Ergasilus* may be considered fairly established. And this development must serve as the type of the family, for at present nothing is known of that in any other genus. But since *Ergasilus* has served also as the type for the ecology and morphology, this only makes the account the more complete.

Mating.—The males of the genus *Ergasilus* remained unknown until 1863 when they were discovered and described by G. O. Sars from specimens captured in the tow. This author rightly concluded that the male leads a free and roving life in comparison with that of the female, and based his conclusion upon the fact that the male had never been observed before, and also upon the small size and comparatively weak development of his second antennæ. Sars then adds in substance as follows:

From this we are justified in assuming that the females are fertilized by the males once for all during their early free-swimming development stages, and that this fertilization is sufficient for the constant production of eggs and young during their subsequent fixed life. In fact it would be absurd to suppose that the males would be able to hunt for the females while the latter were concealed on the fishes' gills.

Subsequent observations, as well as the anatomy of the sexual organs already given (p. 301), have only served to confirm Sars's assumptions, but they still lack absolute proof.

However, it is reasonably certain that after the spermatophores are once fastened to the genital segment of the female, and their contents have passed into the semen receptacles, a sufficient amount is thus stored to fertilize all the eggs which that female can produce during her after life (note size of semen receptacle, figs. 15 and 16).

Breeding seasons.—Like the Caligidæ, the Ergasilidæ have no regular breeding season; females with egg-strings in different stages of development are found on the same host with those which have no egg-strings at all. But there seem to be three periods when females with fully ripe eggs are more common than at other times. These periods are the months of April—May, July—August, and October—November, in each instance including the last two weeks of the first month and the first two weeks of the second. During these times the examination of a few hosts is fairly sure to yield one or more females whose egg-strings are about ready to hatch. The most of the observations of the present author were made at Lake Maxinkuckee, Indiana, during the summers of 1906 and 1908 while in the employ of the U. S. Bureau of Fisheries. Females with ripe eggs began to be found in the middle of July, became more common by the last of the month, and then gradually diminished until by the middle of August they were extremely rare.

The intervals between these breeding seasons, eight or nine weeks, may therefore be taken to represent approximately the time of incubation plus the interval of rest which intervenes after each brood has been hatched.

Fertilization and extrusion of the eggs.—During the winter months from December to March these parasites appear to remain dormant, so far as any sexual activity is concerned.

When captured during this period the females are without egg-strings, and, as Nordmann states, the ovaries are usually empty, leaving the body more transparent than usual. The same thing happens sometimes between the breeding seasons in summer. But with the advent of warmer weather the ovaries quickly fill and the eggs are soon ready to be extruded.

As in the Caligidæ, each egg is fertilized when it passes out of the oviduct into the external sack. The latter is secreted only as there is a demand for more space and is extended by the pressure of the issuing eggs. But this pressure is not exerted along the axis of the sack, as in the Caligidæ, and hence the eggs are not flattened at right angles to that axis. The reason for this is a mechanical one and is to be found in the structure and arrangement of the ovary and oviduct, and in the muscular control of the external openings of the latter.

In the Caligidæ while the ovary is situated in the cephalothorax the eggs formed there are very small, simple nucleated cells, entirely without yolk. In this condition they pass down into the genital segment, which is much enlarged during the breeding season, and in which the posterior portion of the oviduct (uterus) is also enlarged and strongly convoluted. Here the eggs remain some time, increasing in size by the acquisition of yolk particles, and becoming strongly flattened or biscuit shaped in a single row along the terminal portion of the oviduct. But the part of the duct just inside the external opening is so convoluted that quite a little of it lies in the same straight line with the axis of the external sack. Thus the eggs, already flattened, pass out through the os uteri and are pushed straight back along the axis of the external tube. The only change is an increase in width and a corresponding decrease in thickness as they emerge into the external tube.

Here in the Ergasilidæ the conditions are very different. The ovaries are situated in the cephalothorax as before, but the eggs are fully formed there, taking on the yolk particles and attaining their maximum size. They then push back through the oviduct one by one, being compressed a little laterally, but not flattened into a biscuit shape. They pass through the genital segment as rapidly as through any other portion of the oviduct, and are at once extruded into the external sack. The opening of the oviduct, however, is on the side or dorsal surface of the genital segment and not at its posterior end. Hence the terminal portion of the oviduct inside this opening does not point backward in the direction of the body axis, but outward, more or less at right angles to that axis. But the external sack as soon as it acquires any length at all is carried back alongside the body and approximately parallel to the body axis. Hence the issuing eggs, instead of being passed out along a continuous straight line, have to turn almost at right angles as soon as they get into the sacks. This prevents them from forming in a single straight row and produces a multiserial arrangement, similar to that found in *Cyclops* and other free-swimmers.

The eggs mature in the posterior portion of the ovaries individually or in small groups and not collectively, and pass out through the oviduct similarly. Nordmann, in his admirable account, says:

Die Beobachtung Ramdohrs, dass die Eierstöcke ihren Inhalt nicht auf einmal in die Trauben ausleeren, stimmt mit meiner hierüber gemachten Erfahrung in sofern überein, als auch bei Ergasilus, während die Trauben schon mit Eiern angefüllt sind, zugleich noch in den Eierstöcken minder entwickelte Eiergruppen wahrgenommen werden (p. 12).

Each of these "Eiergruppen" contains but two or three eggs, sometimes only one, and as there is quite an interval between the ripening of successive groups, the external egg-sacks fill out slowly.

Their rate of growth is well shown in figure 29, which gives three stages of development. At the beginning one egg evidently ripened alone; in the second group there were three eggs on one side and four on the other, while in the third group there were again three eggs on one side and four on the other.

So long as the eggs remain in the oviduct they are granular and homogeneous and surrounded by only a single delicate membrane. The formation of the second outer shell takes place in the external sacks. As development proceeds these two shells separate more and more from each other, and the outer one thickens and hardens a little.

Coming thus separately, with intervals between the successive groups, each egg has time to assume a spherical shape in the proximal

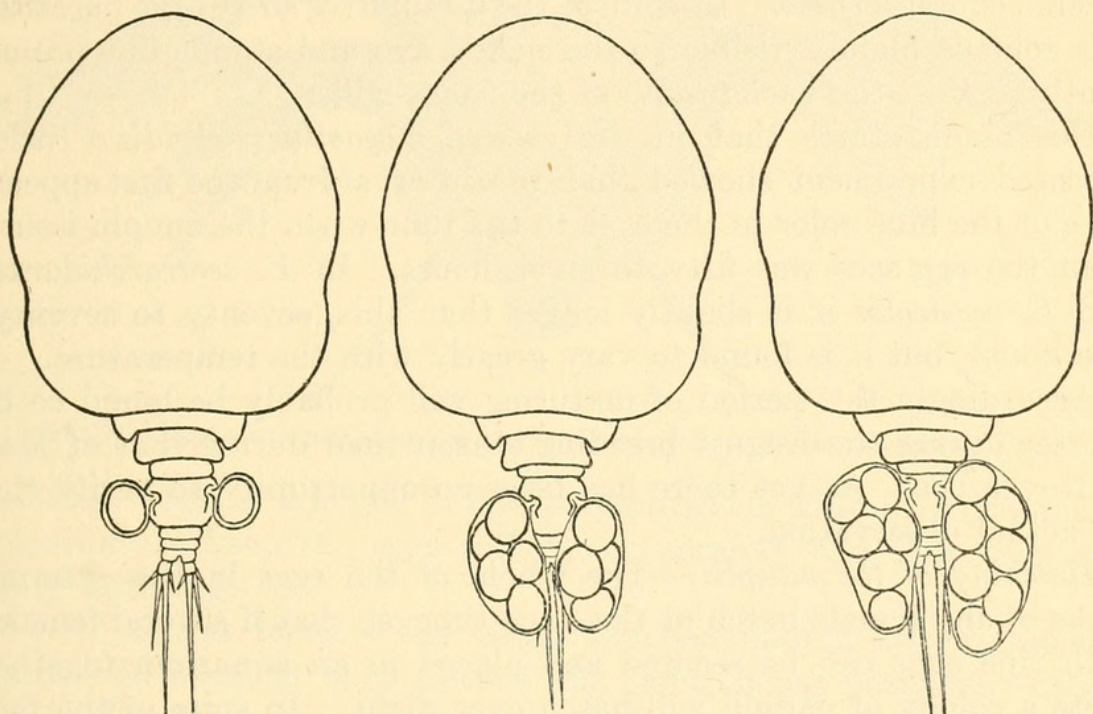


FIG. 29.—THREE SUCCESSIVE STAGES IN THE GROWTH OF THE EGG CASES OF *ERGASILUS CENTRARCHIDÆ*, SHOWING THAT THE EGGS RIPEN IN GROUPS AND NOT SINGLY.

end of the sack before the next lot issues. And the pressure being diffused around an angle, is distributed in different directions; while some of it may continue to be parallel to the axis of the egg-tube by far the greater part is tangential. In consequence the eggs do not assume a biscuit shape but remain more or less spherical, being flattened only where they press against one another.

Again there are no partitions here between the individual eggs as in the *Caligidæ*, but the eggs lie in actual contact one with another. This allows the pressure to be evenly distributed throughout the entire tube, thereby reducing it to the lowest possible terms. The eggs are also capable of moving about within the tube and can readjust themselves whenever necessary. Consequently there is usually very little flattening even at the points of contact.

Furthermore, there can be no such regularity in the arrangement of the germinal areas as was found in the Caligidæ. But in those eggs which remain in contact with the wall of the tube there seems to be a tendency to have the germinal area on the outer side. Yet even here, there is nothing definite in the orientation of the embryo itself.

Maturation in the external sacks.—The eggs change in color with advancing development; at first they are white and opaque but gradually assume the color of the pigment which is to distinguish the nauplius when it finally issues.

This color varies in the different species so far as observed, and is constant in the same species, and so furnishes a good secondary specific characteristic. In spite of the diminutive size of the parasites this color is plainly visible to the naked eye and stands out prominently against the background of the fishes' gills.

Nordmann states that in the case of *Ergasilus sieboldii* a thrice repeated experiment showed that the interval from the first appearance of the blue color in the eggs to the time when the nauplii issued from the egg sacs was fifty to sixty hours. In *E. centrarchidarum* and *E. versicolor* it is slightly longer than this, seventy to seventy-five hours, but it is found to vary greatly with the temperature.

Accordingly this period of maturing will probably be found to be shorter during the August breeding season than during that of May or November. As yet there has been no opportunity to verify this by actual observation.

Hatching of the nauplii.—The whole of the eggs in the external sacks of any female hatch at the same time, so that if several females with ripe eggs can be secured and placed in an aquarium together quite a colony of nauplii will hatch over night. In spite of the fact that most of the nauplii are in contact with the wall of the egg tubes, each one does not break through the latter for itself, but the tube ruptures in one or two places only, and all the nauplii issue through the same opening. Hence the tubes are only rarely broken away from the mother, but are nearly always left as empty bags after the last nauplius has emerged.

The embryos then rupture the outer or vitelline membrane of the egg, issuing forth covered only with the delicate inner membrane. This is much more difficult to break than the outer membrane, and the movements of the inclosed embryo, with the consequent unfolding of its appendages, frequently enlarges this inner membrane fully one-half before it finally gives way. Nordmann makes the statement that the cutting off of the egg sacs or the death of the mother does not disturb the development of the young. This is true only within certain limits, and those limits must be understood if the statement is to be accepted. All the mother can do for the eggs after their

extrusion into the external sacks is to keep them properly aerated. But this is of vital importance here as in all the Crustacea.

If the eggs are so far advanced that they will hatch out in from twenty-four to thirty-six hours after capture, then Nordmann's statement holds true. And if they are placed in fresh water it makes no difference whether the mother is alive or not—they will hatch just

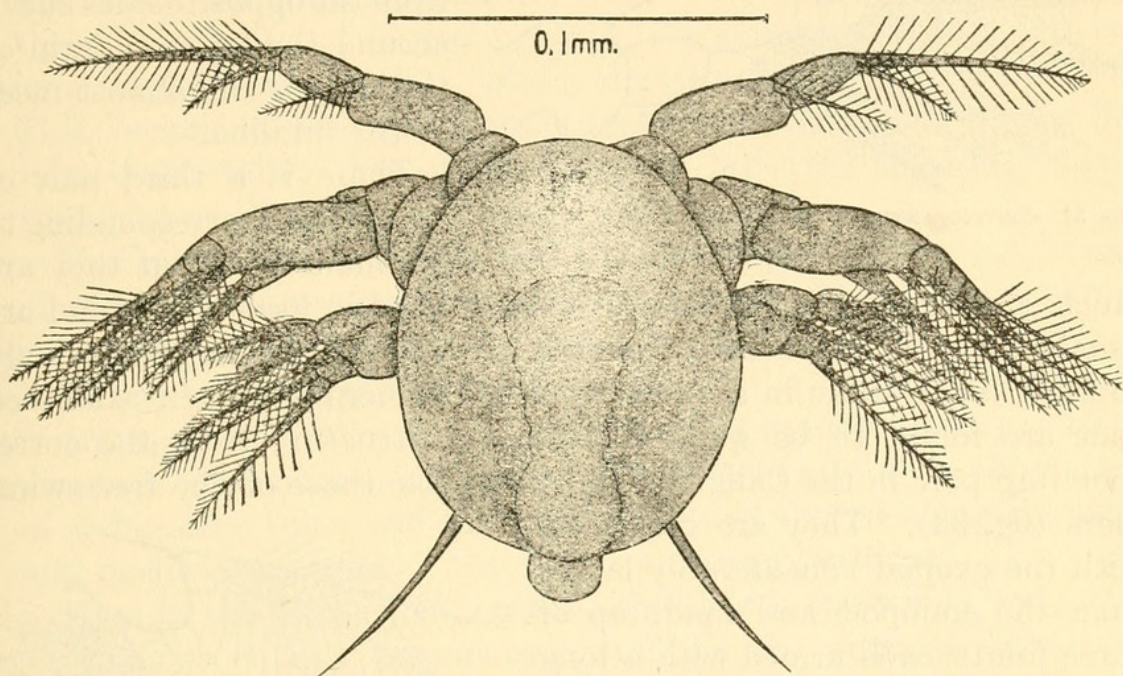


FIG. 30.—NEWLY HATCHED NAUPLIUS OF *ERGASILUS CENTRARCHIDARUM*, DORSAL VIEW.

the same. But if a longer period is required, it will be found almost impossible to keep the eggs sufficiently aerated, and they then die before hatching.

The Nauplius larva.—The newly hatched nauplii are extremely minute and swim at once toward the light, being positively heliotropic. On being viewed under normal conditions they are seen to have the typical nauplius form, elliptical or oval in outline and strongly flattened (fig. 30). Yet they differ very noticeably from the nauplii of the Caligidæ and considerably from those of the free-swimming forms, as can be seen in the following description:

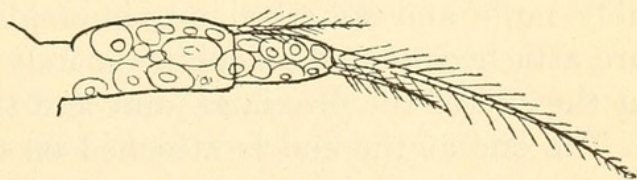


FIG. 31.—FIRST ANTENNA OF NAUPLIUS OF *ERGASILUS CENTRARCHIDARUM*.

In dorsal view there are often apparently only two pairs of appendages, corresponding to the first and second antennæ, which are of the usual structure and proportionally much larger than in the Caligidæ. Each of the first pair is uniramous, two-jointed, and terminates in two unequal setæ, the anterior of which is much longer than the posterior (fig. 31). These first appendages are carried straight forward, side by side, while the second pair extend outward at right angles to the body axis. This latter pair are stouter than the first

and are the principal locomotor organs. They are of the usual form, biramose, and armed with long plumose setæ.

From the ventral surface of the basal joint of each there extends inward a short masticatory process, ending in a stout curved spine, much longer than those found in ordinary free-swimming forms (fig. 32). The two spines from the opposite sides curve around the lower margin of the labium and almost meet at the midline.

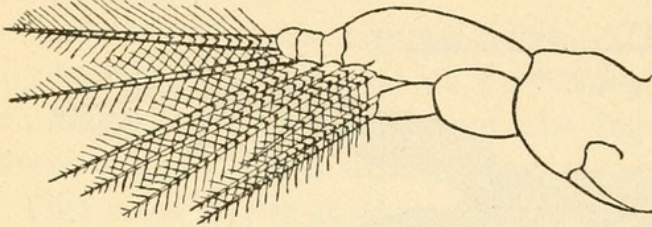


FIG. 32.—SECOND ANTENNA OF NAUPLIUS OF ERGASILUS CENTRARCHIDARUM.

There is a third pair of appendages corresponding to the mandibles, but they are much smaller than the others, are seldom used in locomotion, and are usually carried folded back beneath the lateral margin of the body so as to be invisible in a dorsal view. Furthermore when examined they are found to be quite different in structure from the corresponding pair in the Caligidæ, and more like those of the free swimmers (fig. 33). They are biramose, with the exopod considerably larger than the endopod and made up of three joints, each armed with a long plumose seta. Thus these exopods, while they are larger than those of the free swimmers, are at the same time smaller than in the Caligidæ, where they have the same number of joints as the exopods of the second appendages. This diminution in the mandibles offsets the increase in size of the second antennæ and makes the general average about the same in both families.

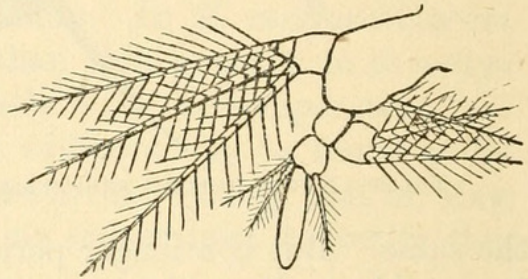


FIG. 33.—MANDIBLE OF NAUPLIUS OF ERGASILUS CENTRARCHIDARUM.

The endopods depart radically from the form seen in the Caligidæ and approach that of the free-swimmers. Each consists of a tolerably large and spherical proximal joint, the protopodite, to which are attached two distal joints entirely separate from each other, one at the end of the proximal joint and the other on its ventral surface.

The one at the end is attached on a level with the dorsal surface of the proximal joint. It is considerably widened along its distal margin, which is armed with three spines and a curious flattened lamina, shaped like the blade of a case knife. The other joint forms a masticatory blade which extends downward at right angles to the axis of the basal joint. It is also widened at its distal end where it carries two long setæ of equal size.

The median eye is placed far forward and is comparatively large; it is almost entirely concealed in dorsal view by the supraesophageal

ganglion, which lies above it and which is heavily pigmented with black.

The balancers at the posterior end of the body are cylindrical, very slender, and slightly curved, but there is no trace of the spatulate form so characteristic of the Caligidæ. They are attached on the dorsal surface some little distance in front of the posterior end of the body, and project obliquely backward and outward. Between these balancers and projecting from the posterior end of the body is a large hemispherical knob, slightly flattened dorsoventrally. This, combined with the symmetrical elliptical outline, gives a body form quite unlike that of the Caligidæ, but very similar to that of *Cyclops nauplii*.

The body itself is simple and without segmentation, and consists of a cellular exterior surrounding the general body cavity, through the center of which passes the digestive tube.

In the Caligidæ the anterior portion of the body of the nauplius is transparent, while the posterior half is rendered opaque by the presence of numerous yolk cells. There is hardly more than a trace of a digestive tube, and the pigment is distributed along the lateral and posterior margins of the body in various patterns.

Here in the Ergasilidæ, on the other hand, the whole body of the nauplius is equally transparent, and all the pigment except that appearing in the supraesophageal ganglion is confined to the walls of the digestive tube. The cellular exterior is not quite as clear as in the Caligidæ, but the individual cells can be more plainly seen.

The fluid which represents blood and which circulates in the body cavity is also more distinctly visible. Along the sides of the body can be seen the muscles which move the appendages, each extending backward obliquely from the base of the appendage nearly to the posterior end of the body; they are all plainly striated.

The digestive tube is much more distinctly visible than in the *Caligus* nauplius and fills the center of the posterior half of the body. To make it still more prominent all the pigment, as just stated, is confined to its walls, which thus stand out prominently in contrast to the colorless tissues surrounding them. It is enlarged at the anterior and posterior ends into a more or less spherical sac, and constricted in the intervening space.

Not only is it thus more visible, but it is better developed and the peristaltic movements of its walls are plainly in evidence. No opening could be seen at its posterior end, and when, in consequence of the increasing pressure of the cover glass, the body finally burst and its contents escaped the rupture took place at one side of the intestine and not at its end; and the intestine itself was not ruptured nor did its contents pass out for a long time. This is good

evidence that there is no anal opening at this stage of development, and also that the walls of the intestine are stronger than the body walls.

First metanauplius larva.—Three molts occur in from eighteen to twenty-four hours, and the larva then emerges in the first metanauplius stage (fig. 34). The body form as well as the appendages have changed considerably, but there is yet much resemblance to the original nauplius.

The body is now an elongated oval, twice as long as wide, and decidedly narrowed posteriorly. The division into regions is indicated by notches in the lateral margins and by faint grooves running across the body. The cephalothorax is much the largest division and constitutes fully two-thirds of the entire body. It is elliptical

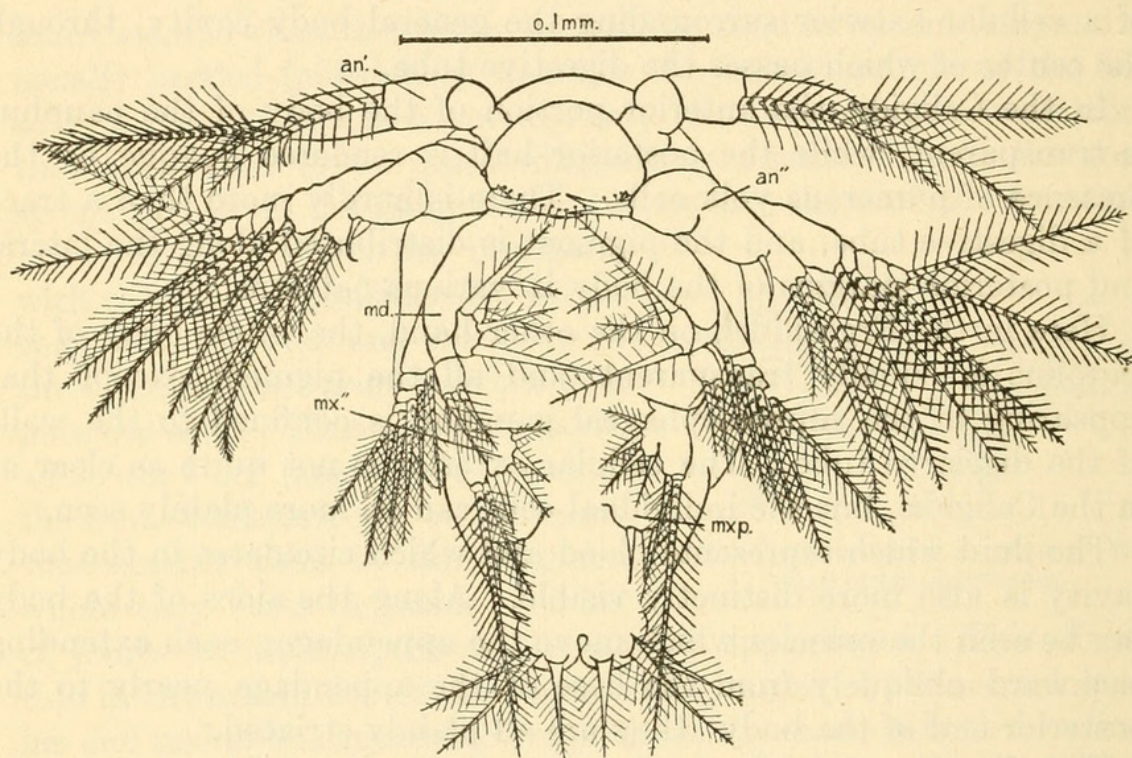


FIG. 34.—FIRST METANAUPLIUS LARVA OF *ERGASILUS CENTRARCHIDARUM*. THE FIRST MAXILLÆ IN THIS FIGURE ARE CONCEALED BENEATH THE MANDIBLES. LETTERING AS IN FIG. 4, P. 273.

in shape, as wide posteriorly as anteriorly, with the lateral margins often reentrant.

The eyes are situated far forward and in contact on the mid-line; they are concealed in dorsal view by the heavily pigmented supraesophageal ganglion, but can be seen fairly well from the ventral side in most larvæ.

The segments of the free thorax are indistinguishably fused and strongly tapered. The segments of the abdomen are also fused, and this region consists of little more than a pair of relatively enormous anal laminæ, each of which is armed with three or four stout setæ. The appendages remain very similar to those of the nauplius stage. The first antennæ have now become four-jointed, of which the ter-

minal joint is the longest and is well armed with setæ; there is also a large seta on the ventral surface at the end of the third joint. The second antennæ are still biramose, the exopod exactly like that of the nauplius, while the endopod has become three-jointed, the joints diminishing regularly in size, and the setæ with which they are armed increasing as regularly. The masticatory process from the basal joint of these appendages has increased in size and is now armed with two large claws of about the same length.

The right and left antennæ in these first two pairs are attached close to the lateral margin of the head, leaving a wide space between their bases. This space is entirely filled by the large, transversely elliptical upper lip, which carries a row of stiff hairs along its posterior margin (fig. 35).

In the third pair of appendages the exopod and endopod remain practically the same as before, but the masticatory process has completely changed. It is now flattened and triangular, one angle serving as a point of attachment to the endopod, while from each of the other angles

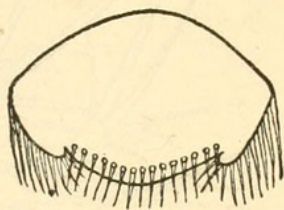


FIG. 35.—LABRUM OF FIRST METANAUPLIUS LARVA.

proceeds a large plumose seta, with a third smaller one at the center of the side between them. On these three setæ and on two others which project inward from the inner margin of the basipod the plumose hairs are attached in pairs with long intervals between them.

In addition to these three pairs of appendages the metanauplius has acquired three others, two pairs of maxillæ and a pair of maxillipeds. The first maxillæ are just behind and close to the bases of the mandibles, where they easily escape notice. They are not shown in figure 34, being concealed by the bases of the mandibles, but may be seen in figure 36. The rest of figure 34 showed so well it was considered better to secure the drawing rather than risk its entire loss by trying to manipulate the mandibles. The latter are uniramous processes, one-jointed, and tipped with two spines.

The second maxillæ are some distance behind the first pair, are one-jointed, and bilobed at the tip. The outer ramus is longer than the inner, and is armed with two large setæ, the outer of which reaches back beyond the tips of the setæ on the anal lamina; the four endopod setæ are much shorter. The maxillipeds are very rudimentary and consist of a mere knob projecting slightly from the ventral surface and armed with two short setæ. But that knob is very distinctly posterior to the notch in the lateral margin of the cephalothorax, which marks the dividing line between the cephalon and the first thoracic segment.

Here, then, is another species to add to those already described by Hansen, Giesbrecht, and Claus, in which the maxillipeds are definitely

thoracic in origin, while the other mouth-parts are cephalic. In the internal anatomy of these metanauplii there has been a considerable rearrangement of the muscles which move the appendages. Owing to the insertion of muscles for the two new pairs of appendages, those which move the three original pairs can not extend as far back in the body as formerly, but run more directly inward from the bases of the respective appendages.

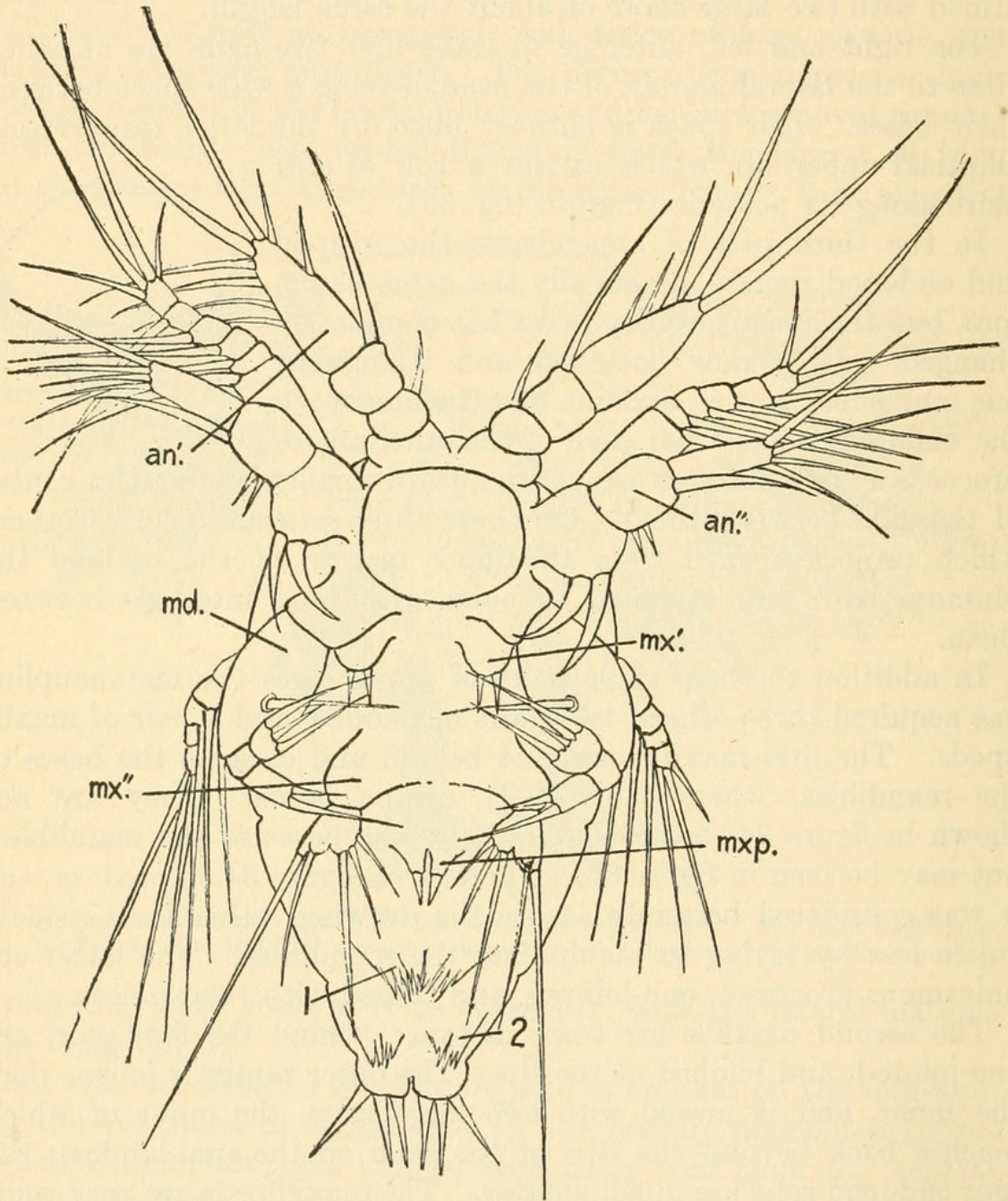


FIG. 36.—SECOND METANAUPLIUS JUST READY TO MOLT INTO THE FIRST COPEPODID STAGE.
LETTERING AS IN FIG. 4, P. 273.

The digestive canal still retains its deep blue pigment, and at its anterior end has developed a well-defined stomach, from which a straight intestine of gradually decreasing width runs back to the anus. This latter is situated between the anal laminae and is now distinctly visible. The larva begins to eat during this period and the peristaltic movements concerned in digestion are very evident. At the same

time the yolk cells gradually disappear, so that by the close of this stage there are only a few left. The brain is now connected behind the nauplius eye and a rudiment of the genital organs can be detected in a small mesodermal growth on either side of the alimentary canal.

The second metanauplius larva.—Two more molts now take place in from twenty-four to thirty-six hours, and the emerging larva shows a more decided oval shape, the body having increased in length, and its posterior end being somewhat narrowed (fig. 36). The anterior antennæ are five-jointed; the

terminal joint is about half the entire length and copiously supplied with setæ of all lengths and sizes (fig. 37). The posterior antennæ also have one more joint than in the preceding stage and the number of their setæ have increased. Otherwise they have not essentially changed from their previous condition, and still retain

the masticatory claws on their basal joints. In the mandibles (fig. 38) the exopod has increased in the number of segments and correspondingly in the number of its setæ. The endopod has lengthened until it is more than twice as long as wide and carries five setæ, but it is still one-jointed. The masticatory blade is widened and is now

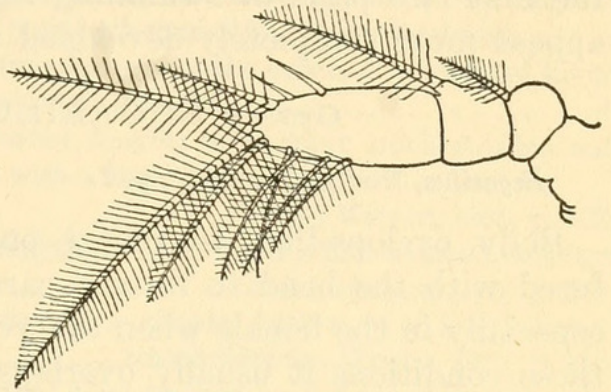


FIG. 37.—FIRST ANTENNA OF SECOND METANAUPLIUS LARVA.

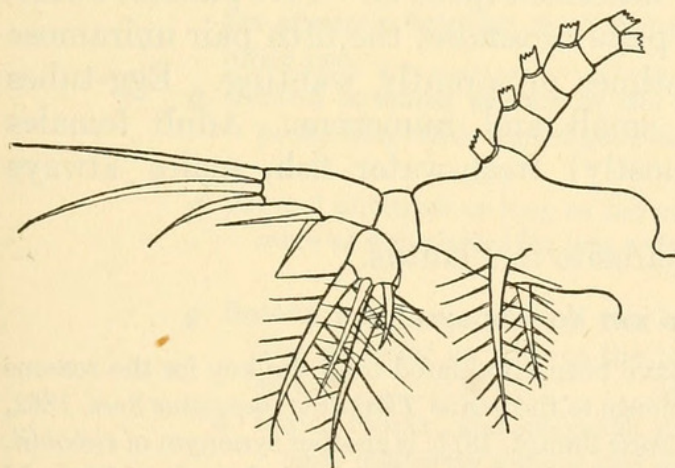


FIG. 38.—MANDIBLE OF SECOND METANAUPLIUS LARVA. THE EXOPOD IS TURNED BACK IN ORDER TO SHOW MORE DISTINCTLY THE ENDOPOD AND THE MASTICATORY PROCESS.

armed with four setæ, while the basal joint (protopodite) of the appendage shows traces of segmentation. The maxillæ remain as in the previous stage, except that they have migrated a little toward the median line. The maxillipeds have moved still farther inward until they have met on the midline. They have also degenerated greatly and are now nothing more than slender papillæ, each tipped with a single spine. Evidently this is a female larva and these appendages will disappear at the next molt into the copepodid stage.

It was impossible to carry the larvæ into this latter stage, but since they remain free-swimming during their entire metamorphosis such

stages must be present in the plankton at the right season and could be obtained by towing, or they could be reared in suitable aquaria.

It would be of particular interest to obtain the complete development of both sexes, following especially the movements of the maxillipeds and the backward migration of the mouth-parts. The rest of the details are doubtless quite similar to those found in free-swimming forms.

Behind the disappearing maxillipeds may be seen the rudiments of the first two pairs of swimming legs (fig. 36, 1 and 2), which will appear more completely developed in the first copepodid stage.

Genus *ERGASILUS* Nordmann.

Ergasilus, NORDMANN, 1832, p. 7.

Body cyclops-like, narrowed posteriorly; first thorax segment fused with the head to form a carapace which is inflated dorsally, especially in the female when the ovaries are well developed. Under these conditions it usually overlaps and conceals the following free segments, of which there are four, followed by the genital segment, which is but slightly enlarged. Fourth free (fifth) segment very short and not easily distinguished; abdomen also short, narrow, and indistinctly jointed; anal laminae with very long setae. First antennae six-jointed and well armed with setae; second pair stout, four-jointed, very strong in the female, much smaller and weaker in the male. Mouth nearly in the center of the carapace on the ventral surface; mouth-parts already described (p. 311). Five pairs of swimming legs; the four anterior pairs biramose, the fifth pair uniramous and very rudimentary, sometimes apparently wanting. Egg-tubes like those of *Cyclops*, eggs small and numerous. Adult females parasites on the gills of (mostly) fresh-water fish, males always remaining free.

(*Ergasilus*, the name of a parasite in Plautus.)

ARTIFICIAL KEY TO THE SPECIES.

The following published species have been eliminated from the key for the reasons stated. *Biuncinatus* Gadd, 1901, belongs to the genus *Thersitina*; *depressus* Sars, 1862, proves to be a synonym of *sieboldii*; *esocis* Sumpf, 1871, is another synonym of *sieboldii*. Sumpf does not tell us the host of this species, but the name he has given it would make it certain that it came from some species of *Esox*, which is also one of the hosts of *sieboldii*. Furthermore in this portion of his paper Sumpf is discussing only Die Mundwerkzeuge der sogenannten Poecilostomen, and he describes and figures nothing but the mouth-parts of *esocis*, without any mention of its body form or other appendages, or any further description of it as a separate species. Four years later Claus, from whom Sumpf obtained his material, published a description of *sieboldii*, and his figure of the mouth-parts is printed from the same plate as this one of Sumpf's. Hence *esocis* must be regarded as a name wrongly given by Sumpf to *sieboldii*, under the impression that it was a new species. *Gasterostei*, given by some authors as a species of *Ergasilus*, belongs rather to the genus *Thersitina* (p. 349). *Mugilis* Vogt, 1877,

which was put forth as a probable synonym of Hesse's *Megabrachinus suboculatus*, must stand valid until some one can give us confirmation of Hesse's species.

- a. Head completely fused with the first thorax segment, with no indication of the union; carapace elongate, much longer than wide, and more than half the entire length.....b.
- a. Head fused with the first thorax segment, but the fusion indicated by distinct indentations on the lateral margins; carapace half the entire length and violin shaped.....e.
- a. First thorax segment distinctly separated from the head by a well-defined groove; carapace short, as wide as long, and much less than half the entire length.....h.
- b. Anterior margin of carapace evenly rounded; first antennæ hardly reaching the end of the first joint of the second pair; both rami of fourth legs 3-jointed.....c.
- b. Anterior margin of carapace projecting strongly at the center in a rounded knob; first antennæ much longer and heavily bristled.....d.
- c. Second antennæ one-third the entire length; basal joint much swollen and widened distally; second joint with a large process on its outer border.
funduli Kröyer, 1863, p. 328.
- c. Second antennæ half the entire length, the two basal joints without swellings or processes.....*labracis* Kröyer, 1863, p. 329.
- d. Second antennæ normal; terminal claw simple; both rami of fourth legs 3-jointed.....*centrarchidarum* Wright, 1882, p. 331.
- d. Second antennæ normal; terminal claw toothed on the inner margin; exopods of fourth legs two-jointed.....*cæruleus*, new species, p. 334.
- d. Second antennæ with large processes in the form of sleeves around the base of each joint; terminal claw with a large tooth on the inner margin; fourth exopods 2-jointed.....*manicatus*, new species, p. 337.
- e. Both rami of fourth legs 3-jointed.....f.
- e. Exopod of fourth legs with but two joints.....g.
- f. Ventral surface of genital segment smooth; three abdominal segments the same length.....*sieboldii* Nordmann, 1832, p. 338.
- f. Ventral surface of genital segment armed posteriorly with a large number of coarse bristles; third abdomen segment much shorter than the other two.....*lizæ* Kröyer, 1863, p. 340.
- g. Second antennæ as long as the carapace; the latter much narrowed posteriorly; fifth legs of good size, armed with three setæ.
nanus van Beneden, 1870.
- g. Second antennæ as long as the carapace; posterior portion of latter as wide as anterior; fifth legs reduced to a single small spine.
versicolor, new species, p. 341.
- g. Second antennæ only half the length of the carapace; posterior portion of latter as wide as the anterior; fifth legs reduced to a single spine.....*chautauquaënsis* Fellows, 1888, p. 343.
- h. Head, thorax, and abdomen diminishing regularly in width; carapace relatively narrow and evenly rounded anteriorly.....i.
- h. Carapace relatively wide, with a rounded projection at the center of the anterior margin; first thorax segment as wide as the carapace, second abruptly narrowed to half that width.....j.
- i. Second antennæ one-third the entire length; abdomen one-half longer and a little narrower than the genital segment; fifth legs short and stout, with a single seta.....*peregrinus* Heller, 1865.
- i. Second antennæ one-half the entire length; abdomen shorter and much narrower than the genital segment; fifth legs reduced to a mere spine.....*longimanus* Kröyer, 1863.

- i. Second antennæ two-thirds the entire length, first pair also very long; abdomen one-half longer, and as wide, as the genital segment, fifth legs long and slender and tipped with a pair of long setæ.....*osmeri* van Beneden, 1870.
- j. First thorax segment half as long as the carapace; grooves between thorax segments deep and saddle-like; anal laminæ five times as long as the last abdomen segment, each with two unequal setæ.....*gibbus* Nordmann, 1832.
- j. First thorax segment fully as long as the head; grooves between thorax segments shallow; anal laminæ the same length as the last abdomen segment, each with two unequal setæ.
mugilis Vogt, 1877, p. 345.
- j. First thorax segment less than a quarter the length of the head; grooves between thorax segments shallow and indistinct; anal laminæ five times the length of the last abdomen segment, each with three setæ.....*trisetaceus* Nordmann, 1832.

ERGASILUS FUNDULI Kröyer.

Ergasilus funduli, KRÖYER, 1863, p. 228, pl. 11, figs. 1, a to f.

Female.—Body pyriform, from two and a half to three times as long as wide, strongly narrowed posteriorly. Head completely fused with the first thorax segment, without groove or emargination at the point of union. Carapace two-thirds the entire length, with the antennal area strongly projecting at the center of the frontal margin, and separated from the rest of the cephalon by a well-defined groove.

Free thorax segments diminishing regularly in size; genital segment somewhat oval, with a pair of rudimentary legs near the openings of the oviducts. Abdomen three-jointed, all the joints very short and wider than long; anal laminæ minute, as broad as long, each tipped with three setæ, the inner of which is twice as long as the others. Egg-tubes cigar-shaped, narrow and about as long as the entire body; eggs in three or four longitudinal rows, fifteen or sixteen eggs in a row.

First antennæ very short, not reaching the end of the basal segment of the second pair, and indistinctly segmented; segments broader than long, the last one only with setæ. Second antennæ about one-third the entire length, the first two segments thick and swollen and forming together a stout base, the terminal joints much more slender, the last one in the form of a claw with a small conical knob on the concave side near the base. The second joint also has a stout, thumb-like protuberance at the proximal end on the outer margin. Kröyer makes the structure of these second antennæ the distinctive characteristic of the species.

The mouth-parts have never been described, but Kröyer states that they are the same as those of other species, with no apparent peculiarities. The first four pairs of swimming legs are biramose, each ramus with three joints; the fifth pair are reduced to mere spines on the sides of the fifth segment.

Nothing is said of the color of the specimens.

Total length, 0.70 mm. Length of carapace, 0.285 mm. Width of same, 0.25 mm. Length of egg-strings, 0.8 mm.

(*funduli*, the generic name of the host.)

A few specimens of this species were found on the gills of *Fundulus ocellaris* (*F. limbatus*, Kröyer).

The fish had been obtained near New Orleans, Louisiana, and sent as specimens to the Royal Museum of Copenhagen.

There they were examined and these parasites found and afterward sent to Kröyer. No specimens have been discovered since, but neither have any of the *Fundulus* from that locality been examined for them. In all probability a little search would rediscover this species and there would be a chance to find the male which is as yet unknown.

ERGASILUS LABRACIS Kröyer.

Plate 41.

Ergasilus labracis, KRÖYER, 1863, p. 303, pl. 11, figs. 2, *a* to *e*.

Ergasilus labraces, SMITH, 1874, p. 573.

Ergasilus labracis, LEIDY, 1888, pp. 125 and 166.

Female.—Body elongate, more than twice as long as wide, abruptly narrowed posteriorly. Head completely fused with the first thorax segment, with no indication of the union.

Carapace three-fifths the entire length, projecting somewhat at the center of the frontal margin, nearly squarely truncated posteriorly. Free thorax less than half the width of the carapace, its segments diminishing regularly backwards.

Genital segment small, about the same width as the fifth segment and half as long as the four free segments, with nearly straight sides. Abdomen three-fifths as wide as the genital segment, three-jointed, the joints about the same length but diminishing in width. Anal laminae the same length as the last abdomen joint, each armed with three setæ, of which the inner one is very stout and twice the length of the other two. Egg-tubes cigar-shaped, narrowed posteriorly, and as long as the entire body; eggs in four to six longitudinal rows, about twenty in each row.

First antennæ very short, hardly reaching the tip of the first segment of the second antennæ, six-jointed, each joint as broad as long and fairly well provided with setæ of moderate length. Second antennæ half as long as the body, distinctly four-jointed; basal joint short, swollen, and very obliquely truncated at its distal end; second joint longer, narrower, and slightly curved, with a small knob at the center of the inner border. The last two joints constitute the claw, which is strongly curved and armed near the joint on the inner margin with several small knobs or teeth.

Mouth-parts large and distinctly defined; the terminal joints of the mandibles very wide and fringed with long hairs, the basal joints large and muscular. The palps are rather narrow, but are fringed with long hairs like the mandible itself. First maxillæ in the form of large and nearly spherical knobs, each armed with two setæ.

Second maxillæ with large and triangular basal joints, which extend outward nearly to the lateral margin, and forward in front of all the other mouth-parts. The terminal joints are also large and stout and are heavily fringed along their anterior margin.

In the swimming legs the endopod of each pair is larger than the exopod; both rami are three-jointed, except the exopods of the fourth legs, which have but a single joint.

The fifth legs are reduced to small spines nearly invisible.

The arrangement of the spines and setæ on the first four pairs of legs is as follows: First exopod, I-0; 0-1; II-6: endopod, 0-1; 0-1; II-3: second exopod, I-0; 0-1; 0-6: endopod, 0-1; 0-2; II-4: third exopod, I-0; 0-1; I-5: endopod, 0-1; 0-2; II-5: fourth exopod, I-4: endopod, 0-1; 0-2; I-3.

Color in sexually mature specimens a uniform milk-white on the dorsal surface; in other individuals with a bluish tinge and translucent, but always with a variegated pattern of blue pigment along the center of the ventral surface on either side of the mid-line (fig. 43).

Total length, 1 to 1.25 mm. Length of carapace, 0.65 mm. Width of same, 0.5 mm. Length of free segments, 0.17 mm. Length of egg-strings, 0.95 mm.

(*labracis*, from *Labrax*, the generic name of its host.)

This species was first found by Krøyer in considerable numbers on the gills of the striped bass, *Roccus lineatus* (*Labrax lineatus* Krøyer) at Baltimore, Maryland, in the year 1860. It was afterwards (1887) found by Leidy to be common on the gills of the same fish in the Philadelphia markets, but he added nothing in the way of description to what Krøyer had given.

The first description and drawings, therefore, are the only ones that have ever been given, and it is hoped that the present account will supplement this in many ways.

The National Museum collection contains four bottles of specimens obtained at different times by Dr. H. M. Smith, of the U. S. Bureau of Fisheries, from the gills of the same striped bass in the fish markets at Washington, District of Columbia. These bottles are numbered respectively 38633, 38653, 38654, and 38657.

The first and the last of these contain the gills themselves, with the parasites still clinging to the filaments, and are very instructive in showing how thoroughly our food fish may become infested with these creatures. Beside these there are two bottles, numbered 38655 and 38656, which also contain infested gills of striped bass

taken at Woods Hole, Massachusetts. These have even more parasites on them than the foregoing, one of the gills being almost literally covered. A seventh lot was collected by S. G. Worth at Franklin, Virginia, from the same host, and is numbered 13019.

These records prove that this species is common on the striped bass along the entire Atlantic coast, and the examination of such fish in any of the markets where they are kept for sale will almost certainly yield specimens of the parasites.

ERGASILUS CENTRARCHIDARUM Wright.

Plate 42, text-figures 2, 3, 7, 13 to 25, 27, 29 to 38.

Ergasilus centrarchidarum, WRIGHT, 1882, p. 243, pl. 1, figs. 12-18.

Female.—Cephalothorax elliptical, projecting a little at the center of the frontal margin and nearly as broad as long, the proportion being about 85 to 110 in young females and 90 to 100 in mature adults. In the latter this region is so strongly inflated by the genital products that it also projects backward over the free segments and hides them in dorsal view. Lateral constriction between the head and first thorax segment barely noticeable in the young, not visible at all in the adult. First three free segments about the same length and regularly narrowed backwards, the first of them (second segment) less than half the width of the cephalothorax. Fifth segment very short and narrow; genital segment no wider and barrel-shaped, with rounded sides. Egg-sacks cylindrical or cigar-shaped and a little longer than the entire body; eggs of good size and arranged in five or six longitudinal rows, about 100 in each sack. Abdomen half the width of the genital segment, three-jointed, the middle joint a little shorter than the other two. Anal laminæ large, as long as the terminal joint of the abdomen and each armed with three setæ, of which the inner one is from two to three times as long as the two outer ones, which are of about the same length.

First antenna six-jointed, the joints unequal in length and not corresponding in different individuals, nor even in the two antennæ of the same individual. Usually the second joint is the longest and the sixth is next.

These antennæ originate on the under surface of the frontal projection and some distance apart; each joint bears one or more simple setæ, the longest of which are as long as the entire antenna. The setæ on the first four joints are directed chiefly downward; on the last two joints backward and outward. To judge from the innervation of these antennæ they must constitute very delicate tactile organs. Second antennæ a little longer than the cephalothorax, but always carried folded up so that they reach only to the mouth, or slightly beyond. Antennary sternum between the bases of these appendages

well developed, entering at either end into the sockets of the antennæ themselves (see fig. 13).

Basal joints much inflated and reenforced on the inner margin by two stout chitin ribs in each joint; second joint the same length as the basal, but tapering considerably; hinge between second and third joints quite complicated; third joint about the same diameter throughout; fourth joint a short, curved claw, bluntly pointed. The last two joints together are not quite as long as the second (fig. 7).

The mouth-parts project strongly from the ventral surface in a side view (see fig. 52), with the maxillæ at the tip of the projection. The labrum is so thoroughly fused with the head that its outlines are often indistinguishable, but the evenly rounded posterior margin is usually visible. Basal joint of the mandible with a large rectangular outer portion set in a socket of similar shape at the extreme lateral margin of the labrum and just posterior to it, so as to allow the mandible to move forward under the lip. At the inner end the posterior border of this portion is cut diagonally forward and inward, while a deep circular incision is cut out of the anterior border. The narrowed neck between the diagonal cut and the circular incision constitutes the inner portion of the basal joint and is turned forward at an angle of about 45 degrees (fig. 27). To the end of this neck is attached the cutting blade, which is triangular in shape, a little longer than the neck, usually curved forward, and armed along its posterior margin and around the tip with a row of long hairs or spines. The palp is also triangular, its base attached to the diagonal cut on the posterior border of the basal joint, its anterior side fastened for a short distance to the posterior margin of the neck. It also has a row of shorter spinelike teeth along its outer margin. First maxillæ reduced to mere knobs, projecting from the ventral surface between the basal joints of the mandibles and those of the second maxillæ. From the top of each knob project two stout curved spines, articulated at the base so as to be movable, the outer one a little longer and stouter than the inner, and both plumose. Second maxillæ similar to the mandibles except that they have no palps; basal joint of the same width and length, triangular in shape, with the apex pointing inward and narrowed to a short neck which is curved forward. The cutting blade is long and triangular; its anterior margin and the entire ventral surface are covered with a dense growth of bristles. Maxillipeds entirely lacking. Labium reduced to a transverse ridge, its posterior margin nearly straight. Rami of first four pairs of swimming legs three-jointed and well armed with spines and setæ. Fifth legs reduced to a comparatively well-developed sternum, at either end of which in young females is a very short, one-jointed process tipped with two spines; in the fully developed adult the process is wanting and there is but a

single spine. The arrangement of spines and setæ on the first four pairs of legs is as follows: First exopod, I-0; 0-1; II-5: endopod, 0-1; 0-1; II-4: second exopod, I-0; 0-1; 0-6: endopod, 0-1; 0-2; I-4: third exopod, I-0; 0-1; 0-6: endopod, I-0; 0-2; 0-5: fourth exopod, 0-0; I-0; 0-4: endopod, 0-1; 0-2; 0-4.

The anatomy of the muscular, digestive, and reproductive organs of this species have been described on pages 285 to 302; the nauplius and two metanauplius stages of development were described and figured under the ontogeny of the Ergasilinæ, pages 319 to 326.

Body a clear cartilage color, translucent in young females, but becoming dense and opaque in the adults; ovaries and testes an opaque white. Eggs also an opaque white when freshly extruded, acquiring blue pigment gradually upon development, until when ready to hatch the entire egg-sacks appear blue to the naked eye.

Total length, 0.8 to 0.9 mm. Length of cephalothorax in adult, 0.66 mm. Width of same, 0.58 mm. Length of egg sacks, 0.9 mm. In young females with their first egg-sacks the body is relatively longer and narrower, and the proportion between the length of the cephalothorax and the remainder of the body is as 11 to 8 (see fig. 21).

(*centrarchidarum*, of or belonging to the Centrarchidæ, the family of fish upon whose gills this parasite is found.)

The red eye (*Ambloplites rupestris*) is the most common host of this parasite, and nearly every one of them which the author has examined has been found infested to some extent. During the summer of 1906 quite a number of red eyes were examined at Lake Maxinkuckee, Indiana, for the purpose of ascertaining their food and the kinds of parasites which infested them. These were all young fish, 2 inches long and upward, in the second year of their growth. Almost every fish showed some of this species on its gills, and several of them, scarcely 3 inches long, yielded from 15 to 25 of the parasites apiece. An adult red eye often has as many as 75 or 100 of these creatures on its gills. The National Museum collection includes four bottles of specimens from this host, taken at Lake Maxinkuckee and numbered, respectively, 38609, 38610, 38620, and 38632; one bottle containing a single female taken from the gill of a pike perch, *Stizostedion vitreum*, and numbered 38616; another single female found on the gill of a blue-gill, *Pomoxus sparoides*, numbered 38634; 15 females taken from the gills of the small-mouth black bass, *Micropterus dolomieu*, numbered 38624; 3 females from the gills of the war-mouth bass, *Chænobryttus gulosus*, taken in Lost Lake, close to Lake Maxinkuckee, and half a dozen females from red eyes and blue-gills, taken at Lake Winona, Indiana, these last two being numbered, respectively, 38613 and 38630.

ERGASILUS CÆRULEUS, new species.

Plate 43.

Female.—Body more elongate than that of *centrarchidarum*, but not as much so as *versicolor*, nearly three times as long as wide. Carapace elliptical, about as wide posteriorly as anteriorly, with the sides only very slightly reentrant, the longitudinal and transverse diameters being in the proportion of eleven to six. Antennal area two-thirds the width of the carapace and projecting much farther than in any known species, bringing the posterior margins of the second antennæ far enough in front of the body of the carapace to leave an open space between the two. Frontal margin evenly rounded; eye removed a little from this margin and covered with an irregular spot of deep blue pigment, so as to be almost invisible (fig. 60). Posterior body (second thorax segment) narrowed abruptly to five-ninths of the width of the carapace.

Thoracic segments diminishing regularly in width, the third one considerably longer than the second or fourth, which are the same length, the fifth one very short and rudimentary.

Lateral processes on the dorsal surface of the second segment projecting considerably beyond its posterior margin, narrow and bluntly rounded. Genital segment nearly twice as wide as long, barrel-shaped, with well-rounded sides.

Egg-strings elliptical, narrower than in *centrarchidarum*, but not as narrow as in *versicolor*, two-thirds as long as the entire body and tapering very little posteriorly.

Eggs large, arranged in three or four longitudinal rows, about 25 or 30 eggs in each string.

Abdomen, exclusive of the anal laminæ, the same length as the genital segment, and abruptly narrowed to half the width of the latter; composed of three segments of about the same length. Anal laminæ as long as the last abdomen segment, widely separated, sub-rectangular in outline, and each armed with two setæ, the inner of which is twice the length of the outer.

First antennæ apparently seven-jointed, the joints diminishing regularly in width, but of about the same length, except the two basal ones, which together equal one of the others.

These two basal joints have no setæ; the third joint is slightly larger than any of the others, and carries two stout setæ at its outer anterior corner; the fourth, fifth, and sixth joints are each armed with a single seta, the terminal joint with a tuft of four or five, none of them very long.

Second antennæ with two stout basal joints, fully twice as wide as long, and two slender terminal joints; first joint with a short powerful muscle along its anterior margin, its posterior margin projecting and

evenly rounded, sometimes forming a half circle. Second joint projecting on its anterior margin, and abruptly narrowed just beyond its center to furnish the articulation for the third joint.

The latter is as long as the two basal joints, but only one-quarter as wide, narrowed near its proximal end, widened at the distal end, and armed with a small rounded knob on its inner margin. Terminal joint a claw, with a curved outer margin and a nearly straight inner margin, the latter with one or two short teeth near its proximal end.

The structure of these antennæ is thus very different from that in *centrarchidarum* and *versicolor* and furnishes a good specific character.

Mouth-parts resembling those of *centrarchidarum* more than those of *versicolor*, but quite distinct from either. Mandibles so short that they hardly meet at the mid-line, with the knob on the anterior margin of the basal joint prominent and well rounded as in *centrarchidarum*. But the terminal joint is hardly longer than the narrowed portion of the basal joint, tapers rapidly to an acute point, and is armed with setæ along its inner margin only. The palp also is attached farther back on the basal joint than in other species; it is very narrow, almost linear in fact, one-fourth longer than the terminal joint, six times as long as wide, and armed with minute tooth-like setæ on its anterior margin only.

The first maxillæ are similar to those in other species, but are armed with shorter setæ. The second maxillæ resemble those of *centrarchidarum*, but are shorter, acutely pointed at the tips, and with a sharper curve near the base.

Behind these second maxillæ can be distinctly seen on the ventral surface a set of chitin ribs for the attachment of the maxillipeds, but the appendages themselves are lacking, as in all the females of this genus.

The presence of these ribs, however, proves conclusively that it is a pair of mouth-parts corresponding to the maxillipeds in the male which have disappeared, and thus adds one more convincing testimony to the correctness of this interpretation of the mouth-parts.

The swimming legs are similar to those in other species, all biramose and the rami three-jointed, except the exopods of the fourth pair, which have but two joints. The following is the arrangement of the spines and setæ: First exopod, I-0; 0-1; II-5: endopod, 0-1; 0-1; 0-5: second exopod, 0-1; I-1; 0-5: endopod, 0-1; 0-2; 0-5: third exopod, 0-1; 0-1; 0-5: endopod, 0-1; 0-2; 0-4: fourth exopod, I-1; 0-5: endopod, I-1; 0-2; 0-4. Fifth legs reduced to a pair of long spines.

Total length 0.8 mm. Carapace 0.5 mm. long, 0.25 mm. wide. Length of free thorax 0.18 mm. Length of egg-strings 0.55 mm.

Color a transparent horn color, the ovaries opaque but not as white as in *centrarchidarum*. A large spot over the eye on the dorsal surface

and numerous scattered spots covering the entire ventral surface, as seen in figure 61, a deep purplish blue. Near the posterior margin of the first thorax segment and along the median axis of the second, third, and fourth segments the blue spots coalesce into a large area visible to the naked eye, even from the dorsal surface.

This will serve to distinguish the species ordinarily. The eggs when ripe are a pale blue, so that the parasite shows up distinctly against the red gills.

(*cæruleus*, blue.)

This parasite infests the gills of the bluegill, *Lepomis pallidus*, but is local in its distribution. Thus far it has been obtained only from the Twin Lakes in Marshall County, and Tippecanoe Lake in Kosciusco County, Indiana. Blue-gills are plentiful in Lake Maxinkuckee, 7 miles south of Twin Lakes, but although several hundred of them have been examined by the author at different times, only six specimens belonging to the Ergasilidæ were obtained from the entire number. These were *Ergasilus centrarchidarum* and were found on the outside of the gill filaments, as in every other fish which they infest.

The present species, however, is found between the two layers of gill filaments, and more than a hundred specimens were obtained from two small blue-gills scarcely 5 inches long. This radical change of habit and their abundance suggested at once that they were a new species, which was verified upon further examination. The author is not acquainted with any other species of the genus *Ergasilus* that thus habitually frequents the space between the gill filaments. The blue-gill is a vegetable feeder and its mouth is filled with fragments of algæ and other water plants much of the time. These fragments are bound to produce more or less friction over the gills themselves, particularly during breathing. *Ergasilus centrarchidarum*, inhabiting the outside of the gill filaments, does not take kindly to these conditions. Hence they are only rarely found upon the blue-gill or the croppie, another vegetable feeder.

The present species, however, by frequenting the space between the gill filaments escapes the discomforts incident upon vegetable feeding, and is thus enabled to thrive where the other species failed.

There are two lots of specimens of this species obtained at different times from the blue-gills in Twin Lakes. They are numbered, respectively, 39550 and 39554 U.S.N.M.; the former is made the types of the new species, the latter becoming cotypes. A third lot consisting of half a dozen females was obtained from 10 blue-gills caught in Tippecanoe Lake, and is numbered 39548, U.S.N.M.

ERGASILUS MANICATUS, new species.

Plate 44, text figures 1 and 5.

Female.—Head and first thorax segment completely fused, with no visible indication of the union except in the young.

Resultant cephalothorax elliptical, strongly arched dorsally, one-fifth longer than wide, projecting anteriorly in a large median rostrum, and produced posteriorly into a small lobe on either side of the first free segment. The latter only two-fifths the width of the carapace; third, fourth, and fifth segments diminishing regularly in width and length, the fifth being almost entirely concealed between the fourth and genital segments, especially in mature adults. Genital segment narrower than even this fifth segment and about half as long as all the free segments combined; barrel shaped with its sides evenly rounded. Egg-sacks relatively large, each of them longer than the entire body and four-fifths as wide, and tapered posteriorly; eggs large, arranged in four or five longitudinal rows, about fifty or sixty in each sack.

Abdomen the same length as the genital segment, three-jointed, with the joints equal. Anal laminae rectangular, about as long as the last abdomen joint, each tipped with two setae, of which the inner is three times the length of the outer.

First antennae six-jointed, the joints of unequal lengths and widths, the five basal ones sparsely armed with setae, the terminal one tipped with a tuft of about a dozen (fig. 5 and 71).

The basal joint is curiously grooved, so as to appear like three joints, or to be made up of three parts, according to the point of view. But in dorsal view the grooves are concentric and show that they are not dividing lines between joints.

Second antennae four jointed, each of the two basal joints being prolonged into a large sleeve or hood, covering the dorsal surface of the joint succeeding it. The basal joint itself is triangular, one angle fastened to the ventral surface of the carapace, and the distal end a side. The second joint is attached to the anterior corner of this side, while the whole side is produced into a semielliptical flap or sleeve, twice the width of the second segment and covering the whole of its dorsal surface. In its turn the distal end of the second joint is enlarged to twice the diameter of the third joint, and produced into a sleeve covering the proximal end of the dorsal surface of the latter for about one-third of its length. The third joint is considerably narrower than the second, of the same diameter throughout, and without any sleeve or projection. The terminal joint is in the form of a stout claw, with an accessory tooth on its inner margin near the base.

Mouth-parts projecting quite strongly; mandibles with a short basal joint which is divided through the center longitudinally by an

irregular chitin rib; neck relatively wide and long; cutting blade curved well forward and terminating in a tuft of long bristles; palp the same length as the neck and toothed along the posterior margin. First maxillæ small and weak, each knob bearing two nonplumose setæ, of which the outer is somewhat the larger. Basal joints of the second maxillæ very large and triangular in shape, reaching out on the surface of the head far beyond the base of the mandibles; the terminal joints relatively short and weak, their tips densely covered with spines.

First four pairs of legs biramose, all the rami three-jointed except the exopod of the fourth pair, which is two-jointed; the fifth pair are reduced to a mere pimple tipped with a single tiny spine. The basal joints of all these legs are much narrower than is usual in this genus; the following is the arrangement of the spines and setæ:

First exopod, 0-0; 0-1; II-4: endopod, 0-0; 0-0; 0-6: second exopod, 0-0; 0-1; 0-7: endopod, 0-0; 0-0; 0-7: third exopod, 0-0; 0-1; 0-6: endopod, 0-0; 0-0; 0-6: fourth exopod, 0-0; 0-6: endopod, 0-2; 0-2; 0-4.

Color a uniform milky white in mature specimens, the more the internal ovaries are developed the whiter the color. As the eggs are also white until nearly ready to hatch, these copepods show up in strong contrast to the red gill filaments.

Total length, 0.75 mm. Length of cephalothorax, 0.5 mm. Width of same, 0.33 mm. Length of egg-strings, 0.8 mm. Width of same, 0.28 mm.

(*manicatus*, furnished with long sleeves, in allusion to the overlapping joints of the second antennæ.)

This tiny parasite is very common on the gills of the silversides minnow, *Menidia notata*, along the Atlantic coast. The National Museum collection includes the following lots, all obtained at or near Woods Hole, Massachusetts: 38612, 38614, 38615, 38621, 38623, and 38626. The 25 specimens in No. 38621 are made the types of the new species. Most of the drawings illustrating this species were made by Dr. Richard Rathbun, assistant secretary in charge of the National Museum, and were generously turned over to the author, with many notes. For this efficient assistance sincere thanks are here returned.

ERGASILUS SIEBOLDII Nordmann.

Ergasilus sieboldii, NORDMANN, 1832, p. 15, pl. 2, figs. 1 to 9.—KRÖYER, 1863, p. 237, pl. 13, figs. 2, *a* and *b*.—CLAUS, 1875, p. 339, pl. 23, figs. 12 to 18.—GADD, 1904, p. 4, pl. 1, figs. 20 to 25.

Nordmann's original description and figures of this species were excellent, and as this was the first species he described, it would naturally become the type of the genus. This position it is in every way fitted to fill, since it is by far the most common of the European species and is found upon the greatest number of hosts.

Furthermore, in bodily structure and habits it comes as near to being a golden mean between the extremes shown by other species as could well have been selected. And being thus common, there is far greater chance for the discovery of its life history than in the case of a rarer species.

These facts have combined to make it the best known of all species, and nearly every European author who has dealt with the parasitic copepods has at least mentioned it.

Nordmann, whose description in other respects was singularly accurate, contents himself with a mere mention of the mouth-parts. This defect was amply remedied by Claus, who gave a detailed description of these appendages, with excellent figures. The last author mentioned above, Gadd, has recently tried to assail this description given by Claus; his opinions will be found discussed on page 279.

Nordmann described only the female; Kröyer tried to remedy this by a brief notice of a form which he took to be the male. He tells us first of all that the finding of the young and the males of *E. gasterostei* induced him to make a search for similar specimens of *E. sieboldii*, and that this search was rewarded by the discovery of half a score of males among several hundred females. Many facts, however, combine to prove that these specimens were not males, but simply females without their egg-strings.

1. The males have been proved to be free swimmers throughout life, and the only chance of finding them among females taken from fishes' gills would be in rare instances when the two are found in union. Kröyer's percentage is far too large for anything of this sort, and he makes no mention of finding the two sexes together.

2. The "males" are represented as being of the same size as the females; this is possible, but not very probable, since the male usually shows considerable variation in size.

3. The "males" showed no sex characters whatever; the few trifling differences noted by Kröyer are what would be expected between a young and a fully mature female; but not one of them is worthy of being made a sexual distinction.

4. If they were really males, they should possess the large maxillipeds characteristic of that sex. But Kröyer's figures clearly show that no such mouth-parts were present in his specimens.

5. If the females of Kröyer's new species, *longimanus*, be compared with these "males" of *sieboldii*, both being shown by Kröyer on the same plate, there will be found so complete a similarity between the two as to leave little doubt of their identity.

Gadd (1904) found a single specimen which he considered to be a male of the present species. And his claim seems just, for in this instance the male was fastened to the body of a female, was considerably smaller than the latter, and showed several decided sex

variations, especially in the way of prehensile organs. Unfortunately the specimen was crushed before it had been fully examined, and we do not know whether it possessed maxillipeds or not.

(*Sieboldii*, from Carl Theodor Ernst von Siebold, an eminent authority on the crustacea.)

ERGASILUS LIZÆ Kröyer.

Ergasilus lizæ, KRÖYER, 1863, p. 232.

Female.—Body elongate, length twice the width, narrowed considerably posteriorly. Head fused with the first thorax segment, the two covered by a broad violin-shaped carapace, the posterior portion of which is longer than the anterior.

The emargination on either side is long and rather shallow, and the posterior margin is almost squarely truncated.

Free thorax segments diminishing regularly in size, the last one (fifth segment) very short. Genital segment oval, shorter than the first three free segments but longer than wide; armed on the ventral surface near the posterior margin with a large number of long and coarse bristles.

Abdomen three-jointed, each joint wider than long and the last one much shorter than the preceding ones, the three together about the same length as the genital segment. Anal laminæ the same length as the joint to which they are attached, as wide as long, and armed with two setæ, the inner of which is much the larger. Egg-sacks usually much shorter than the body and quite stout, but in some specimens they are longer than the entire creature, seven or eight times as long as broad. Eggs in three or four longitudinal rows, about one hundred in each sack.

First antennæ short, only reaching the basal joint of the second pair; six-jointed, the two basal joints elongate, the others much shorter and all armed with heavy bristles. Second antennæ half the entire length, slender, four-jointed, the several joints in the proportion of 4 : 8 : 7 : 5. The second joint carries a small knob on the center of the concave margin. Eyes fused on the median line, about one-third the distance from the anterior margin of the carapace; eye pigment bright red.

First four pairs of swimming legs biramose, rami three-jointed, the joints diminishing in size distally; fifth legs uniramose, flattened, one-jointed, and nearly squarely segmented at the distal end, from whence arises a pair of long setæ.

In his description Kröyer gives these fifth legs as appendages of the genital segment at its anterior end, but they belong of course to the fifth thorax segment, which is very short in all the species of this genus and often thoroughly fused with the genital segment. With the exception of this and a few other minor corrections the preceding account is little more than a free translation of that given by Kröyer. No mention is made of the color of this species.

Total length of female, 0.9 mm.

(*lizæ*, from *liza*, the specific name which Kröyer gave to the mullet on which this parasite was found.)

A few specimens of this species were taken with other parasites from the gills of *Mugil curema* (*M. liza* Kröyer), captured near New Orleans, Louisiana. As in the case of *Ergasilus funduli*, Kröyer obtained these parasites from the gills of fish which had been sent to the Royal Museum in Copenhagen, and no further specimens have ever been seen. But here again it is also true that no mullet from that region have ever been examined for parasites since Kröyer's time. And it is possible that a little search would show the species to be fairly common.

ERGASILUS VERSICOLOR, new species.

Plate 45, text figures 11 and 12.

Female.—Carapace elliptical, three-fourths longer than wide and violin-shaped, the part in front of the lateral constrictions longer than that behind them. Anterior margin narrowed and projecting strongly between the antennæ; posterior margin somewhat emarginate. First three free segments about the same length but diminishing regularly in width, the fourth a little narrower than the third and not more than a quarter as long. Fourth (third free) segment posteriorly and genital segment anteriorly contracted into a short neck where they join the short fifth segment. Abdomen indistinctly three-jointed, joints about the same length; anal laminæ small, a trifle longer than the last abdomen segment, quadrangular in outline and slightly divergent, each armed with two unequal setæ.

First antennæ six-jointed, the second joint the largest, the fourth joint next in length, and all heavily armed with setæ. Second antennæ long and slender, three-jointed, the basal joint less than half the length of the second, the terminal joint a stout claw, a little longer than the second joint, but bent into a half circle so as to appear shorter.

Labrum not reaching the base of the first maxillæ; mandibles relatively large, the cutting blades curved forward and outward nearly in a half circle, and fringed along the margins with a dense row of stout spines. Palps short and triangular, with a few short and sharp teeth at the apex and a row of rounded teeth along the outer margin.

Basal portion of the first maxillæ in the form of an elliptical papilla, tipped with two stout spines of which the outer is a little larger than the inner. Second maxillæ with a peculiarly stout terminal joint, the two appendages overlapping somewhat at the mid-line, and each armed with a small tuft of bristles, restricted to the center of the distal end. Labium distinctly U-shaped, its ends running forward under the first maxillipeds almost to the base of the mandibles.

Exopods of the fourth swimming legs two-jointed, all the other rami three-jointed; fifth legs rudimentary, each consisting of a small papilla tipped with two spines, the outer of which is longer than the inner. The arrangement of the spines and setæ on the first four pairs of legs is as follows: First exopod, I-0; 0-1; II-4: endopod, 0-1; 0-2; I-3: second exopod, I-0; 0-1; 1-4: endopod, 0-1; 0-2; II-4: third exopod, I-0; 0-1; I-5: endopod, 0-1; 0-2; I-4: fourth exopod, 0-0; I-5: endopod, 0-1; 0-2; I-3.

Color of body in general a pale transparent horn or cartilage tint; ovary a cream yellow; ventral surface covered with a network of brilliant violet purple, in spots and delicate threads; dorsal surface with spots of pale cinnamon brown, irregularly distributed, with very few lines; digestive tube a rich rust color. As the center of the body is transparent this pigment of the digestive tube shows plainly in both dorsal and ventral views as a broad longitudinal line, bordered on either side by the creamy yellow of the ovaries, with an outside margin of the cinnamon brown spots. Eyes a dark reddish brown, almost black; a large space behind the eyes and in front of the digestive tube clear and transparent.

This assemblage of tints makes the present species the most highly-colored of its genus and has suggested its specific name.

Total length, 1.56 mm. Length of cephalothorax, 0.8 mm; width of same, 0.46 mm. Length of free thorax, 0.4 mm. Length of genital segment and abdomen, 0.32 mm. Length of egg-strings, 0.95 mm.

(*versicolor*, variegated, showing many colors.)

This species was fairly common on the two kinds of catfish found at Lake Maxinkuckee, Indiana, *Ameiurus nebulosus*, the common bullhead and *A. natalis*, the yellow cat.

The latter was more often infested with the parasite than the former. This species was never found upon any other fish although many hundreds of them were searched for it. Nor was *Ergasilus centrarchidarum*, which was so common on the other fish, ever found upon either of these catfish.

In this respect the present species appears to have a well-defined habitat. The National Museum collection includes five lots of this parasite distributed as follows: No. 38652 from the gills of *Ameiurus natalis* at Lake Maxinkuckee, contains specimens which are made the types of the new species. Two other lots from the same host and locality are numbered, respectively, 38650 and 38651. No. 38649 includes half a dozen specimens from the gills of *A. natalis* in the Mississippi River at Alton, Illinois. No. 38648 contains eight females from the gills of the channel cat, *Ictalurus punctatus*, captured in the Mississippi River at Clayton, Iowa.

ERGASILUS CHAUTAUQUAËNSIS *Fellows.*

Plate 46, text figures 26 and 28.

Ergasilus chautauquaënsis, FELLOWS, 1887, p. 175, preliminary notice; 1888, p. 246, 8 figs.

Female.—Body with an elongate cyclops form, about four times as long as wide; head fused with the first thorax segment, the union being indicated by a notch in each lateral margin and a partial groove across the body. This cephalothorax considerably less than half the entire length; contracted anteriorly to a narrow rostrum less than one-quarter the width of the body; somewhat narrowed and squarely truncated posteriorly. First three free thorax segments diminishing regularly in width, the third one (fourth segment) being the same width as the genital segment. The fifth segment is practically indistinguishable between the fourth and genital segments; the latter is barrel-shaped and narrowed considerably posteriorly. Abdomen made up of three joints of the same length and width; on the ventral surface the groove between the genital segment and the abdomen, and each of the abdomen grooves is set with a row of long spine-like teeth (see fig. 87). Anal laminæ as long as the entire abdomen; each nearly half as wide and tipped with two setæ of about the same size and four times as long as the laminæ.

Egg-sacks oval, only reaching to the tips of the anal laminæ; eggs quite large and arranged in four or five longitudinal rows, about 25 in each sack.

First antennæ six-jointed and longer than the second pair, the setæ on the fourth, fifth, and sixth joints very long, reaching to the last thoracic segment. Second pair rather weak for this genus; four-jointed, the basal joint not swollen as in most species. Labrum so thoroughly fused with the head as to be indistinguishable. Mandibles with a short and very wide basal joint, the neck short and narrow, the cutting blade long and narrow and densely fringed with bristles along both margins; palp narrow and with a row of fine teeth along its outer margin. First maxillæ narrow, each furnished with two non-plumose setæ of about the same size. Second maxillæ with a long and narrow basal joint; the terminal joint also rather long and with a dense tuft of bristles at the tip. Both mandibles and maxillæ are so placed that they overlap considerably across the mid-line. Labium well curved but so narrow as to be little more than a chitin rib.

First four pairs of swimming legs biramose; rami three-jointed, except the exopods of the fourth legs, which have only two joints. Fifth legs reduced to a long spine on either side of the fifth segment. The following is the arrangement of the spines and setæ on the first four legs: First exopod, I-0; 0-1; II-5; endopod, 0-1; 0-1; II-4:

second exopod, I-0; 0-1; I-6: endopod, 0-1; 0-2; I-4: third exopod, I-0; 0-1; I-6: endopod, 0-1; 0-2; I-4: fourth exopod, I-0; I-5: endopod, 0-1; 0-1; I-3.

Color transparent, except the digestive canal, which is bright blue for its entire length, making the copepod very conspicuous when alive. This color, however, fades and is not visible in preserved specimens.

Total length, 0.86 to 1 mm. Length of carapace, 0.48 mm. Width of same, 0.4 mm. Length of setæ on anal laminæ, 0.4 mm.

Male.—Similar to the female in general body structure, but more slender. First and second antennæ shorter and weaker; maxillipeds present as large, three-jointed, prehensile organs; basal joint short and stout; second joint much longer and tapered toward the distal end, armed with two powerful muscles and with a fringe of stiff hairs along its posterior margin; third joint in the form of a long slender claw, twice the length of the second joint and curved into a half circle, its concave margin facing its fellow on the opposite side of the mid-line; the tip is slightly enlarged and bluntly rounded (fig. 28). Genital segment wedge-shaped, widest posteriorly where it carries a long and stout spine on either side; abdomen and anal laminæ as in the female.

Total length, 0.75 to 0.8 mm. Other measurements corresponding; color as in the female.

(*chautauquaënsis*, from Chautauqua, the place where the first specimens were found.)

Several specimens of this beautifully colored species were obtained among free swimming forms at the surface of Lake Champlain during the session of the American Society of Microscopists held at Chautauqua, New York, in 1886.

They were given to Charles S. Fellows, who published a description of them in the proceedings of the above society for 1887. They had never been found by other observers up to the present year. But in some samples of the tow from Lake Mendota at Madison, Wis. sent to the author by Profs. E. A. Birge and Chauncey Juday of the University of Wisconsin, both sexes of this interesting species were again discovered. These specimens have been placed in the National Museum collection and have been numbered 38617.

All of this species have thus been found while swimming actively at the surface and the natural host has not yet been discovered. But it is reasonably certain that they are parasites like all the other species of the genus, and that their host will be discovered in due time.

ERGASILUS MUGILIS Vogt.

Plate 47, text figure 9.

Ergasilus mugilis, VOGT, 1877, pp. 94 to 100.

Female.—Cephalothorax two-thirds the entire length and nearly twice as long as wide. First thorax segment distinctly separated from the head by a deep groove which forms large lateral emarginations. Head transversely elliptical, with a wide and evenly rounded projection at the center of the anterior margin. First thorax segment the same width and length as the head, but more quadrilateral in outline, with rounded corners. Second, third, and fourth segments diminishing regularly in width, but about the same length, the second one less than one-third the width of the first segment. Fifth segment very short and thoroughly fused with the genital segment; sixth or genital segment the same width as the fourth segment and half as long again, barrel shaped, with rather flat sides.

Abdomen three-jointed, the segments diminishing regularly in width and length, the terminal one deeply incised posteriorly. Anal laminæ rectangular, about the same length as the last abdomen segment, and each tipped with two rather short setæ of unequal length. Egg-cases half as long again as the entire body, somewhat tapered posteriorly; eggs large, arranged in four or five longitudinal rows, from 100 to 125 eggs in each case.

First antennæ six-jointed, the length of each less than one-quarter of the width of the carapace, armed with very short setæ, evenly distributed among the joints.

Second antennæ slender, four-jointed, and reaching but little beyond the margin of the head; basal joint not inflated, second and third joints tapering slightly, the former one-fourth longer than the latter; terminal claw two-thirds the length of the third joint, strongly curved and acutely pointed.

Mouth-parts differing in several particulars from those of other species; labrum very wide, its lateral edges reaching well beyond the bases of the mandibles, its posterior margin nearly straight (fig. 9). Mandibles entirely covered by the labrum, except the posterior proximal corner of the basal joint; the diagonally opposite corner (anterior distal) is armed with a good sized tuft of bristles; the neck at the inner end of the basal joint is narrow; the cutting blade is also narrow and four times as long as wide.

The first maxillæ are slightly overlapped by the labrum, and each is armed with two nonplumose setæ of about the same length. The second maxillæ have an elongate terminal joint, heavily armed with bristles. Both mandibles and maxillæ are attached so far apart that they do not meet on the mid-line, but are separated by quite an interval.

Labium well defined and fairly wide, with an almost straight posterior border.

Rami of the swimming legs with three joints except the exopods of the fourth pair, which have but two joints. The arrangement of spines and setæ is as follows: First exopod, I-0; I-1; I-5: endopod, 0-1; 0-1; I-5: second exopod, 0-0; 0-1; 0-6: endopod, 0-1; 0-2; 0-4: third exopod, 0-0; 0-1; 0-6: endopod, 0-1; 0-2; 0-5: fourth exopod, 0-0; I-5: endopod, 0-1; 0-2; 0-4. Fifth legs made up of a single short joint tipped with two small setæ of equal length.

Color yellowish brown at the extreme front of the cephalothorax and along the free thorax, the abdomen, and the egg-strings, deepening to a dark brown through the cephalon and first thorax segment. On the ventral surface there is a line of spots and streaks of dark blue pigment on either side passing through the basal joints of the swimming legs and running forward, about the same distance apart on the cephalothorax, to the bases of the second antennæ. There is a large spot of the same pigment on either side of the mid line and close to it, at the anterior end of the genital segment, and two other similar spots at the bases of the anal laminae.

Total length, 1.15 mm. Cephalothorax, 0.73 mm. long, 0.46 mm. wide. Width of second segment, 0.15 mm. Length of egg-strings, 1.65 mm.

(*mugilis*, the generic name of its host.)

The collection of the National Museum contains but a single lot of this species, consisting of two females taken from the gills of *Mugil cephalus*, the common mullet, at Beaufort, North Carolina, in the summer of 1901 by Prof. Edwin Linton, and numbered 38631. The species is not a common one, since the examination of many fish yielded but these two specimens. The large cephalothorax, distinctly grooved at the center and the exceptionally long and narrow egg-strings will help to distinguish this from other species.

In 1877 Carl Vogt published in the second mémoire of his *Recherches Cotières* a short description of a species of *Ergasilus*. His specimens also were taken from the gills of the common mullet, which is the same in European waters as on our Atlantic coast. He described nothing but the external appearance of the parasites, having unfortunately mislaid the specimens upon which he intended to work out the mouth-parts and other appendages. He gave the species the provisional name of *E. mugilis*; provisional because to the best of his belief the species was identical with one which Hesse had obtained on *Mugil capito*, and upon which the latter author had founded a new genus and species, *Megabrachinus suboculatus*. If the two proved to be the same, Hesse's generic name would have the precedence: if not, then Vogt's name would become valid.

Vogt's brief description agrees in every detail with that of the present species, and as he never published any figures the description is all there is to guide us.

Furthermore, after careful examination, the present author can not agree that Hesse's *Megabrachinus* is at all likely to be found identical with this *Ergasilus*. It has already been stated (p. 264) that Hesse's species can not be located anywhere with certainty by reason of the manifold mistakes and contradictions in his text and figures.

Again, Vogt has tried to show that the distinctions upon which Hesse founded his species are not generic distinctions at all, but only specific. Be that as it may, Hesse apparently saw one thing and has portrayed it clearly in his figures, which will effectually prevent his species from ever belonging to the genus *Ergasilus*. And that is a pair of good-sized maxillipeds behind the other mouth-parts. In the females of *Ergasilus* the maxillipeds are entirely wanting; if there is any truth in Hesse's figure, therefore, the specimens he was trying to portray certainly did not belong to the genus *Ergasilus*. He does not even mention the appendages in his text, so that we can get no help from that source. We can easily understand how he might omit some descriptions—no author ever describes all the details of his figures. But it would hardly be reasonable to suppose that he deliberately drew a pair of appendages which did not exist. We may safely conclude then that his "*Megabrachinus*" will never prove to be an *Ergasilus*, and may thus with greater assurance restore Vogt's original name for the present species.

Genus THERSITINA Norman.

Thersites, PAGENSTECHER, 1861; *Ergasilus*, KRÖYER, 1863, and GADD, 1901; *Thersitina*, NORMAN, 1906.

This genus was originally described by Pagenstecher in 1861 under the name *Thersites*, borrowed from the Iliad. His description was fairly good, but he acknowledged that the mouth-parts were "indistinct" and presented no details with reference to the swimming legs, both of which are essential for the determination of specific distinctions.

He found three pairs of mouth-parts, which he designated as maxillæ and first and second maxillipeds, respectively; the mandibles he believed to be inside the mouth, where they could not be seen. But mandibles inside the mouth would make of the latter a sort of proboscis, and Pagenstecher distinctly states that nothing of the sort is formed. Hence we can get no satisfactory data from his description.

Two years later (1863) Kröyer described the same species from the same host, but called it *Ergasilus gasterosteus*. He found what he openly designated as a rostrum or proboscis at the mouth, but he did not have the courage to name definitely any of the mouth-parts.

He also mistook a young female without egg-strings for a male, as he had done in several other instances.

Claus, in speaking of the Ergasilidæ, says:

Thersites mochte demnach generisch mit *Ergasilus* zusammenfallen, zumal auch die Gestaltung der Mundwerkzeuge keine wesentlichen Abweichungen zu bieten scheint und die colossale Auftreibung des Weibschens dem Kopf und ersten Brustsegment angehört (1875, p. 339).

On the next page he states that Pagenstecher mistook the mandibles for the first maxillipeds, but he gives us no description of the mouth-parts as they should be, except the above statement that they correspond to those of *Ergasilus*.

Canu, in his excellent work *Les Copepodes du Boulonnais* (1892), published a short account of the mouth-parts of *Thersites gasterostei*. He found a pair of falciform mandibles, a rudimentary maxilla, reduced to a mere stump, carrying two slender setæ, as in all the genera of the Ergasilidæ, and what he called the second maxilla, posterior to the previous pair and corresponding to the second maxillæ in *Ergasilus* and *Bomolochus*. This is really the first description of the mouth-parts that can be looked upon as at all accurate, and it is unfortunate that it was so well concealed in Canu's systematic treatise.

T. Scott in one of his memoirs (1900) mentions this description by Canu under the synonymy of *Thersites*, and then gives us another excellent description of the female, accompanied by admirable figures. He finds four pairs of mouth-parts, a pair of mandibles with a bilobed and pectinate cutting blade, rudimentary maxillæ, simple "first maxillipeds," and three-jointed "second maxillipeds." These last consist of an enlarged basal joint and a curved terminal two-jointed arm, tipped with four or five strong apical spines. He also gives us the details with reference to the swimming legs.

In the following year (1901) we find Gadd trying to establish a new species, which he calls *Ergasilus biuncinatus*, as distinct from the *gasterosteus* of Pagenstecher and Krøyer. But his specific distinctions are based upon comparisons with the imperfect descriptions of the two authors just mentioned. He was evidently unacquainted with the more accurate descriptions of Canu and Scott, for he does not even mention them. While his distinctions seem fairly valid, there are two facts which greatly weaken his claim.

First, he entirely overlooked the first maxillæ, not only in this "new species," but also in another species of *Ergasilus*, which he presents in the same paper. If he had found these maxillæ, it would have radically changed his interpretation of the mouth-parts. Again, the figure he has given us of the mouth-parts of "*biuncinatus*" is inverted, the "first maxilliped" being represented as superior (or anterior) to the "maxilla" (which latter is really the mandible).

Only these two mouth-parts are shown, and nothing is said of any others in the text. In view of such mistakes, we shall have to wait for further testimony before deciding as to the validity of the species. But this need not hinder us from locating the genus. The present author believes *Thersitina* to be a valid genus and distinct from *Ergasilus*, for the following reasons:

1. Its habitat. *Ergasilus* species are always found clasping the gill filaments with their second antennæ; *Thersitina* is found with its second antennæ buried in the skin on the inside of the operculum.

2. Its body form. In mature females of *Ergasilus* the cephalothorax is sometimes swollen by the development of the ovaries and oviducts and their contents, and becomes more or less cylindrical; but it never approaches a sphere, and the second thorax segment does not share in the inflation.

3. The structure and attachment of the antennæ. The first antennæ are very short and five-jointed in *Thersitina*, while in *Ergasilus* they are relatively longer and six-jointed. The second antennæ in *Thersitina* are short and stout, and closely resemble the second maxillipeds in the Caligidæ. In *Ergasilus* they are long and slender and bear no resemblance to those maxillipeds.

4. The structure and number of the mouth-parts. In *Ergasilus* females the maxillipeds are entirely lacking; in *Thersitina* they are present behind the other mouth-parts and of peculiar structure. T. Scott is a very careful and accurate observer, and one who has had much experience with both parasitic and free-swimming forms. His description, therefore, is entitled to great confidence, especially in view of the fact that the other observers have not given much attention to these maxillipeds. Hence we may concede the validity of the genus and present the following

GENUS DIAGNOSIS.

Head fused with the first thorax segment; resultant cephalothorax and the first free segment inflated into an ellipsoid or sphere, to the ventral surface of which at the posterior end is attached the comparatively minute remainder of the body; other free segments less than a quarter of the diameter of the cephalothorax, diminishing regularly in size. Genital segment not much enlarged; abdomen three-jointed, joints about equal.

Anterior antennæ small, scarcely reaching halfway to the margin of the carapace, five-jointed and well armed with setæ. Second antennæ short and stout, suited for burying in the tissues of the host, like maxillipeds, rather than for clasping. Mouth-parts consisting of falciform mandibles, rudimentary first maxillæ like those of *Ergasilus* and *Bomolochus*, simple second maxillæ, and a pair of three-jointed maxillipeds behind the other parts. Egg-cases ellipsoi-

dal, as long as the entire animal; eggs large and numerous. Male unknown.

Type-species.—*Thersitina gasterostei*.

(*Thersitina*, *Thersites* and an ending denoting likeness.)

Subfamily BOMOLOCHINÆ.

Body flattened; head fused with the first thorax segment and the ventral surface of the resultant cephalothorax reentrant, so that its edges, with the bases of the first antennæ and the first swimming legs, form an effective prehensile disk. Free thorax often as wide as the carapace; genital segment enlarged but little; abdomen small and stunted. Basal joints of the first antennæ enlarged, flattened, bent sharply at a right angle, and furnished with a row of dense setæ and tactile hairs along their anterior margin. Second antennæ transformed into prehensile organs, with spines and roughened surfaces, but much shorter and weaker than those of the Ergasilidæ. First

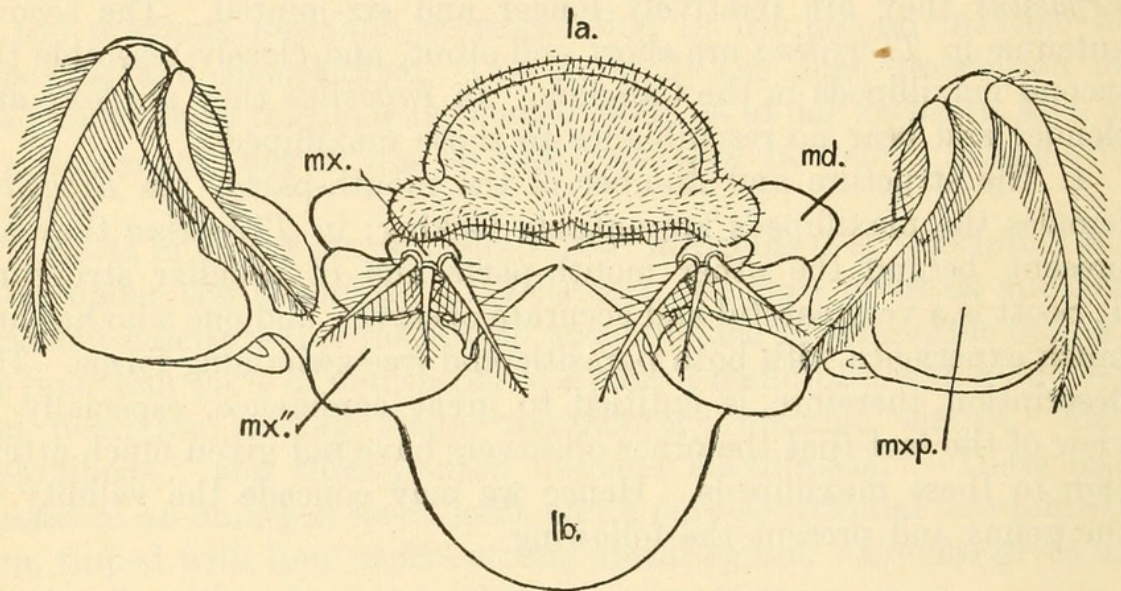


FIG. 39.—MOUTH-PARTS OF FEMALE BOMOLOCHUS TERES. *la*, LABRUM; *lb*, LABIUM; *md*, MANDIBLE; *mx'*, FIRST MAXILLA; *mx''*, SECOND MAXILLA; *mxp*, MAXILLIPED.

swimming legs strongly flattened, not used for locomotion as much as for prehension; fifth legs uniramous, but with two or more joints, each bearing setæ.

Species usually about twice the size of the Ergasilinæ, namely, from one to two millimeters in length.

DESCRIPTION OF THE MOUTH-PARTS.

Female.—Mouth-parts close to the second antennæ. Labrum considerably wider than long, with a roughened surface, projecting prominently from the head and well defined (fig. 39). Labium divided and consisting of a half projecting inward from either side, the two often not meeting at the center. Mandible consisting of a narrow, cylindrical basal joint, which is curved sharply backward

in exactly the opposite direction to that in *Ergasilus*, and armed with a small palp at its posterior distal margin; both palp and terminal joint are conical and destitute of setæ. Maxillary hook wanting. First maxilla made up of a short basal joint, fused to the ventral surface, and a terminal knob armed with three or more divergent plumose setæ. Second maxilla with a wide basal joint fused to the ventral surface of the head, and a conical terminal joint, which may be either simple, as in most species, or bipartite, as in *B. soleæ* Scott and in the genus *Tucca*. Maxillipeds with two stout basal joints, which are turned forward outside the other mouth-parts and fused with the ventral surface of the head, and a terminal claw bent twice into the form of the letter S; both second joint and terminal claw are well armed with plumose setæ.

Male.—Mouth-parts so far forward that the upper lip lies between the bases of the second antennæ. Labrum longer than wide, with a

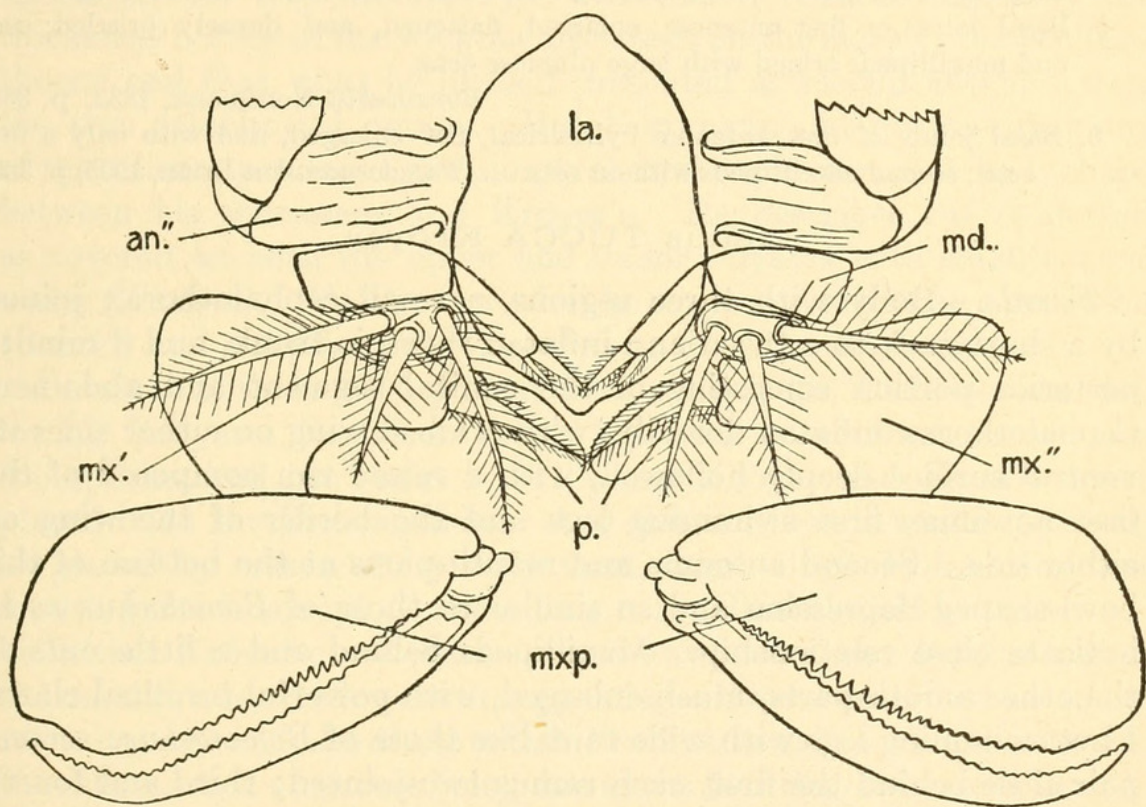


FIG. 40.—MOUTH-PARTS OF MALE BOMOLOCHUS SOLEÆ. *an''*, SECOND ANTENNA; *la.*, LABRUM; *md.*, MANDIBLE; *mx'*, FIRST MAXILLA; *mx'''*, SECOND MAXILLA; *mxp.*, MAXILLIPEDS; *p.*, PARAGNATHS.

prominent and well-roughened surface; labium similar to that in the female. First three pairs of mouth-parts also similar to those in the female except that they are longer and more slender. Maxillipeds large, of normal structure, and some little distance behind the other mouth-parts. Their basal joints are strongly inflated, elongate triangular in shape, and are attached as close to the lateral margin as in the female. Indeed, in spite of the large size of the basal joints, their distal ends do not meet at the mid-line by a considerable interval. The terminal joints are in the form of long slender claws, bent

only once and curved just enough to fit closely along the posterior margin of the basal joint. These maxillipeds about evenly divide the space between the other mouth-parts and the first swimming legs, and thus cause the mouth-parts to appear farther back than in the female. But with the exception of the maxillipeds they are really in the same position.

ARTIFICIAL KEY TO THE GENERA.

- a.* Second segment forming a narrow neck between the cephalothorax and the remainder of the segments, which are fused into a body incapable of flexion; all the swimming legs very rudimentary; abdomen invisible.
Tucca Kröyer, 1863, p. 352.
- a.* Third and fourth segments fused, the latter invisible in dorsal view, being covered by the overlapping third segment; endopods of first and second legs with wide and flattened joints. *Artacolax* Wilson, 1908, p. 360.
- a.* All the thorax segments except the first free and distinct; endopods of all the swimming legs with narrow joints like the exopods. *b.*
- b.* Basal joints of first antennæ enlarged, flattened, and densely bristled; second maxillipeds armed with large plumose setæ.
Bomolochus Nordmann, 1832, p. 365.
- b.* Basal joints of first antennæ cylindrical, not enlarged, and with only a few setæ; second maxillipeds without setæ. . . . *Pseudoecanthus* Brian, 1905, p. 380.

Genus TUCCA Kröyer.

Female.—Body with three regions, a small cephalothorax joined by a short neck to a fused and inflated thoracic trunk, and a minute posterior portion consisting of the genital segment and abdomen. Cephalothorax inflated dorsally, with a lobed wing on either side; its ventral surface deeply hollowed, with a raised rim composed of the first antennæ, first swimming legs and the border of the wing on either side. Second antennæ and mouth-parts at the bottom of this bowl-shaped depression and so similar to those of *Bomolochus* as to indicate close relationship. Maxillipeds behind and a little outside the other mouth-parts, much enlarged, with powerful terminal claws. First swimming legs with wide rami like those of *Bomolochus*; second pair close behind the first, each ramus two-jointed; third and fourth pairs at a considerable distance on the trunk, each with a one-jointed endopod; fifth pair at the junction of the trunk and posterior body. Genital segment small and triangular; abdomen rudimentary, one-jointed; egg-cases cylindrical, as long as the body; eggs multiseriate, small, and numerous.

Male.—Similar to the female but considerably smaller, with the same body regions, but with the genital segment larger and armed with a powerful hook on either side at the posterior corner. Appendages similar with the usual sexual differences in the antennæ and maxillipeds.

(*Tucca*, a friend of Horace and Virgil.)

Type-species.—*Tucca impressus* Kröyer.

This genus was established by Kröyer in 1837 with a short description and seven figures. He had but a single specimen, a female taken from the inner surface of the pectoral fin of a *Diodon hystrix* in the Danish West Indies. And his account includes only the external characters with none of the appendages except one pair of attachment organs.

From its degenerate form and general shape he placed the parasite in the family of Dichelestiidae.

Twenty-seven years later (1864) Nordmann published a second account, based upon ten specimens obtained from a *Diodon* species on the west coast of Africa. He corrected and supplemented Kröyer's description and gave a figure of the under surface of the cephalothorax showing three pairs of appendages, which he named first and second antennæ and second maxillipeds. He claimed that the structures which Kröyer had described as attachment organs were only the thickened border of the winglike processes on the sides of the cephalothorax and that what he himself presented as second antennæ were the true attachment organs. But Nordmann did not discover any of the other appendages, and simply shows the differences in body shape between his specimens and Kröyer's. He describes the epidermis as covered on both the upper and under surfaces with small conical warts (Warzen). He also saw what he suggested might be a proboscis (Russel) and classifies the genus among the Chondracanthidae.

Bassett-Smith in 1899 puts it back among the Dichelestiidae, following Kröyer. No other writer has done more than to mention the species, and the genus is left where Kröyer and Bassett-Smith placed it, in the Dichelestiidae. And this is where it would naturally be placed by reason of its body form, but a single look at the true mouth-parts is enough to show that it is a Bomolochid genus.

Neither Kröyer nor Nordmann saw any of the mouth-parts except the maxillipeds, which were the appendages Kröyer described as attachment organs, and also those which Nordmann called second antennæ, the difference in structure being due to the fact that they were describing different species.

The appendages which Nordmann called second maxillipeds were probably the second pair of swimming legs, as will be seen in the description hereafter given. The reason why both these investigators failed to find the mouth-parts is simple but effective. They lie, as already stated, in the bottom of a bowl-shaped depression; when taken from the fish's fin this depression is filled with slime, which effectually conceals the appendages. In preservatives this slime becomes hardened and is then very difficult to remove. Both of the investigators above mentioned were working with material that had been in alcohol for a long time, and the only thing visible was the maxillipeds, whose tips project above the rim of the depression.

The discovery of the true mouth-parts as well as the swimming legs upon living specimens examined at Beaufort and Woods Hole has completely changed the nature of the parasite and virtually makes of it a new genus, but still retaining the old genus name. The case is exactly similar to that of *Echetus typicus* described by Kröyer as a Lernæid, but afterward found, when its head was discovered, to belong to the Caliginæ.

ARTIFICIAL KEY TO THE SPECIES.

- a.* Posterior portion of the fused thoracic trunk distinctly three-lobed; skin smooth, *impressus* Kröyer, 1837, p. 354.
- a.* Posterior portion of fused thoracic trunk evenly rounded, with no trace of lobes..... *b*
- b.* Fused thoracic trunk wider than long, overhanging and concealing in dorsal view the genital segment and abdomen; skin smooth. . . *corpulentus*, new species, p. 358.
- b.* Fused thoracic trunk one-third longer than wide, genital segment and abdomen wholly visible; skin covered with small warts. . . *verrucosus*, new species, p. 359.

TUCCA IMPRESSUS Kröyer.

Plates 48 and 49.

Tucca impressus, KRÖYER, 1837, p. 479, pl. 5, fig. 2, *a* to *g*.

Female.—Body separated into three distinct regions, a cephalothorax, a fused thorax, and a posterior portion consisting of the fifth thorax segment, the genital segment and the abdomen. The cephalothorax is a fusion of the head and the first thorax segment, and is small and hemispherical in shape, being inflated dorsally and flattened ventrally.

The integument along each lateral margin is formed into a wide lobed wing, made up of two layers of skin, dorsal and ventral, separated from each other and supported upon a chitin framework (fig. 112).

The ventral layer is produced inward from the lateral margin toward the mouth, and is separated a little from the ventral surface of the head, leaving a narrow space between the two. In this space are located the bases of the various mouth-parts, of the second antennæ and the first swimming legs.

The thickened edge of the skin is about half way between the lateral margin and the mouth, and forms an elliptical ring around the latter. On the ventral surface of this raised edge appear anteriorly the first antennæ, and posteriorly the terminal joints of the first swimming legs.

The first antennæ are four-jointed, the three basal joints about the same width, the terminal one much narrower; every joint is heavily armed with setæ, which extend in a continuous row along the anterior margin of the basal joint, and diagonally across the ventral surface of the second and third joints. The second antennæ are three-jointed,

the basal joint not much stouter than the two terminal ones and armed with a large spine at its distal end. The second and third joints are of the same size, the third one roughened over its entire surface and tipped with a narrow conical process at the outer distal corner, a thickened claw at the inner corner, and about five long curved and sharp-pointed claws over the rest of the tip.

The upper lip is very wide anteriorly, contracted and with a reentrant curve posteriorly; it is one-third wider than long (fig. 104).

The mandibles are three-jointed, long, slender, and simple; they start out vertically, then bend at a right angle and extend inward to the mouth opening, parallel with the surface of the head; the terminal joint is short and not toothed.

The first maxillæ are reduced to mere knobs, each bearing three plumose setæ. The second maxillæ are short and two-jointed, the terminal joint bipartite, the posterior branch longer than the anterior, both with smooth and acuminate tips. The maxillipeds are much enlarged and are attached diagonally behind and outside of the other mouth parts, not reaching as far forward as in *Bomolochus*, but not directly behind the other parts as in *Tæniacanthus*.

The basal joint is more or less rectangular and attached to the surface of the head except at the very tip; the terminal joint is in the form of a stout chitin claw with a swollen base and a blunt tip. This claw has somewhat of an S-curve, but not very pronounced, and has no teeth or projections (fig. 115).

The cephalothorax is joined to the fused thorax by a neck, formed of the second thorax segment, which varies much in length in different individuals, but is usually very short. The second pair of swimming legs are on this segment and in close proximity to the first pair; each ramus is two-jointed and the joints are about the same size, the terminal one well armed with setæ. The endopod is apparently always carried flattened back against the basal joint where it is often very difficult to find it.

The fused thorax or trunk is made up of the third, fourth, and fifth joints; it is oblong and so much swollen that the thickness is fully equal to half the width; the corners are evenly rounded and project posteriorly in the form of lobes; the lateral margins and the posterior margin between the lobes are somewhat emarginate. On the dorsal surface there is a third lobe in the center between the other two and about the same size. There are four pits or depressions on the dorsal surface of this swollen trunk, and four others upon the ventral surface. The former are arranged at the four corners of a square, the latter in pairs on the median line, the two anterior ones a little closer together than the two posterior. In the ventral pits are to be found the rudimentary third and fourth legs; each consists of a somewhat swollen basal joint and two rami; the exopod is two-

jointed, the proximal joint with a single spine, the terminal joint with eight plumose setæ in the third leg and four in the fourth leg; the endopod is composed of a single tiny joint, armed with one spine. If the entire length of the trunk be divided into thirds, the pits and legs are on the dividing lines between the thirds.

The fifth legs are at the junction of the trunk with the posterior portion of the body; each is narrow, one-jointed, and tipped with three plumose setæ. The legs themselves are found only in the male, but the appropriate muscles for them are present in the female (fig. 103).

The genital segment is relatively very small, only one-fourth the width of the trunk, and forming with the abdomen a triangle whose base, joined to the body, is a little longer than the two sides. The openings of the oviducts are on either side a little in front of the abdomen (fig. 111). The egg-cases are somewhat cigar shaped and a little longer than the entire body. The eggs are exceedingly minute and arranged in 25 to 40 longitudinal rows, about 50 eggs in each row.

The abdomen is one-jointed, considerably wider than long, and carries on its ventral surface a pair of rudimentary anal laminae, each armed with three setæ, of which the central one is the longest, the outer one two-thirds as long and the inner one very short, sometimes lacking (fig. 111). The ovary occupies the entire cœlomic portion of the fused thoracic segments, the eggs being scattered through the body cavity with no apparent regularity.

Total length, 1.67 mm. Cephalothorax, 0.25 mm. long, 0.53 mm. wide. Trunk 1.2 mm. long, 0.9 mm. wide. Length of egg-strings, 1.75 mm.

Color, a light cartilage gray in living specimens; in preserved material anything from opaque white to a dark gray-brown, according to the method of preservation.

Male.—Body similar to that of the female, but with the cephalothorax fully as wide as the trunk, and the genital segment and abdomen proportionally much larger. Lateral wings of the cephalothorax not lobed; antennæ and mouth-parts similar to those of the female. Maxillipeds considerably enlarged and placed behind the other mouth-parts as in the male of *Bomolochus*. Trunk elliptical in shape, with evenly rounded sides and corners; rudimentary third and fourth legs larger than in the female, posterior pair as close together as the anterior. Genital segment enlarged to half the width of the trunk and armed with a pair of stout hooks on the ventral surface at the posterior corners.

Spermatophore receptacles large and plainly visible in both dorsal and ventral views. Abdomen one-jointed, anal laminae larger than in the female and the setæ much longer.

Total length, 1.27 mm. Cephalothorax, 0.3 mm. long, 0.5 mm. wide. Trunk, 0.75 mm. long, 0.51 mm. wide. Width of the genital segment, 0.25 mm.

Color the same as in the female.

(*impressus*, stamped or marked, in allusion to the pits on the dorsal and ventral surfaces.)

This species is a fairly common parasite on the southern puffer, *Chilomycterus schoepfi*. It is not found on the gills, however, like most of its near relatives, but on the fins, seeming to prefer the inside of the pectoral fins to any other locality. To these it is fastened so securely that the attempt to remove it usually results in tearing off the maxillipeds which are its organs of prehension. The museum collection includes three lots of specimens, two from Beaufort, North Carolina, and one from Woods Hole, Massachusetts, all taken from the same host. The last lot is numbered 38625, the two former ones 38627 and 38628, respectively.

Two points in the morphology of this species are worthy of especial mention. The first is the remarkable increase in the number of eggs, which is accomplished by a corresponding decrease in their size. The egg cases are relatively no larger than those of other species, in fact not as large as some, *Ergasilus manicatus*, for example. But the eggs are only 0.05 mm. in diameter, and are crowded into the cases as thickly as they can lie. Consequently we find in the wider portions of the cases from 35 to 45 eggs in a cross section, while there about 50 in the longest longitudinal rows. This means that each case contains between 1,500 and 2,000 eggs, or from 3,000 to 4,000 in the two cases.

Such an extraordinary supply of eggs indicates a corresponding loss somewhere in their development, and a careful study of the life history of this species ought to yield some interesting data.

The other noteworthy fact is a coiling or folding of the intestine. The stomach is elongated within the third and fourth thorax segments, reaches the extreme posterior margin of the latter, and is widest at this posterior end. It then abruptly narrows into the intestine, which is folded back upon itself so as to be cut three times in a single cross section. In the body of the copepod there has been a fusion of the fifth and sixth thorax segments with the abdomen and a marked shortening or telescoping together of these parts. But the intestine has retained its original length and consequently has been thrown back upon itself during the telescoping process. A more complete account of these anomalous conditions will be published later. They also furnish a further incentive to a study of the life history of the species.

The enlarged figures of the mouth-parts in this and the following species are given without the maxillipeds for the reason that the latter, when in position, hide most of the other appendages, as can be seen in figure 124.

TUCCA CORPULENTUS, new species.

Plate 49, figs. 116 and 117: Plate 50.

Female.—Cephalothorax about the same size and shape as in the preceding species, but with the wings divided into four lobes instead of two. Trunk enlarged to three times the diameter of the cephalothorax, nearly circular in outline and much flattened dorso-ventrally; no traces of pits or impressions on either the dorsal or ventral surfaces.

Posterior margin evenly rounded, without lobes, and overhanging the genital segment and abdomen so that the latter are invisible in dorsal view. Genital segment and abdomen relatively very small. Egg cases cylindrical, somewhat narrowed at either end, and about the same length as the trunk. Eggs minute and arranged like those in *impressus*.

First antennæ large, four-jointed, and heavily armed with setæ; the spine between their bases long and narrow. Second antennæ with the two distal joints much stouter than in *impressus*, the terminal one inflated, but with a narrow process and thick, blunt claws. It is thus the exact counterpart of the same appendage in *impressus*, where the terminal joint was slender, with a thick, blunt process, and narrow, sharp claws. Labrum ovate, one-third longer than wide, with evenly curved margins. Mandibles three-jointed; basal joint no wider than the second joint, the latter carrying on its posterior margin near the distal end a large secondary spine, longer than the terminal joint but not as wide.

First maxillæ similar to those of the previous species, the central seta the largest and longest. Second maxillæ with a tripartite tip instead of a bipartite one; the third division is smaller than the other two and is arranged like a palp covering the basal half of the anterior division on its ventral surface. All three divisions are finely toothed along both margins. Maxillipeds much heavier and stouter than in *impressus*; in particular the terminal claw has a decided S-shaped curve, with a thickly swollen base nearly the size of the basal joint, a short knob or branch on the posterior margin at the distal curve of the S, and a bluntly rounded tip, corrugated by several transverse grooves.

First and second swimming legs very similar to those of *impressus*; third and fourth pairs with relatively larger basal joints, each of which has an indentation or notch on the anterior margin opposite the insertion of the small endopod. In the third legs there is a spine at the outer distal corner of the basal joint, and three spines on the outer margin of the proximal joint of the exopod. In the fourth legs there is also a spine at the outer distal corner of the basal joint, but none on the proximal joint of the exopod.

Total length 2.29 mm. Cephalothorax 0.38 mm. long, 0.78 mm. wide. Length of trunk 1.8 mm., width 2 mm. Length of egg-strings 1.75 mm.

Color, a uniform cartilage gray.

(*corpulentus*, large, thickset.)

There is but a single lot of this species, which was taken from the northern swell-toad, *Spheroides maculatus*, at Woods Hole, Massachusetts, and is numbered 38619, U.S.N.M. It includes three females, two of which bear egg-strings. It can be readily distinguished from *impressus* by the fact that the body is nearly circular in outline instead of oblong; it overhangs and entirely conceals in dorsal view the genital segment and abdomen, and there are no pits on either the dorsal or ventral surface. Whether it is as common as the other species can not be determined, since only a few fish have ever been examined for the parasite.

TUCCA VERRUCOSUS, new species.

Tucca impressus, NORDMANN, 1864, p. 491, pl. 6, figs. 7 to 10.

The species described as *T. impressus* by Nordmann (1864) is certainly distinct from the one so designated in the present paper (p. 354).

It follows that either Nordmann's species or that of the present author is new to science. They can not both be identical with Kröyer's *T. impressus*. After a careful examination of the original descriptions of Kröyer and Nordmann, together with the figures which accompany them, it seems most probable that Nordmann was describing a new species, while the present author had secured new specimens, including both sexes, of Kröyer's species.

In evidence of this we find that Nordmann's description differs from Kröyer's in many important particulars:

1. He does not find the "seitlichen Einschnitte" which Kröyer distinctly shows upon the enlarged posterior body.

2. He claims that the posterior portion of this part of the body, as well as the abdomen, are represented by Kröyer as much too broad.

3. He finds a pair of six-jointed first antennæ projecting from the anterior margin of the cephalothorax which he says Kröyer "overlooked."

4. There are no traces of the two-jointed attachment organs described by Kröyer on the inner margin of the side lappets, and he thinks Kröyer was really looking at the thickened edge of the lappets themselves.

5. He finds the dorsal and ventral surfaces of the body, including the central portion of the cephalothorax, but not the lappets, covered with small conical "Warzen," which were not noticed by Kröyer.

None of these particulars were likely to have escaped Kröyer's attention, except possibly the last one. He certainly would not have

overlooked the prominent first antennæ if they had been projecting as Nordmann figures them.

6. Nordmann's specimens were obtained from a species of *Diodon* found on the west coast of Africa while Krøyer's came from *Diodon hystrix* found in the Danish West Indies.

Those described by the present author were taken from a *Chilomycterus* common in the Danish West Indies, and so closely related to *Diodon* that it was included under that genus until very recently.

Furthermore they agree with Krøyer's specimen and differ from those of Nordmann in every one of the above contrasted points.

It seems practically certain, therefore, that Nordmann was describing a new species, and we may give for it the following

SPECIES DIAGNOSIS.

Female.—Cephalothorax small and circular in outline, with emarginate lappets. Free thorax fused into a rectangular body one-half longer than wide, with rounded corners and straight sides. Genital segment and abdomen very narrow and cylindrical, with prominent anal laminae. Egg-cases spindle-shaped, shorter than the body and much widened at the center. First antennæ cylindrical, the same diameter throughout, and projecting for their entire length in front of the anterior margin of the cephalothorax.

Four pits on the dorsal surface of the free thorax, the two anterior much nearer the midline than the posterior. The entire body, including the dorsal surface of the cephalothorax, but not the side lappets, covered with small conical papillæ.

(*Verrucosus*, covered with papillæ.)

Genus ARTACOLAX Wilson.

First thorax segment united with the head to form the carapace which is much wider than it is long, and is squarely truncated posteriorly. Second thorax segment free and as wide as the carapace or nearly so; third and fourth segments fused and but little narrower than the second; third segment overlapping the fourth dorsally so as to entirely conceal it. In lateral and ventral views the groove between the two segments is still visible, but no motion is possible between them. Fifth segment free and abruptly narrowed to a half or even a third of the width of the preceding fused segments. Genital segment enlarged but little; abdomen narrow and linear. The copepod has thus a sort of tadpole shape, consisting of a much widened and inflated anterior portion and a suddenly contracted and caudiform posterior portion, quite different from the Cyclops form of the genus *Bomolochus*. First antennæ six-jointed, the fused basal joints enlarged and armed with stout setæ; second antennæ four-jointed. Mandibles with two joints in addition to the terminal cutting blade,

and a short claw-like palp at the base of the latter. Second maxillæ with a powerful basal joint and a long cutting blade which extends forward diagonally at an angle of about 120° with the basal joint.

Maxillipeds like those of *Bomolochus*, except that they are usually without setæ. First swimming legs with very wide rami, armed with large flattened setæ; endopod of the second and often of the third legs similarly widened and armed with flattened setæ; exopods of second third, and fourth legs with but three joints like the endopods.

Male like the female, but with the maxillipeds in normal position behind the other mouth-parts and armed with the usual terminal claw.

Type-species.—*Artacolax (Bomolochus) ardeolæ* (Kröyer).

(*Artacolax*, ἀρτὰω, to hang on and κόλαξι, a parasite).

This genus is distinguished from *Bomolochus* by the great comparative width of the first four thorax segments, by the fusion and overlapping of the third and fourth segments, so that there are apparently but three free segments in front of the genital segment instead of four, by the abrupt narrowing of the fifth segment, by the increased width of the rami of the first and second swimming legs, and by peculiarities in the structure of each of the mouth-parts, especially the second maxillæ.

ARTIFICIAL KEY TO THE SPECIES.

- a. Basal portion of first antenna armed with a large chitin plate, split anteriorly into three spines b.
- a. Basal portion of first antenna armed only with setæ and tactile hairs, no chitin plate c.
- b. First antennæ reaching far beyond the lateral margins; fifth legs made up of two very unequal joints; maxillipeds without plumose setæ. *cornutus* (Claus), 1864.
- b. First antennæ reaching just beyond the lateral margins; fifth legs made up of two very unequal joints; maxillipeds armed with large plumose setæ.
sætiger, new species, p. 361.
- b. First antennæ scarcely reaching the lateral margin; fifth legs made up of three short joints of equal length; maxillipeds without plumose setæ.
scomberesocis (Kröyer), 1863.
- c. Exopod of first legs three-jointed; fused third and fourth joints as wide as the second joint; each anal lamina with three setæ of equal length and one much shorter *chatoessi* (Kröyer), 1863.
- c. Exopod of first legs one-jointed; fused third and fourth joints much narrower than the second joint; each anal lamina with but two setæ d.
- d. Cephalothorax widest at the center and narrowed posteriorly; first abdomen joint much longer than the others *unicirrus* (Brian), 1902.
- d. Cephalothorax widest at the posterior margin; the three abdomen joints about the same length *ardeolæ* (Kröyer), 1863, p. 363.

ARTACOLAX SÆTIGER, new species.

Plate 51.

Female.—Cephalothorax semielliptical in shape, but not evenly rounded anteriorly; squarely truncated posteriorly, one-third wider than long. Remaining thorax segments diminishing in width with

fair regularity; second segment very short and well rounded at the sides. Third and fourth segments about the same width as the second segment anteriorly but considerably narrowed posteriorly. The third segment covers dorsally the whole of the fourth and a part of the fifth segments; its contour can be well seen in side view (figs. 129 and 139). The fifth segment is nearly as wide as the fourth but much shorter; the genital segment is not enlarged and its sides are straight. The abdomen is three-jointed, the joints diminishing regularly in width, the terminal one the longest, with a deep anal incision on its posterior border. The anal laminæ are rectangular, wider than long, each armed with two unequal setæ, the inner one more than twice the length of the outer. The egg-cases are elliptical, the same width as the genital segment and about one-third the entire body length. The eggs are of medium size and arranged in six or seven longitudinal rows, about sixty or seventy-five in each case.

The first antennæ are narrow and of medium length; the three terminal joints are distinctly marked, while the three basal ones are well fused. The terminal joints are sparingly armed with setæ and there is no tuft at the tip. The basal joints are heavily armed with stout and coarse setæ mixed with slender tactile hairs; attached to their ventral surface on each antenna is a narrow chitin plate, which points diagonally forward and is split into three flattened spines of about equal length.

The second antennæ are two-jointed, the terminal joint roughened with rows of short spines and tipped with three curved claws.

The labrum is transversely elliptical, one-third wider than long and perfectly smooth. The mandibles have two stout basal joints besides the cutting blades; the proximal joint is considerably enlarged, the second joint is long and narrow, the terminal cutting blade is shorter than the second joint and is armed with a fringe of short hairs along both margins.

The first maxillæ are knobs of large size, each armed with three widely divergent setæ. The second maxillæ have a powerful basal joint and a cutting blade, whose triangular base is as wide as the basal joint, but is abruptly narrowed into the slender cutting portion, which is half as long again as the basal joint, and is armed along its anterior border with a row of stout hairs. The shape of this cutting blade and its mode of attachment to the basal joint is totally different from that found in *Bomolochus* species, and illustrates one of the characteristics of the genus.

The maxillipeds are also peculiar; they are very large and the triangular basal portion is attached well forward so that its distal end is opposite the second antennæ. From this end projects the terminal claw which is bent into an almost perfect S-shape, and does not show the abrupt curve found in *ardeolæ*. This claw is also perfectly smooth,

without tooth or branch, but is armed with two huge plumose setæ, which are attached to the outer curve close to the base of the claw.

First swimming legs with a one-jointed exopod and a three-jointed endopod. The former is armed with five plumose setæ; the two basal joints of the latter each carry one seta on their inner margin, the terminal joint carries five. The arrangement of the spines and setæ on the second, third, and fourth legs is as follows: Second exopod, I-1; II-1; III-5: endopod, 0-1; 0-2; II-3: third exopod, I-0; I-1; II-5: endopod, 0-1; 0-2; III-2: fourth exopod, I-0; I-1; II-5: endopod, 0-0; 0-0; II-1.

The arrangement of the spines and setæ as well as the contour of the leg itself makes it reasonably certain that the last joints of the exopods of these three pairs of legs is really a fusion of two joints, but there are no signs of any groove between them. The claws have the structure shown in figure 137, and are thus peculiar.

Total length, 2 mm. Cephalothorax 0.8 mm. long, 1 mm. wide. Length of second, third, and fourth segments, 0.75 mm. Length of egg-strings, 0.75 mm. Length of inner seta on the anal laminae, 0.6 mm.

Color a rich seal brown, uniform over the entire dorsal surface, lighter and somewhat yellowish on the ventral surface.

(*sætiger*, armed with setæ, alluding to the large ones on the maxillipeds).

The National Museum collection contains a single lot of this species, consisting of three females taken from the flying fish, *Exocætus volitans*, at Woods Hole, Massachusetts, which is numbered 38629, U.S.N.M. These are made the types of the new species.

ARTACOLAX ARDEOLÆ (Krøyer).

Plate 52; Plate 53, fig. 147.

Bomolochus ardeolæ, KRØYER, 1863, p. 220, pl. 11, fig. 3, *a* to *e*.

Artacolax ardeolæ, WILSON, 1908, p. 434.

Female.—Body tadpole-shaped, the cephalothorax more than four times the width of the posterior portion. Cephalothorax semi-elliptical in shape and almost twice as wide as long, the anterior margin evenly rounded, the posterior margin a straight line. Second (first free) segment considerably narrower than the carapace and tapered posteriorly; third and fourth segments rigidly fused, one-third narrower than the second segment, and together about equaling it in length. Fifth segment abruptly narrowed to one-third the width of the fused segments, and distinctly separated from the genital segment, its lateral margins slightly concave. Genital segment the same width anteriorly as the fifth segment, but somewhat narrowed posteriorly, the same length as the second segment and barrel shaped, with nearly straight sides.

Abdomen three-jointed, the first joint as wide as the posterior end of the genital segment, the other joints diminishing regularly. Anal laminae shorter than the last abdomen joint and less than half its width, each bearing three setæ, of which the inner one is twice the length of the outer. There is also a short spine at the base of each lamina on the outer margin. Egg-cases elongate, about two-thirds the entire length and three times as long as wide.

First antennæ very large, each one-fourth longer than the cephalothorax, probably six-jointed, but with the joints of the basal portion indistinctly separated. These basal joints are much enlarged and are attached to the front of the carapace some little distance apart, with a fringe of large flattened setæ around their anterior margin. They are operated by a set of powerful muscles which extend diagonally backward and inward nearly to the posterior margin of the cephalothorax and which are plainly visible in dorsal view. On the dorsal surface of the third joint of each antenna are two long tactile hairs which point directly forward. The second antennæ are two-jointed, the last joint with the usual roughened surfaces and terminal claws.

The mouth-parts agree with those of *Bomolochus* in the main particulars, but differ in details. The labrum is much broader than long and crescentic, projecting at the angles on either side. The mandibles are three-jointed, the basal joint much wider than the others, about one-third the entire length of the appendage, and evenly rounded at the distal end. The second joint is shorter and narrower, and bears at its distal end both a cutting blade and a palp. The former is longer than even the basal joint and quite narrow, with a fringe of short hairs along its posterior border.

The latter consists of a rounded knob terminated by a short curved claw, and is ventral to the cutting blade.

The first maxillæ are elevated well above the surface of the head, and each is armed with three widely divergent setæ. The second maxillæ have a long and narrow basal joint, running back to the basal joint of the mandibles, and a slender cutting blade turned diagonally forward, a little more than half as long as the basal joint and entirely smooth.

The maxillipeds are comparatively small, the basal joint is triangular and armed with powerful muscles, while the terminal claw is bent completely back upon itself and then turned inward at a right angle like a sickle, with a large accessory tooth on the outer or convex side. Neither basal joint or claw shows any plumose setæ, but the latter has a small smooth bristle on the ventral surface of the first bend.

The first legs have very broad and flattened rami, the exopod one-jointed and as long as the two-jointed endopod; the joints of

the latter are two or three times as wide as long, and both rami are armed with large and strongly flattened plumose setæ. The second, third, and fourth legs have three-jointed rami, the endopods wider and longer than the exopods, the spines and setæ arranged as follows: Second exopod, I-0; I-1; III-5: endopod, 0-0; 0-2; II-2: third exopod, I-0; I-1; III-6: endopod, 0-1; 0-2; III-2: fourth exopod, I-0; I-0; I-5: endopod, 0-1; 0-1; II-1.

The claws are large and toothed along their posterior margin; the fifth legs are two-jointed, the terminal joint much larger than the basal, spatulate in form and tipped with four spines of unequal length; there is also a short spine on the anterior border of the basal joint (fig. 145).

Color, a light yellowish cartilage gray, inclining to brown on the cephalothorax.

Total length, 2.4 mm. Cephalothorax, 1 mm. long, 1.7 mm. wide. Length of second, third, and fourth segments, 0.5 mm. Width of genital segment, 0.4 mm. Length of egg-strings, 1.6 mm.

(*ardeolæ*, from the name of the host, *Belone ardeola* Kröyer, which was probably *Tylosaurus marinus*, the silver gar.)

There is a single female of this species taken from the gills of the Little Garibaldi, *Hypsypops rubicundus*, at La Jolla, California, by Dr. J. C. McClendon, and is numbered 38597, U.S.N.M. When the present author endeavored to locate this specimen among the described species of *Bomolochus*, it was found to possess differences which could not consistently be included in the same genus. Accordingly a new genus was constructed for this and the species mentioned on p. 361. In the paper dealing with Doctor McClendon's fine lot of specimens nothing but the diagnosis of the new genus was given.^a In the present paper Kröyer's species, *ardeolæ*, which was taken as the genus type, has been redescribed and figured. This, with the description and figures of the new species, *sætiger*, will fix the genus definitely. It is worthy of note that Kröyer's type of the species, *ardeolæ*, was taken from the gills of a fish captured at New Orleans, and is hence North American.

Genus BOMOLOCHUS Nordmann.

Female.—Body with a general *Cyclops* shape, but usually with a widened cephalothorax and a narrowed abdomen. First thorax segment fused with the head, the others free and diminishing regularly in size; genital segment enlarged but little; abdomen narrow and tapering. First antennæ six-jointed, the three basal joints fused together, enlarged, flattened, bent at a right angle near the base, and fringed with a dense row of plumose setæ, with a few tactile hairs

^aProc. U. S. Nat. Mus., vol. 35, p. 433.

and sometimes digitate chitinous processes. Second antennæ four-jointed, the two terminal joints with their entire surface roughened, and tipped with short processes and curved claws.

Mandible simple, sometimes with a short palp; first maxillæ, reduced to mere knobs armed with plumose setæ. Second maxillæ three-jointed and simple; maxillipeds also three-jointed, the basal joint directly behind that of the second maxilla, the second joint turned forward outside the other mouth-parts and fused to the surface of the head, the third joint in the form of a stout claw bent twice like the letter S and armed with plumose setæ.

First swimming legs strongly flattened and widened; second, third, and fourth exopods four-jointed; fifth legs rudimentary, two-jointed. Egg-cases cigar-shaped, narrowed posteriorly; eggs small and numerous.

Male.—About half the size of the female; general body form elongate and slender. Cephalothorax nearly circular in outline; free segments diminishing regularly in size; genital segment considerably enlarged and lobed at the posterior corners. Abdomen short and tapering; anal laminæ medium size but the setæ are usually half the entire length or more.

First antennæ cylindrical, not enlarged and flattened at the base, and armed with smaller and more slender setæ than in the female. Maxillipeds in normal position behind the other mouth-parts, three-jointed, the two basal joints stout, the terminal claw long and slender and toothed along its inner margin. Other appendages like those of the female, except that they are smaller.

Type-species.—*Bomolochus bellones* Burmeister.^a

(*Bomolochus*, βωμολόχος, the rabble that waited about the altars to beg or steal, veritable parasites.)

ARTIFICIAL KEY TO THE SPECIES.

In the following key certain species which have previously appeared under the genus *Bomolochus* have been eliminated because, after careful study, they are found to be so different from the type as to constitute separate genera:

Ardeola, *chatoessi*, and *scomberesocis* (Krøyer, 1863), *cornutus* (Claus, 1864), and *unicirrus* (Brian, 1902) belong under the genus *Artacolax* (Wilson, 1908) (see p. 361). *Gracilis* (Heller, 1865) and *tetodontis* (Bassett-Smith, 1898) are placed as species of the new genus *Irodes* (see p. 390).

^a Nordmann who established the genus described but one species, *parvulus*, which ought ordinarily to become the genus type. But he had only a single specimen, his description is meager and lacking in most of the details, he published no figures, and his species has neither been described nor seen by any investigator since his day. It can not serve, therefore, as a type-species, but must give place to *Bomolochus bellones*, which was well described and figured by Burmeister in the following year (1833), and has been repeatedly found, described, and figured by subsequent investigators.

Murænæ (Brian, 1906) is made the type of the provisional new genus *Phagus* (see p. 391). *Ostracionis* (Richiardi, 1870) is transferred to Brian's genus *Anchistrotos*. Finally there are two species, *minus* and *oblongus* (Richiardi, 1880) which have never been described, and hence can not be definitely located at the present time.

- a. Maxillipeds turned forward outside of the other mouth-parts, with the basal joint fused to the ventral surface of the head, females.....b.
- a. Maxillipeds in normal position behind the other mouth-parts, both joints free and of the usual shape, males.....l.
- b. Terminal claw on maxillipeds very stout, with one or more teeth or branches and turned backward along the central axis of the basal joint in a sigmoid curve.....c.
- b. Terminal claw on maxillipeds slender, without teeth or branches, and usually turned backward along the lateral margin of the basal joint, or even outside it, in a simple curve.....g.
- c. Exopod of first swimming leg with a single triangular joint, well armed with plumose setæ.....d.
- c. Exopod of first swimming leg with two joints, the terminal one only armed with plumose setæ.....e.
- c. Exopod of first swimming leg with three joints like the endopod, the two terminal ones with plumose setæ.....f.
- d. Basal joints of first antennæ close together; third joint only with tactile hairs; first abdomen joint as long as the other two.
eminens, new species, p. 368.
- d. Basal joints of first antennæ close together, each with one or two slender tactile hairs; three abdomen joints the same length.
bellones Burmeister, 1833.
- d. Basal joints of first antennæ widely separated, each with several stout spines; first abdomen joint as long as the other two.....*megaceros* Heller, 1865.
- e. Frontal margin well rounded, entirely covering the bases of the first antennæ and filling the space between them; mandible and second maxilla simple and smooth.....*concinuus*, new species, p. 371.
- e. Frontal margin well rounded, entirely covering the bases of the first antennæ and filling the space between them; mandible with a secondary spine on the second joint; second maxilla bipartite, both appendages toothed.....*nitidus*, new species, p. 374.
- e. Frontal margin reentrant, showing the entire bases of the first antennæ in dorsal view; mandible and second maxilla simple and smooth.
solex Claus, 1864, p. 375.
- f. First three free thorax joints nearly as wide as the cephalothorax; fourth joint abruptly narrowed to one-third that width; maxillipeds with but a single plumose seta.....*glyphisodontis* Krøyer, 1863.
- f. Only the first free thorax joint as wide as the cephalothorax, the second narrowed to two-thirds, the third to one-third of that width; maxillipeds with three large plumose setæ.....*exilipes*, new species, p. 377.
- g. Frontal margin of carapace deeply notched; basal joints of first antennæ fully visible and heavily armed with stout spines and digitate processes.....h.
- g. Frontal margin of carapace protruding and covering the bases of the first antennæ; the latter distinctly jointed and armed with short setæ, without spines or processes.....k.
- h. Maxillipeds with but a single plumose seta; carapace much wider than free segments.....i.
- h. Maxillipeds with two large plumose setæ; carapace but little wider than the first free segment.....j.

- i. Exopod of first swimming leg with two joints, endopod with three; short digitate processes on the first antennæ.
denticulatus Bassett-Smith, 1898, *b*.
- i. Exopod of first swimming leg with one joint, endopod with two; processes on first antennæ with very long spines.
tricerus Bassett-Smith, 1898, *a*.
- j. Second free segment swollen and overlapping the third; fifth legs three-jointed; abdomen joints equal.
parvulus Nordmann, 1832.
- j. Second free segment not swollen; fifth legs two-jointed; first abdomen joint as long as the other two.
teres, new species, p. 379.
- k. Terminal abdomen joint much longer than either of the other two; the setæ on the claw of the maxillipeds widely separated.....*onosi* T. Scott, 1902.
- k. Basal abdomen joint considerably the longest; the setæ on the claw of the maxillipeds close together.
zeugopteri T. Scott, 1902.
- l. Exopod of first swimming leg two-jointed, endopod three-jointed.....*m*.
- l. Both rami of the first swimming legs three-jointed, neither ramus widened.....*n*.
- m. Second joint of maxillipeds very small, only one-eighth the length of the basal joint; terminal claw longer than both joints, and coarsely toothed along the entire inner margin.....*solex* Claus, 1864, p. 376.
- m. Second joint of the maxillipeds swollen to three or four times the size of the basal joint; terminal claw about the length of the second joint, slender and finely toothed along the inner margin.
concinus, new species, p. 371.
- n. Second joint of maxillipeds twice as long as wide, narrower than the basal joint; terminal claw coarsely toothed, with two stout spines at its base.
onosi T. Scott, 1902.
- n. Second joint of maxillipeds enlarged and flattened, much wider than the basal joint; terminal claw finely toothed, with a single bristle at its base.
megacerus Heller, 1865.

BOMOLOCHUS EMINENS, new species.

Plate 53, text figure 6.

Female.—General body form long and slender; cephalothorax transversely elliptical, three-fifths wider than long, with strongly projecting lateral margins. Anteriorly the carapace projects over the first antennæ so as to entirely conceal them in dorsal view, except the very tips of the setæ with which they are armed. From the center of the anterior margin an almost circular lamina projects like a rostrum.

Second, third, fourth, and fifth segments diminishing regularly in width, the fifth segment three-eighths the width of the carapace. The respective lengths of the carapace and the four free segments are rep-

sented by the figures 11, 5, 4, 6, and 2. Genital segment narrower than the fifth segment, with nearly straight sides and short evenly rounded lobes at the posterior corners. From the center of each lobe on the ventral surface projects a single short spine, while from the angle between the lobe and the first abdomen segment projects a short finger-like process, curved slightly outward. Abdomen three-jointed, tapering posteriorly, the first segment as long as the other two and twice the width of the terminal segment. Anal laminae as long as the last segment, inclined toward each other, and each armed with a single stout seta at the tip, twice as long as the entire abdomen, a very short seta on either side of it, and a slightly longer one on the outer margin near the base.

Egg-cases ellipsoidal, half as long as the entire body, and narrowed a little at either end; eggs arranged in six or eight longitudinal rows, about eighteen in the longest central rows.

First antennæ showing the joints distinctly, the fused basal joints with a fringe of heavy setæ around the anterior margin and running back on the dorsal surface of the third joint to the posterior margin, the last seta projecting diagonally backward from the posterior corner of the third joint and considerably longer than the others. From the anterior margin of the second joint project a pair of tactile hairs nearly three times the length of the setæ (fig. 6).

Second antennæ of the usual pattern, the terminal joint ending in two long curved claws of about the same size, and a finger-like process covered with short spines.

Labrum two-fifths wider than long, narrowed into a knob on either lateral margin. Mandible long, smooth, and slender, directed diagonally backward along the margin of the labrum.

First maxillæ small, each armed with two short and nearly parallel setæ. Second maxilla long and slender, the terminal joint simple, covered with short hairs and directed slightly forward, almost meeting the tip of the mandible.

Maxilliped very large, the basal joint distinctly visible, showing even the musculature, and extending laterally far outside of the other mouth-parts. Second joint turned forward and inward and about the same size as the basal joint, with a single large plumose seta at the tip on the ventral surface, alongside the terminal claw. The latter is stout but short, not reaching the middle of the second joint, and with a simple crescentic curve, the outer convex margin of which is broken at the center by an angular protuberance.

Swimming legs of the usual form, each ramus of the first pair two-jointed, the terminal joint of the exopod with ten setæ, covering its entire margin, the basal joint unarmed. The terminal joint of the endopod carries six large setæ, the basal joint one on the inner margin.

The second, third, and fourth legs each have a three-jointed endopod and a four-jointed exopod, the two terminal joints of the latter more or less fused. All the swimming legs stand out prominently in dorsal view; the tips of the rami of the first pair and the entire rami and most of the basal joints of the other pairs are plainly visible. The arrangement of the spines and setæ is as follows: Second exopod, I-0; I-1; I-1; II-3: endopod, 0-0; 0-1; I-3: third exopod, II-0; I-1; I-1; I-4: endopod, 0-1; 0-1; I-2: fourth exopod, I-0; I-1; I-2; II-2: endopod, 0-1; 0-1; I-2. Fifth legs composed of a single broad and spatulate joint, two-thirds as long as the genital segment and tipped with three setæ, the middle one longer than the other two.

Color (preserved material) a light gray, becoming thick and opaque on the dorsal surface.

Total length, 2.75 mm. Carapace, 0.85 mm. long, 1.25 mm. wide. Free thorax, 1.34 mm. long. Egg-strings, 1.75 mm. long, 0.50 mm. wide.

(*eminens*, eminent, notable, in the sense of being well distinguished from other species.)

There is a single lot of this species, numbered 38638, U.S.N.M., and consisting of two females, both of which carry fully formed egg-strings. They were taken from the gill cavity of the false Spanish sardine, *Clupanodon pseudohispanicus*, at the Tortuga Islands, by Dr. Edwin Linton.

In spite of the poverty of specimens the species stands out in marked contrast to all others in the following particulars:

1. General body form; the comparatively small size of the carapace and the length of the free thorax segments.
2. The prominence of the swimming legs; not merely the rami but the most of the basal joints are visible in dorsal view.
3. The peculiar fusion of the last two joints of the exopod in the second, third, and fourth legs.
4. The size of the maxillipeds, their position so far outside the other mouth-parts, and the fact that their basal joints are visible for their entire length.

This last characteristic is of great importance since, in connection with the developmental stage to be described later (see p. 373), it completely proves the identity of these appendages as maxillipeds.

In other species these basal joints are so thoroughly fused with the ventral surface of the head that they are indistinguishable, and only the second joint and terminal claw are visible. The position of these last two joints is not such as to suggest that they belong to the maxillipeds, and hence much confusion has arisen with reference to them. But here we have the entire appendage visible and there can be no question of its identity.

BOMOLOCHUS CONCINNUS, new species.

Plates 54 and 55.

Female.—General body form like that of *Cyclops*; cephalothorax one-half wider than long, with a rounded posterior margin and projecting sides. Free segments diminishing regularly in size; genital segment considerably enlarged, half as wide again as the fifth segment, and barrel shaped, with the sides strongly convex. Abdomen three-jointed, the basal joint considerably the largest; anal laminae oblong, three-quarters the length of the last abdomen joint and tapered posteriorly, each armed with four setæ, two short ones on the sides of the lamina and two long ones at its tip, the inner one longer than the outer. Egg cases about half the entire length, anteriorly the same width as the genital segment, but narrowed posteriorly; eggs in five or six longitudinal rows, about seventy or eighty in each case.

First antennæ slender and similar to those in *exilipes*, except that the basal joints are almost entirely covered by the carapace in dorsal view. Two long tactile hairs are inserted close together and near the center of the anterior margin of the fused basal portion, and there is an extra long plumose seta at the distal end of this portion on the dorsal surface. The three slender terminal joints carry these antennæ far beyond the lateral margins of the carapace. In the second antennæ the anterior surface of the second joint and a portion of the ventral surface of the basal joint are covered with transverse ridges. The anterior surface of the two terminal joints is covered with longitudinal rows of short spines; the terminal claws on the last joint are interspersed with spines and setæ, making a dense tuft.

The labrum is transversely elliptical, twice as wide as long, with a smooth surface. The mandibles have a smooth and slender cutting blade about the same length as the basal joint. The first maxillæ project moderately from the ventral surface, and are each armed with four widely divergent plumose setæ. The second maxillæ are simple, the terminal blade conical and covered with fine hairs. The maxillipeds are large, with a terminal claw long enough to reach the proximal end of the second joint. The tip is acute and there is a short curved accessory claw on the outer margin near the center. To the base of this claw on its outer side is attached a large plumose seta; another much smaller one is attached to the tip of the second joint inside the terminal claw; a third, and by far the largest of the three, is attached to the ventral surface of the second joint close to its inner margin and points backward.

The first legs have a two-jointed exopod, the basal joint unarmed, the terminal one with six large setæ. The endopod is three-jointed; each of the two basal joints carries a single huge seta on its inner

margin, while the terminal joint has five. The arrangement of the spines and setæ on the other legs is as follows: Second exopod, I-0; I-1; II-1; II-4: endopod, 0-1; 0-2; 0-3: third exopod, I-0; I-1; I-1; II-4: endopod, 0-1; I-1; II-2: fourth exopod, I-0; I-1; I-1; II-4: endopod, 0-1; 0-1; I-2. The fifth leg is two-jointed, the basal joint triangular, with a small spine on the outer distal corner; the terminal joint carries a spine at the center of the outer margin and three at the tip, the central one longer than the others.

Color, a uniform light cinnamon brown, deepening in preservatives.

Total length, 1.80 mm. Cephalothorax, 0.65 mm. long, 0.9 mm. wide. Length of free segments, 0.55 mm. Length of anal setæ, 0.5 mm. Length of egg cases, 0.85 mm. Width of genital segment, 0.3 mm.

Male.—General body form much longer and narrower than that of the female; cephalothorax nearly circular in outline, a little wider than long, with evenly rounded lateral and anterior margins, and a nearly squarely truncated posterior margin.

Second, third, and fourth segments about the same length and diminishing regularly in width, but with the bases of the swimming legs projecting at the sides, and so making them appear nearly as wide as the carapace. Fifth segment very short and hidden between the fourth and genital segments. The latter is the same width as the fourth segment, oblong, widened posteriorly, with straight sides and truncated corners.

Abdomen three-jointed, basal joint much shorter than the other two, the three about the same width; anal laminae as long as the last joint, twice as long as wide, evenly rounded posteriorly, and each armed with five nonplumose setæ, three short ones on the outer margin and two longer ones at the tip, the inner one of the latter being over half the entire length of the animal, the outer one a third as long.

First antennæ similar to those of the female, but the basal portion is not as heavily armed with setæ and the tactile hairs are shorter. The third joint of the second antennæ is considerably more swollen than in the female, and there is a similar tuft of claws and setæ at the tip of the last joint. The maxillipeds are in normal position behind the other mouth parts; each consists of a fairly stout basal joint with three or four short spines on its ventral surface, a very much stouter second joint furnished with powerful muscles, and a long slender terminal claw slightly curved and armed with fine sawteeth along its inner margin.

The swimming legs are similar to those of the female, except the first and fifth pairs; in the former a stout and flattened plumose seta, fully as long as either ramus, is attached to the outer margin of the basal joint; in the latter each leg has but a single slender joint, tipped with two nonplumose setæ. Color the same as that of the female.

Total length, 1 mm. Cephalothorax, 0.4 mm. long, 0.45 mm. wide. Length of free segments, 0.19 mm.; of genital segment, 0.22 mm.; of abdomen, 0.24 mm.; of anal setæ, 0.65 mm.

(*concinus*, beautiful, elegant in appearance.)

Young female, a developmental stage. General body form long and narrow, similar to that of the male, but with marked differences in detail. Cephalothorax circular in outline, about as long as wide, narrowed and projecting a little between the antennæ, and squarely truncated posteriorly.

Free and genital segments all about the same length, but diminishing regularly in width. Each of the free segments carries a rounded projection on either margin, covering the base of the swimming leg. The genital segment is almost a perfect rectangle, and the abdomen contains but a single joint, which is deeply cut posteriorly by the anal fissure. Each anal lamina is armed with three setæ, one, short and slender, on the outer margin near the base, and two at the tip, the inner of which is nine times the length of the outer and more than half the length of the entire body.

The first antennæ are distinctly six-jointed, the three terminal joints much narrower than the basal and armed throughout with densely plumose setæ. The large seta given off from the distal end of the third joint is itself jointed near the base and thus forms a sort of ramus.

The mouth-parts are similar to those of the adult but with the following differences. The first maxillæ project well from the ventral surface and each carries four plumose setæ diverging but little.

The basal joints of the second maxillæ are considerably elongated and the cutting blade is covered with long bristles. The maxillipeds are distinctly three-jointed; the proximal joint is in normal position behind the second maxillæ, the second joint turns forward outside the base of the second maxillæ but is not long enough to reach their anterior margin, while the terminal claw is comparatively small and weak. Of the swimming legs each ramus of the fourth pair contains but two joints, while the fifth legs are represented by mere spines on the sides of the fifth segment like those in the adults of some *Ergasilus* species.

Total length, 0.5 mm. Cephalothorax, 0.2 mm. long, 0.21 mm. wide. Length of free segments, 0.18 mm.; of anal setæ, 0.28 mm.

This developmental stage helps to fix the anatomy of several appendages in this genus which have been heretofore somewhat in doubt. The first antennæ are really six-jointed and the three basal joints become fused in later development. The fifth thorax segment is at first of equal importance and corresponding size with the other segments, but it loses its size and importance as the sexual products

are developed within the segments in front of it, until finally in the fully mature adult it may almost disappear.

The maxillipeds are three-jointed appendages, with the basal joint in proper position behind the other mouth-parts. It is therefore only in the very last stage of development that they become abortive and the basal joint disappears to a greater or less degree. On the contrary, the first maxillæ are rudimentary from the very beginning and are never developed any more than we see in the adult.

This species is found occasionally upon the gills of the gar-fish or bill-fish, *Tylosaurus marinus*, and is never very common. The Museum collection includes a single lot obtained at Beaufort, North Carolina in 1905 and numbered 38622, U.S.N.M. There are a goodly number of specimens, and the lot includes both sexes and development stages.

BOMOLOCHUS NITIDUS, new species.

Plate 56; text-figure 8; plate 58, fig. 201.

Female.—Cephalothorax semielliptical, one-half wider than long and squarely truncated posteriorly; bases of the first antennæ widely separated, with a broad rectangular rostrum projecting between them. Free thorax segments diminishing regularly and rapidly in width, their lengths in the proportions expressed by the numbers 25, 35, 18, 9; genital segment not enlarged, as wide as the fifth segment, with strongly convex sides. Abdomen three-jointed, the joints diminishing slightly in width, the terminal one a little the longest and cut off obliquely at the posterior corners. Anal laminae as long as the last abdomen joint and somewhat tapered, each tipped with two large setæ, of which the inner one is considerably longer than the outer, and three shorter ones. Egg-cases large and cylindrical, half the entire length and nearly twice the diameter of the genital segment; eggs large, arranged in six or seven longitudinal rows, about seventy-five in each case.

First antennæ stout but rather short, scarcely reaching the lateral margin of the carapace, and very indistinctly segmented, even the terminal portion. These antennæ are sparsely armed with short setæ, large and flattened at the base, smaller and hair-like toward the tip. Second antennæ of the usual pattern for this genus.

Labrum almost circular, with evenly rounded margins and a smooth surface; mandibles small and weak, the cutting blade short and smooth.

First maxillæ large and swollen, each armed with three widely divergent setæ. Second maxillæ with a large and stout basal joint, the terminal cutting portion bipartite, each ramus acuminate and covered with short hairs. Maxillipeds of good size and placed well forward, the terminal claw smooth, without teeth or branches, and armed with a single medium sized plumose seta at its base.

First swimming legs with a one-jointed exopod, triangular in shape, and armed with six flattened plumose setæ along its posterior margin and a single spine on its anterior margin. Endopod made up of three joints, the first without spines or setæ, the second with a single large seta on its inner margin, the third with five setæ. Exopods of second, third, and fourth legs distinctly four-jointed, endopods three-jointed. Endopod of the second pair with the flattening of the joints and setæ carried to such a degree that it seems as if it must be abortive. And yet it is alike on the right and left sides and on the two specimens at command. Each joint is much widened and flattened, very similar to those of the first legs; the setæ with which they are armed are also widened and flattened like those on the first legs (see fig. 180). The arrangement of the spines and setæ is as follows: Second exopod, I-0; I-1; II-2; II-3: endopod, 0-1; 0-1; 0-2: third exopod, I-0; I-1; I-1; II-3: endopod, 0-1; 0-1; 0-4: fourth exopod, I-0; I-0; I-0; II-4: endopod, 0-1; 0-1; 0-3. Fifth legs two-jointed, the basal joint short and narrow, the terminal joint four times as long, enlarged into a spatulate form, and tipped with three nonplumose setæ, of which the central one is three times the length of the other two.

Total length, 2.2 mm. Cephalothorax, 0.77 mm. long, 1.18 mm. wide. Length of free segments, 0.87 mm.; of genital segment and abdomen, 0.55 mm.; of anal setæ, 0.55 mm.; of egg-cases, 1.1 mm.

Color a rich seal brown inclining to reddish, lighter on the ventral surface.

(*nitidus*, neat, tasty in appearance.)

The National Museum collection includes but a single lot of this species, obtained from the gills of the common mullet *Mugil cephalus*, at Beaufort, North Carolina, in 1905.

This lot is numbered 38611, U.S.N.M., and consists of two females which are made the types of the new species.

These parasites are not at all common, since the examination of several hundreds of fish yielded only the two specimens. They were found in company with *Ergasilus mugilis* Vogt.

BOMOLOCHUS SOLEÆ Claus.

Plate 57, text-figure 40.

Bomolochus soleæ, CLAUS, 1864, p. 374, pl. 25, figs. 16-20.—T. SCOTT, 1902, p. 288, pl. 13, figs. 13-18.—A. SCOTT, 1904, p. 117.

Male.—General body form elongate and narrow; first thorax segment distinctly separated from the head; carapace (cephalon) circular, abruptly narrowed anteriorly between the bases of the first antennæ, elsewhere evenly rounded.

First and second free segments the same width, which is two-thirds that of the carapace, the second segment a little the longer. Remaining free segments diminishing regularly in width, the third and fourth the same length as the second, the fifth about half as long. Genital segment barrel-shaped, the same width as the fifth segment, a little longer than wide and contracted posteriorly in front of the abdomen.

Abdomen half the width of the genital segment, two-jointed, the segments equal in length, the terminal one somewhat narrower than the basal. Anal laminæ large, covering together almost the entire width of the terminal segment and two-thirds as long, each armed with two terminal setæ, of which the inner is twice the length of the outer, and three short spines, one at the outer distal corner, another on the ventral surface near the tip, and the third on the lateral margin nearer the base.

The terminal joint of the abdomen and the anal laminæ have large patches of coarse hairs upon their ventral surface, arranged as shown in fig. 185.

First antennæ distinctly six-jointed, the basal joint not enlarged nor projecting as much as in the female, but armed with the same fringe of broad plumose setæ. No tactile hairs, however, could be found among these setæ. Second antennæ with the two terminal joints heavily corrugated and tipped with five curved claws, which diminish regularly in size from within outward.

Labrum shield-shaped, one-third longer than wide, with short rounded projections at the center of the anterior and posterior margins and a reentrant sinus on each lateral margin one-third of the distance from the anterior end (fig. 40).

Mandibles similar to those of the female, with a small secondary spine at the base of the larger terminal one on the inner side.

First maxillæ with three long plumose setæ, the central one the shortest; second pair with a single terminal spine and without the accessory ciliated spine found in the female.

Maxillipeds in normal position behind the other mouth-parts, consisting of a swollen basal joint and a slender terminal claw, the same length as the basal joint and curved near its tip so as to fit tightly against the posterior margin of the basal joint when flexed. The inside of the claw and the margin of the basal joint against which it fits are covered with short saw-teeth.

First swimming legs not widened nor fringed with broad plumose setæ as in the female, but consisting of a broad basal portion and two narrow rami armed with spines and setæ like the other legs (fig. 219).

Endopod of fourth legs two-jointed, the terminal joint twice the length of the basal and tipped with three setæ. Above the base of each of the fifth legs there projects from the dorsal surface of the fifth thorax segment a single long nonplumose spine.

Color a clear cartilage gray without pigment markings.

Total length, 1.12 mm. Carapace, 0.40 mm. long and wide. Free thorax segments, 0.40 mm. long, the first and second 0.28 mm. wide. Genital segment 0.17 mm. long, 0.15 mm. wide.

A single lot of this species obtained from the nostrils of the cod off the coast of Scotland, and containing a male and three females, was sent to the author by A. Scott, esq., of the Fishery Board of Scotland. For this courtesy, as well as for permission to include a description of the hitherto unknown male in the present paper, the sincere thanks of the author are hereby tendered.

This lot of specimens has been placed in the National Museum and is numbered 38618, U. S. N. M.

BOMOLOCHUS EXILIPES, new species.

Plate 58; text-figure 10.

Female.—General body form small and slender; cephalothorax semielliptical, nearly twice as wide as long and slightly rounded posteriorly. First antennæ projecting so that nearly all the basal portion is visible in dorsal view; the bases of these antennæ are well separated with a rounded rostrum protruding a little between them. Second thorax segment nearly as wide as the carapace, but short; third segment longer and considerably narrower; fourth segment also much narrowed and partly concealed beneath the third segment; fifth segment the same width and length as the fourth, projecting strongly on either side at the bases of the fifth legs. Genital segment about as wide as the fifth segment, barrel-shaped, with strongly convex sides. Abdomen three-jointed, joints diminishing evenly in width, the first two the same length, the terminal one a little longer. Anal laminæ oblong, about half the length of the last segment, each tipped with three unequal setæ, the inner and longest of which is as long as the genital segment and abdomen combined. Egg-cases long and narrow, two-thirds of the entire length, and two-thirds as wide as the genital segment; eggs in six or eight longitudinal rows, about 70 eggs in each case.

First antennæ distinctly six-jointed, slender, and not reaching far beyond the lateral margins; the base for insertion is rather long and narrow, causing the appendages to project well in front of the carapace. The basal joints are fringed along their anterior border with a dense row of flattened plumose setæ and a couple of tactile hairs. The terminal joints are only sparingly supplied with short setæ which are nonplumose. The second antennæ have the basal joint longer than the other two, the second joint very short, the terminal joint armed with the usual longitudinal rows of spines. The last joint terminates in five claws of different lengths and a

rounded process covered with short spines. In life the two terminal joints are carried folded back against the basal joint, and each antenna points forward and inward in front of the mouth-parts toward its fellow on the opposite side, the distal ends of the basal joints meeting at the mid-line. From each of these distal ends projects a long curved claw, the two crossing each other like the letter X. The labrum is ovoid, with an evenly rounded outline and a smooth surface; the mandibles are very slender and the terminal blade is smooth; each first maxilla is armed with three divergent setæ, of which the one in the center is much smaller than the others. The second maxillæ are as slender as the mandibles, and the spine-like terminal portions are covered with short hairs.

The maxillipeds are large and stout, and are placed well forward; the terminal claw is bent sharply at the angles, and has a large accessory spine or tooth on its outer margin; it also carries a single large plumose seta on its ventral surface, and there are two others on the inner margin of the second joint. The first four pairs of legs have three-jointed rami, all of which and especially those of the fourth pair are comparatively long and slender. The arrangement of the spines and setæ is as follows: First exopod, I-0; 0-2; 0-3: endopod, 0-1; 0-1; 0-5: second exopod, I-0; I-1; III-7: endopod, 0-1; 0-2; II-3: third exopod, I-0; I-1; I-6: endopod, 0-1; 0-1; II-2: fourth exopod, I-0; I-1; III-5: endopod, 0-1; 0-1; I-2. The fifth legs are two-jointed, the basal joint very short, the terminal one long and spatulate and squarely truncated at its distal end. It carries a seta on its outer margin and three at the end, of which the middle one is the longest. There is a pair of rudimentary sixth legs projecting from the genital segment just inside the openings of the oviducts; they are in the form of good-sized papillæ, each tipped with three long, cylindrical, nonplumose setæ (fig. 200).

Color a light yellowish brown, darkening to cinnamon brown in the thicker and more opaque parts of the body.

Total length, 1.55 mm. Cephalothorax, 0.5 mm. long, 0.8 mm. wide. Length of free segments, 0.55 mm.; of egg-cases, 1 mm.

(*exilipes*, *exilis*, slender and *pes*, foot.)

The National Museum collection contains a single lot of this species, consisting of 15 females taken from the gills of the sheepshead, *Archosargus probatocephalus*, at Beaufort, N. C., in 1905; it is numbered 38608, U.S.N.M.

The parasite is a fairly common one, the above number of specimens being obtained from half a dozen sheepsheads.

It may be distinguished from other species by the long claws at the distal ends of the basal joints of the second antennæ, and by the slender rami of the swimming legs, particularly those of the first and fourth legs.

BOMOLOCHUS TERES, new species.

Plate 59, text figure 39.

Female.—Cephalothorax semielliptical, one-half wider than long, and squarely truncated posteriorly. Anteriorly it does not cover the bases of the first antennæ at all, but leaves them wholly visible in dorsal view. The free segments diminish regularly in width; the second, third, and fourth about the same length, the fifth a little shorter. The latter segment is also widened considerably at the center through the bases of the fifth legs. The genital segment is narrower than the fifth segment, as long as wide, with nearly flat sides. The abdomen is very long and slender, and three-jointed, the joints diminishing one-third in length from the base toward the tip, but all about the same width.

The terminal joint is cut diagonally at the posterior corners; the anal laminae are narrow and cylindrical, a little more than twice as long as wide, and strongly divergent. Each is tipped with a stout inner seta, whose base is the same diameter as the tip of the lamina, and a much smaller outer seta.

The latter usually can hardly be seen because it is pressed close to the base of the larger one, but sometimes it gets away from the latter and becomes distinct. Both these setæ are nonplumose. Egg-cases somewhat wider than the genital segment, about the same diameter throughout, and only reaching to the center of the terminal setæ; about 100 eggs in each case.

First antennæ long and slender, reaching well beyond the lateral margins, basal portion not much enlarged, fused so that the joints are invisible, and bent so strongly that it forms an acute angle of 60° instead of a right angle. This angle is armed with a row of very large setæ around its entire margin; elsewhere the setæ are scattering except for a small tuft at the extreme tip. Second antennæ of the usual pattern, the terminal joint entirely covered on its ventral and posterior surfaces with dense rows of short spines. The terminal claws are rather short and are reenforced by a long, straight plumose seta at the inner distal corner of the terminal joint.

The mouth parts are well defined; the labrum is semielliptical, with the posterior corners enlarged, rounded, and projecting, and the posterior margin reentrant. Every portion of the surface of the labrum, even to its extreme margin, is densely covered with fine hairs. The mandibles are smooth and simple and are well concealed beneath the labrum.

The first maxillæ are of the usual pattern, each bearing three strongly divergent setæ. The second maxillæ are two-jointed, the basal joint considerably enlarged, the terminal joint in the shape of a large smooth spine five times as long as wide and acutely pointed.

The maxillipeds have small and weak terminal claws, each bearing two huge setæ, much larger than the claw itself. The second joint of these maxillipeds reaches well in front of all the other mouth parts, and overlaps the base of the second antennæ for half its length. The labium is large and is nearly a half circle in outline, extending back from about the center of the basal joint of the second maxilla, on either side.

The rami of the first swimming legs are each two-jointed and armed with extra large and flattened setæ, three on each exopod joint, one on the basal and six on the terminal joint of the endopod. The second, third, and fourth legs have each a four-jointed exopod and a three-jointed endopod, the latter being longer than the former. The arrangement of the spines and setæ is as follows: Second exopod, I-0; I-1; II-1; I-5: endopod, 0-1; 0-2; I-3: third exopod, I-0; I-1; I-1; I-5: endopod, 0-1; 0-2; I-3: fourth exopod, I-0; I-1; I-1; I-4: endopod, 0-1; 0-1; I-2. The fifth legs are each composed of a single two-jointed ramus, the basal joint short, the terminal one four times as long as wide, armed with a single seta on the outer margin near the center, and three of unequal length at the end, the inner one twice the length of the middle one and the latter twice the length of the outer one.

Color a light brown, inclining to green on the dorsal surface, paler and yellowish below.

Total length, 2.14 mm. Cephalothorax, 0.65 mm. long, 0.9 mm. wide. Length of free segments, 0.7 mm.; of abdomen, 0.7 mm.; of egg-strings, 1 mm.

(*teres*, graceful, slender.)

The National Museum collection contains two lots of this species, both obtained from the gills of the common menhaden, *Brevoortia tyrannus*, at Woods Hole, Massachusetts. The lots are numbered 38606 and 38607, U.S.N.M., and the former are made the types of the new species. The species is quite rare, the examination of many fish yielding but a few specimens.

Genus PSEUDOEUCANTHUS Brian.

Cephalothorax elliptical or somewhat ovate, with a continuous raised border around its margin. Second to the sixth (genital) segments all free and of about the same width, which is three-fifths that of the carapace. Abdomen suddenly contracted to one-third the width of the genital segment, three times as long as wide; anal laminae longer than the last segment; First antennæ cylindrical and four-jointed, the basal portion neither enlarged nor flattened nor bent at a right angle. The second antennæ three-jointed and like those of *Bomolochus*. Mandibles strongly curved, simple and smooth; first

maxillæ apparently lacking; second maxillæ stout and simple, the terminal joint covered with hairs; maxillipeds similar to those of *Bomolochus*, but without plumose setæ. First swimming legs with flattened rami; both rami of the second, third, and fourth legs three-jointed, the exopods not well supplied with setæ. Fifth legs uniramous, two-jointed; rudimentary sixth legs on the genital segment. Egg-cases short and narrow; eggs large, only about thirty in each case.

Type-species.—*Pseudoecanthus alosæ* Brian, 1906.

(*Pseudoecanthus*, *pseudo*, false and *Eucanthus*).

There are several points in the description of this genus that need confirmation or correction. In the first place, Brian himself places a question mark after the sex of his specimens. The only thing in the anatomy of the individual he has figured as a "male(?)" which suggests that sex is the lack of egg-strings. On the contrary, the genital segment is exactly the same as in the female and the maxillipeds are turned forward outside the other mouth-parts instead of being in normal position behind them.

Again, Brian has failed to discover any first maxillæ, although he found them in *Bomolochus* and *Anchistrotos*, described in the same paper, and he says nothing about them in the text. If this pair is really lacking that would constitute a generic distinction stronger than any he has advanced.

Finally, in the figure he has given there are only three free segments in front of the genital segment, but there are the usual four pairs of legs. From the arrangement of the latter it is impossible to tell which two of the segments are fused. Until these points of vital importance are settled the genus must be left as Brian has described it.

Subfamily TÆNIACANTHINÆ.

Body strongly flattened; head fused with the first thorax segment and the resultant cephalothorax reentrant on the ventral surface, so that its lateral margins with the basal joints of the first antennæ and the first legs form an effective prehensile disk as in the Bomolochinæ. All the other thorax segments are free; the genital segment is not enlarged; the abdomen is cylindrical and tapers gradually, producing a typical *Cyclops* form like that of the Ergasilinæ. First antennæ cylindrical, the basal joints enlarged but little, and usually not flattened; second antennæ similar to those in the Bomolochinæ. First swimming legs flattened, rami wide and with only one or two joints; the other legs of the usual pattern. Male considerably smaller than the female, with the ordinary sexual differences in the second antennæ and second maxillipeds. Species averaging somewhat larger than the Bomolochinæ, 2 to 2.5 mm. in length.

DESCRIPTION OF THE MOUTH-PARTS.

Female.—Mouth-parts close to the second antennæ; labrum much wider than long, not prominent, in *Tæniacanthus* reduced to a very small size; labium reduced to a mere ridge on the ventral surface of the head. Mandible three-jointed, the basal joint fused to the surface of the head, second and third joints free and turned backward; third joint consisting of one or two slender spines of equal length, shorter than the second joint. Maxillary hook in the form of a claw similar to those in the Caliginæ and attached to the ventral surface near the lateral margin and just behind the first antenna. In *Anchistrotos* it

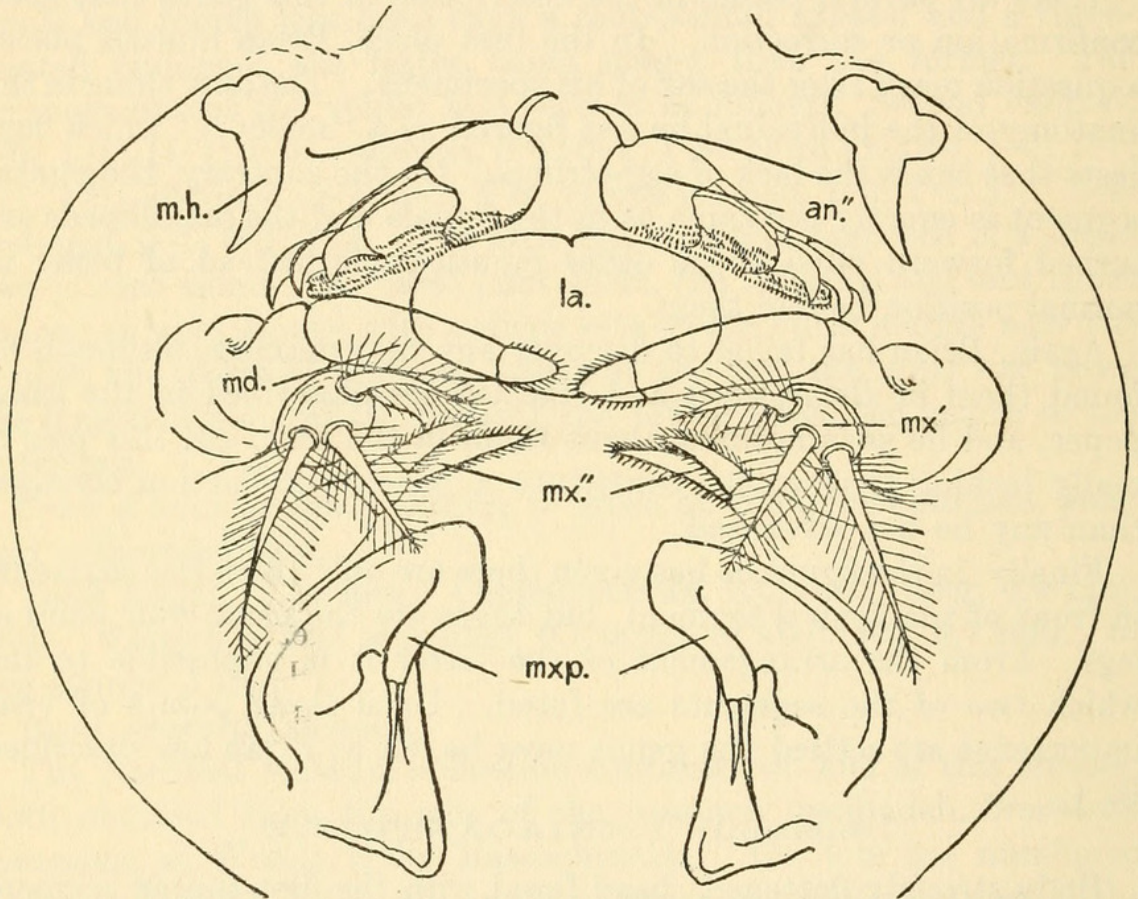


FIG. 41.—MOUTH-PARTS OF FEMALE *TÆNIACANTHUS ALBIDUS*. *an''*, SECOND ANTENNÆ; *la*, LABIUM; *md*, MANDIBLE; *m. h.*, MAXILLARY HOOK; *mx'*, FIRST MAXILLA; *mx''*, SECOND MAXILLA; *mxp*, MAXILLIPEDS.

is long and two-jointed, in *Irodes* and *Tæniacanthus* it has but a single joint, and in *Phagus* it is apparently wanting. First maxilla in the form of a knob armed with from two to four plumose setæ. Basal joints of the second maxillæ fused to the ventral surface, terminal joints slender and bipartite or simple in the different genera. Maxillipeds in their normal position but very rudimentary, the basal joint fused with the ventral surface close behind the other mouth-parts, and directed diagonally inwards and forwards. The terminal joint consists of a slender and weak claw bent in a simple curve (*Tæniacanthus*, *Anchistrotos*), or of two or more slender setæ (*Phagus*, *Irodes*).

Male.—Mouth-parts a little farther back than in the female, labrum more nearly circular in outline. Mandibles similar to those of the female; maxillary hook considerably enlarged, the terminal claw elongate, slender, and strongly curved. First and second maxillæ as in the female.

Maxilliped in the same position as in the female but much larger and not as rudimentary; basal joint inflated and armed with powerful muscles, not fused with the ventral surface of the head and armed with coarse teeth on the inner margin near the proximal end; terminal joint a stout claw, but in a simple curve, its tip shutting against the teeth on the basal joint.

ARTIFICIAL KEY TO THE GENERA.

- a. Each of the first three free segments as large as the cephalothorax, the four together fully four-fifths of the entire length.....*Tæniacanthus* Sumpf, 1871, p. 387.
- a. Each of the first three free segments much smaller than the cephalothorax, the four together about half the entire length.....b.
- b. Maxillipeds little larger than the second maxillæ, their terminal joint seta-like, pointing inwards and forwards, and covered with hairs, with one or two accessory plumose setæ.....*Irodes*, new genus, p. 390.
- b. Maxillipeds much larger than the second maxillæ, and armed with a curved claw, or with smooth spines folded back against the basal joint.....c.
- c. Mandibles and second maxillæ bipartite; maxillary hooks wanting.
.....*Phagus*, new genus, p. 390.
- c. Mandibles and second maxillæ simple; maxillary hooks large and often two-jointed.....*Anchistrostus* Brian, 1906, p. 391.

Of the seven species here included five have already been described under other genus names. For such a radical transposition the author feels that a full explanation is demanded. Accordingly the species are taken in chronological order, and the reasons are clearly stated for the changes that have been made. This subfamily closely resembles the Bomolochinæ; perhaps the most obvious differences are the presence of a part of the first maxillæ in the form of prehensile hooks on the ventral surface of the cephalothorax opposite the bases of the second antennæ, and the structure and position of the maxillipeds.

With reference to the latter nothing need be said beyond emphasizing the fact that both structure and position are more nearly normal than in either of the other subfamilies.

In regard to the former there has been considerable diversity of opinion, and this in connection with a corresponding diversity in the interpretation of the maxillipeds has occasioned the mislocation of four out of the five species.

The fifth is a case of simple preoccupation which chronologically comes first.

Eucanthus balistæ.—Claus established the new genus *Eucanthus* in 1864; in speaking of its distinguishing characters he says:

Unterscheidet sie sich von *Bomolochus* durch den Besitz von zwei kräftigen Kopfhaken, durch eine abweichende Form und Lage des untern Kieferfusses Nach den beide ausserhalb der untern Antennen befestigten Haken mag die Gattung *Eucanthus* heissen (p. 378).

He thus recognizes that the presence of these prehensile hooks is an important generic character, but he makes no attempt to explain them. In fact the above quotation is all that is said of them.

Unfortunately the name *Eucanthus* had been used in 1848 by Woodward for a genus of Coleoptera, and so can not stand for this genus of copepods. Brian, however, described in 1906 a new subgenus which he called *Anchistrotos*, and which seems to be identical with *Eucanthus*, and hence his name can be substituted for the one given by Claus.

Bomolochus gracilis.—In the following year (1865) Heller published in his account of the crustacea obtained during the Reise der *Novara* descriptions of *Ergasilus peregrinus*, *Bomolochus megaceros*, and a form which he called *Bomolochus gracilis*, all new species. In speaking of *B. megaceros*, which is a genuine *Bomolochus* species, he calls the large maxillipeds "Diese grossen seitlichen Hornhaken." After noting that they were found by Kröyer (1863) in most of the *Bomolochus* species which he investigated and were designated—

Als das vergrösserte zweite Fusspaar (zweites Kaufusspaar der Autoren)—

Heller goes on to say that he can not agree with this designation. He adds by way of explanation:

Man findet nämlich auch hier die gewöhnlichen zwei Kaufusspaare (das erste und zweite Fusspaar Kröyers) ganz in der Nähe des Mundes eingefügt. Sie sind zwar klein und zart, eber bei starker Vergrösserung ganz dentlich als solche wahrzunehmen. Die seitlichen Hornhaken sind dieselben Gebilde, welche wir bei den Geschlechtern *Caligus* und *Lepeophtheirus* fast constant an der Aussenseite der hintern Antennen bemerken, sie sind hier nur auf eine ausserordentliche Weise entwickelt und bilden jedenfalls ein ganz kräftiges Werkzeug, mit welchem das Schmarotzerthier sich an seinen Wirthe festsetzen kann (p. 155).

Then in speaking of *Bomolochus gracilis* he says:

Der seitliche Hornhaken is hier viel weniger entwickelt und mehr nach vorne hingerrückt, so dass er wie ein Anhang der vor deren Antennen erscheint (p. 153).

Heller made several mistakes which, when clearly understood, go far to explain these apparently conflicting statements. In the first place he finds what he calls the mandibles of *B. megaceros* inside of the mouth instead of on the ventral surface of the head, where all other investigators have located them and where he himself locates them in *B. gracilis*. This leaves him free to designate the true mandibles as first maxillipeds and the second maxillæ as the second pair, and under these conditions the only thing he could do with the

true maxillipeds was to call them "seitlichen Hornhaken." But it would be manifestly impossible to have two species belonging to the same genus in one of which the mandibles were inclosed within the mouth-tube while in the other they were entirely free.

What Heller really saw inside the mouth can not even be surmised, but at all events it was not a pair of mandibles, for these are in their normal position at the side of the mouth.

Again Heller did not see the first maxillæ in any species of *Ergasilus* or *Bomolochus* which he described; they do not appear in his figures and are not mentioned in his text. If he had seen them he would never have placed one pair of "maxillipeds" in front of them. But his most serious error is the assumption that the prehensile hook in *gracilis* corresponds to the maxilliped in *megaceros*, when the two are entirely different in structure and position. The hook in *gracilis* corresponds to that found in *Caligus* and *Lepeophtheirus* in structure, function, and sex variation. But if so, the species *gracilis* can not belong to the genus *Bomolochus*, but must be made the type of a new genus, *Irodes* (see p. 390).

Bomolochus ostracionis.—Richiardi in 1870 established a new species which he referred to the genus *Bomolochus*, and which possessed similar prehensile hooks. He describes them as follows:

All' esterno dell' inserzione del primo articolo delle antenne del primo paio, si staccano dalla superficie del cefalo-torace due grossi uncini robusti, rigidi, i quali si prolungano indietro fino oltre le antenne del secondo paio quasi paralleli al margine laterale del corpo, curvi nella loro lunghezza, a punta molto acuta, sul margine interno verso la loro base anteriormente presentano una piccola appendice unciniforme, essi servono evidentemente all' animale a fissarsi sulle membrane sulle quali vive parassito (p. 53).

He thus recognizes their function, but makes no further attempt at an explanation of their presence.

In endeavoring to locate his species he states at the close of his paper that, from the presence of these two large hooks and from the form and position of the maxillipeds, it ought to belong to the genus *Eucanthus* of Claus. But in spite of this he places it under the genus *Bomolochus*, giving as his reasons for so doing the shape of the basal joint of the first antennæ, the form of the mandible and maxilla, the shape of the last joint of the endopod of the fourth legs, and the number of body segments. But variations in shape and form, especially within the narrow limits here described, are manifestly specific in value and not generic. Furthermore, the only difference in the number of body segments is found in the abdomen where variety is the rule among all the parasitic copepods. Such differences as these can not offset the presence of maxillary hooks and the structure and position of the maxillipeds. Hence the species mani-

festly belongs to the genus *Eucanthus* (*Anchistrotos*), where the present author has placed it.

Taeniacanthus carchariæ.—In the following year (1871) Sumpf described the new genus *Taeniacanthus*, on whose cephalothorax are found these same hooks which he calls "Klammerhaken" and says of them:

Letztere liegen seitlich über der Basis der hintern Antenne und erinnern durch ihre Gestalt auffallend an die Haken, mit denen das Rostellum der Taenien bewaffnet ist (p. 10).

He then adds in the next sentence:

An Gliedmassen sind am Cephalothorax folgende vorhanden.

This is the only hint given as to the nature of the hooks and he evidently does not regard them as appendages.

This genus stands as he described it and proves to be a most interesting and instructive one, since we find all the mouth-parts in their normal position beside and behind the mouth, and in addition the maxillary hooks opposite the bases of the second antennæ.

Bomolochus tetrodontis.—No more species bearing these maxillary hooks were discovered until 1898, when Bassett-Smith described *Bomolochus triceros* and *B. tetrodontis*, both new species. He repeated Heller's errors, for his first species is a true *Bomolochus*, while the second is so different that it must be placed with Heller's *B. gracilis* in the new genus *Irodes* (see p. 390). Like Heller, Bassett-Smith has never found the first maxillæ in any species of either *Ergasilus* or *Bomolochus* which he has examined. And like the German investigator, he makes these maxillary hooks in *tetrodontis* the homologues of the true maxillipeds (which he calls hamuli) in *triceros*.

Bomolochus murænæ.—In 1906 Brian described two new species belonging to this subfamily; one he made the type of a new genus to which he gave the name *Anchistrotos*; the other species which he called *murænæ*, was referred to the genus *Bomolochus*.

Brian's *Anchistrotos* is apparently identical with the *Eucanthus* of Claus, described forty years before, but Brian's genus name must be retained as already stated (p. 384).

The second species, *murænæ*, had been named by Richiardi in 1880, but had never been described. Brian identifies all his specimens as females; he does not find any maxillary hooks, and we may be reasonably sure he would have detected them if present, since he found them in *Anchistrotos*. But neither do they possess the characteristic maxillipeds of *Bomolochus* females; on the contrary their maxillipeds are very similar to those of *Anchistrotos*, and are in a normal position behind the other mouth-parts. This species, therefore, can not be referred to either *Bomolochus* or *Anchistrotos*, but must constitute a genus by itself, intermediate between the two,

for which the author would propose the name *Phagus*. At present, however, the genus must be regarded as more or less provisional, since the distinctions on which it is founded require confirmation by further study (see p. 391).

That the maxillary hooks found in this subfamily are not the homologs of the maxillipeds in *Bomolochus*, as some authors have described them, is self-evident when once the mandibles and maxillæ are correctly located. That they are homologous with the corresponding hooks in *Caligus* and *Lepeophtheirus*, as Heller and Brian suggest, is shown by their identity in structure, by their articulation directly to the ventral surface of the head, by their sex variation, being larger and longer in the male, and by their position. They appear relatively farther forward than in many *Caligus* species, but even there they are opposite the bases of the second antennæ and in front of the other mouth-parts, which is exactly their position here. And as their presence is one of the things that shows the Caliginæ to be the least degenerate family of the Caligidæ, so their presence here testifies that the Tæniacanthinæ is the subfamily showing least degeneration among the Ergasilidæ. This fact is still further attested by the presence of so degenerate a form as *Tucca* in one of the other subfamilies.

Genus TÆNIACANTHUS Sumpf.

Tæniacanthus carchariæ, Sumpf, 1871, pp. 7-18, pls. 1 and 2.

Female.—Head joined with the first thorax segment; each of the three following free segments somewhat enlarged so that the four together make from one-half to four-fifths of the entire length. The lateral margins on these segments are turned over ventrally, and each of the four pairs of legs projects strongly from the ventral surface. Fifth and genital segments more or less abruptly narrowed. In *T. carchariæ* these two segments with the abdomen form a sort of diminutive tail, one-fifth of the entire length, tapering angularly backward, and inclined at an angle of about 30° to the anterior part of the body.

First antennæ probably six-jointed as in other genera; the three basal joints thoroughly fused and half the entire length. Second antennæ similar to those of *Bomolochus*. Mandibles bipartite. A portion of the first maxillæ in the form of prehensile hooks opposite the bases of the second antennæ, similar to those in *Caligus* and *Lepeophtheirus*. (Fig. 4.) First maxillæ of the usual pattern and armed with plumose setæ. Second maxillæ rudimentary; maxillipeds also rudimentary, the terminal claw the same length as the basal joint. Both rami of the first swimming legs widened, and well armed with broad plumose setæ. Egg-tubes narrow and elongate; eggs minute.

(*Tænia*, a genus of tapeworms, and ἄκανθα, a spine, the maxillary hooks being similar to the hooks on the rostellum of *Tænia*).

Type-species.—*Tæniacanthus carchariæ* Sumpf.

ARTIFICIAL KEY TO THE SPECIES.

- a.* Free segments diminishing regularly in size; fourth segment but little wider than the fifth.....*albidus*, new species, p. 388.
a. Second, third, and fourth segments fully as wide as the carapace; fifth segment abruptly narrowed to one-third that width.....*carchariæ* Sumpf, 1871.

TÆNIACANTHUS ALBIDUS, new species.

Plate 60, text fig. 41.

Female.—First thorax segment fused with the head; resultant cephalothorax semielliptical, one-half wider than long, with a slight incision between the antennæ and a squarely truncated posterior margin. Second and third thorax segments the same length and width, four-fifths as wide as the carapace. Fourth segment the same length but one-third narrower; fifth segment half as long and three-quarters as wide. Genital segment trapezoidal in outline, with rounded corners, the same width as the fifth segment and twice as long, widest at the anterior margin and tapering posteriorly. The genital orifices are on the upper surface of the segment and close to the anterior margin. Abdomen three-fourths as wide as the genital segment and four-jointed, the first two joints somewhat longer than the last two. Anal laminae narrow and widely divergent, two-thirds as long as the last joint, and each tipped with two setæ, of which the inner is two and a half times the length of the outer; there is also a short spine on the outer margin of each lamina near the center. Egg-cases of good size, tapered at each end, half the entire length and as wide as the genital segment. Eggs minute, arranged in fifteen or more longitudinal rows, about four hundred in each case.

First antenna presumably six-jointed, the three terminal joints distinct, the three basal ones thoroughly fused. This basal portion of the antenna is enlarged and turned outward at a right angle, as in *Bomolochus*. It carries along its anterior border a row of flattened plumose setæ, all of which are the same size and structure, and there are no tactile hairs or spines among them. The terminal joints are also well supplied with setæ, of which one at the distal end of the fourth joint is much larger than the others.

The second antennæ are three-jointed, the basal joint as long as the other two and serving for the attachment of the appendage, the second and third joints the same length and folded back against the basal joint. The ventral and posterior surfaces of these last two joints are roughened with rows of short spines, and the last joint terminates

in three large curved claws, graded in size, the outer one a little more than twice the length of the inner. Beneath them the joint sends out a rough and flattened process, which reaches the tip of the second claw. From the anterior proximal corner of the second joint a stout curved claw projects inward toward its fellow on the opposite antenna, and the two nearly meet at the mid-line.

The mouth-parts are close behind the antennæ; they consist of a well-defined upper lip, a pair of mandibles, two pairs of maxillæ, and one pair of maxillipeds (fig. 41). The upper lip is transversely elliptical, twice as long as wide, with a fairly regular outline. The mandibles are three-jointed, the joints diminishing regularly in size; the basal joint starts out perpendicularly from the surface of the head and is then bent over inward at a right angle, carrying the last two joints beneath the upper lip. The terminal joint is conical, twice as long as wide, and covered with fine hairs.

The maxillary hooks are attached to the raised edge of the disk which surrounds the other mouth-parts; each consists of a rounded base and a stout curved claw. The first maxillæ are in the form of knobs, each armed with three widely divergent setæ. Each second maxilla has two joints beside the terminal blades, the proximal one much longer and stouter than the distal. The terminal blades are attached side by side, the dorsal or superior one twice the length of the ventral, both entirely covered with short hairs.

The maxillipeds are immediately behind the maxillæ; the basal joint is elongate, triangular in outline, with the apex extending forward and inward, and is fused to the surface of the head. From the anterior apex the slender and cylindrical terminal joint is turned backward in an S curve, as in *Bomolochus*. This terminal joint is only about half the length of the basal and ends in two stout, non-plumose setæ of unequal length.

The first four pairs of legs are biramose, with three-jointed rami, the joints in the exopods of the first pair being thoroughly fused. The arrangement of the spines and setæ is as follows: First exopod, 0-0; I-0; I-5: endopod, 0-1; 0-2; 0-7: second exopod, I-0; I-1; III-6: endopod, 0-1; I-2; II-4: third exopod, I-0; I-1; I-7: endopod, 0-1; I-2; II-3: fourth exopod, I-0; I-0; II-2: endopod, I-0; II-0; II-6. The fifth legs are uniramous and two-jointed; the basal joint is very narrow and short and is armed with a small spine on its anterior border. The terminal joint is enlarged into a broad ovate lamina, tipped with four short spines.

Color a dull white throughout, the ovaries and oviducts a deeper shade than the rest of the body.

Total length, 2.64 mm. Cephalothorax, 0.6 mm. long, 0.88 mm. wide. Length of free segments, 1 mm.; of egg-strings, 1.53 mm.; of anal setæ, 0.6 mm.

(*albidus*, whitish, in allusion to the general color.)

Only a single lot of this species, consisting of two females, was obtained from the vent of a shovel-headed shark, *Sphyrna tiburo*, at Beaufort, N. C., in the summer of 1905. These are numbered 38587, U.S.N.M., and are made the types of the new species. They are readily distinguished from *carchariæ* by the fact that the free segments diminish regularly in size, leaving the fourth segment but little wider than the fifth. On closer examination all the appendages show specific differences, notably the first maxillæ, mandibles, and second maxillipeds.

IRODES, new genus.

Female.—Cephalothorax much larger than any of the free segments, which diminish regularly in size from in front backwards.

Genital segment but little enlarged; abdomen cylindrical, and four-jointed in the two species known; anal laminæ small and armed with very short bristles. Egg-tubes also short and club shaped. First antennæ cylindrical, the basal joint but little enlarged and armed with short setæ, not flattened, and without tactile hairs or chitin processes. Second pair similar to those of *Bomolochus*. Mandibles three-jointed, the terminal joint bipartite and toothed; maxillary hooks like those of *Tæniacanthus*; first maxillæ probably of the usual pattern. Second maxillæ simple and three-jointed; maxillipeds behind these and only a trifle larger. They are also like the second maxillæ in structure and arrangement, except that they are tipped with two or three plumose setæ instead of one smooth spine. Each ramus of the first legs with a single widened joint; other legs as in *Bomolochus*.

Type-species.—*Irodes (Bomolochus) gracilis* Heller.

(*Irodes*, *Irus*, the well-known beggar of Ithaca, and εἶδος, similarity or likeness.)

Here belong the type species just mentioned and Bassett-Smith's "*Bomolochus tetradontis*." The description of these two forms is complete, except that neither author discovered the first maxillæ. There is no reason to believe, however, that they differ from the type found in the other genera of the Ergasilidæ. If it should turn out that the authors are right and that these maxillæ are really lacking that would be a still stronger reason for creating the above new genus.

PHAGUS, new genus.

Female.—Cephalothorax much larger than any of the free segments, which diminish regularly in size. Genital segment considerably enlarged, nearly twice the diameter of the abdomen; the latter cylindrical and tapering; anal laminæ short, each armed with three setæ, of which the inner one is more than half the entire length.

First antennæ cylindrical, basal joint moderately enlarged and flattened, with a right-angled curve similar to that in *Bomolochus*, and armed with a scraggy row of short setæ, interspersed with tactile hairs. Second pair distinctly three jointed, second joint nearly as long as the terminal; the latter roughened and tipped with two slender processes, nearly as long as the joint itself, and a tuft of spines.

First maxillary hooks wanting; mandibles and second maxillæ slender and two-jointed, the last joint bipartite; first maxillæ each armed with three short plumose setæ.

Maxillipeds behind the second maxillæ, each made up of a very large and flattened basal joint, bent inwards at a right angle near its center and bluntly rounded, and two smooth setæ or spines which arise from the posterior margin near the distal end and extend backward parallel with the body axis.

Each ramus of the first legs contains two widened joints.

Egg-tubes unknown.

Type-species.—*Phagus (Bomolochus) murænæ* Richiardi.

(*Phagus*, φάγος, a glutton.)

As already explained (p. 387), this new genus is provisionally proposed for *Bomolochus murænæ* Richiardi, as described and figured by Brian (1906). As will be seen from Brian's figures of the second antennæ and mouth-parts, the generic distinction is a valid one provided the maxillary hooks have not been overlooked and there has been no mistake in the sex of the specimens.

Genus ANCHISTROTOS Brian.

Anchistrotos gobii, BRIAN, 1906, p. 33; pl. 12, figs. 1-10.

Female.—General body form like that of *Cyclops*; cephalothorax much larger than any of the free segments; the latter diminishing regularly in size. Genital segment enlarged but little; abdomen tapering considerably; anal laminæ narrow and short, but well armed with setæ. First antennæ cylindrical and six-jointed, the basal portion enlarged hardly at all, not bent at a right angle, and armed with small setæ which are neither widened nor flattened; there are also no tactile hairs nor chitin processes. Second antennæ similar to those of *Bomolochus*, three-jointed, the second joint very short, the terminal claws large.

First maxillary hooks of good size, with a well developed basal joint and a short and curved terminal claw; mandibles and second maxillæ simple, with a smooth terminal joint; first maxillæ small, each armed with three short plumose setæ.

Maxillipeds in normal position behind the other mouth-parts, made up of a large basal joint and a curved terminal claw, sometimes bearing long setæ. Each ramus of the first swimming legs made up of a

single widened joint; other legs as in *Bomolochus*. Egg-strings wide and long; eggs of medium size, about one hundred in each string.

Male.—Body smaller than that of the female and similar to the males of the Corycæidæ. The two pairs of antennæ and the swimming legs are like those of the female; the first maxillary hooks are considerably enlarged and the terminal claw is elongated and strongly curved. The mandibles are stouter than those of the female, especially the basal joints; the first and second maxillæ are small and slender. The maxillipeds are large and strong and of the usual pattern for the male sex; the basal joint is furnished with powerful muscles and armed with a row of coarse teeth on the inner margin near the proximal end; the terminal claw is stout, bent in a half circle, so that the tip shuts against the teeth on the basal joint.

Type-species.—*Anchistrotos gobii* Brian.

(*Ἀγκιστροτός*, barbed or armed with hooks, alluding to the maxillary hooks.)

To this genus belong the type species, *gobii*, described by Brian in 1906, the species designated as *Bomolochus ostracionis* by Richiardi in 1870, and Claus's genus *Eucanthus*, with the species *balistæ* Claus, and probably *marchesetti* Della Valle, 1884. This last species has never been described to the author's knowledge, and hence we do not know its distinguishing characters. It is therefore omitted from the following key.

ARTIFICIAL KEY TO THE SPECIES.

- a.* Exopod of fourth swimming legs without setæ, its terminal joint prolonged into a claw..... *balistæ* Claus, 1864.
- a.* Both rami of fourth swimming legs of normal shape and well armed with plumose setæ..... *b.*
- b.* Terminal claw of maxillipeds as long as the basal joint and without filaments; abdomen three-jointed, last joint the longest.. *ostracionis* Richiardi, 1870.
- b.* Terminal claw of maxillipeds less than one-fourth the length of the basal joint and armed with two filaments longer than the entire appendage; abdomen four-jointed, joints equal..... *gobii* Brian, 1906.

Brian established *Anchistrotos* as a new subgenus under the genus *Bomolochus*, but there can be no question that it is entitled to be made a separate genus, when one considers the structure of the first antennæ, the maxillary hooks, and the maxillipeds. It is, however, very doubtful whether the specimen figured by Brian (Pl. 12, figs. 1, 2, and 7 to 10) is really a male. It looks much more like a young female without egg-strings, and it shows no sex distinctions from the female in the first maxillary hooks, the maxillipeds, or the genital segment. Certainly one or more of these parts ought to be modified in the true male.

Claus shows such differences clearly in his species, *balistæ*, and he certainly had both sexes. It is from the male which he describes and not from Brian's doubtful specimen that the sex distinctions of the present genus have been drawn.

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EXPLANATION OF PLATES.

PLATE 41.

Female of *Ergasilus labracis* Kröyer.

Fig. 42, dorsal view. Fig. 43, ventral view showing pigment pattern. Fig. 44, genital segment and abdomen, dorsal view. Fig. 45, second antenna. Fig. 46, mouth-parts; *lb.*, labium; *md.*, mandible; *mdp.*, mandibular palp; *mx'*, first maxilla; *mx''*, second maxilla. Figs. 47 to 49, first, third, and fourth swimming legs.

PLATE 42.

Female of *Ergasilus centrarchidarum* Wright.

Fig. 50, dorsal view. Fig. 51, dorsal surface of second (really the third) thorax segment. Fig. 52, side view of mouth-parts, showing protrusion of first maxillæ. Figs. 53 and 54, diagonal views of the mouth-parts. Figs. 55 to 58, first, second, third, and fourth swimming legs. Fig. 59, spermatozoan, highly magnified.

PLATE 43.

Female of *Ergasilus cæruleus*, new species.

Fig. 60, dorsal view. Fig. 61, ventral view, showing distribution of the deep blue pigment. Figs. 62 and 63, first and second antenna. Fig. 64, mouth-parts; *md.*, mandible; *mdp.*, mandibular palp; *mx'* and *mx''*, first and second maxillæ. Figs. 65 to 68, first, second, third, and fourth swimming legs.

PLATE 44.

Female of *Ergasilus manicatus*, new species.

Fig. 69, dorsal view. Fig. 70, genital segment and abdomen, dorsal view. Fig. 71, first antenna. Fig. 72, one of the peculiar second antennæ, furnished with large sleeves or hoods at the joints. Fig. 73, mouth-parts; *md.*, mandible; *mdp.*, mandibular palp; *mx'* and *mx''*, first and second maxillæ. Figs. 74 to 77, first, second, third, and fourth swimming legs. All the figures except 69 and 72 were drawn by Richard Rathbun.

PLATE 45.

Female of *Ergasilus versicolor*, new species.

Figs. 78 and 79, dorsal and ventral views, showing the distribution of pigment. Fig. 80, first antenna. Fig. 81, mouth-parts (see fig. 46). Figs. 82 to 85, first, second, third, and fourth swimming legs.

PLATE 46.

Male of *Ergasilus chautauquaënsis* Fellows.

Fig. 86, dorsal view. Fig. 87, ventral view of abdomen, showing armature of species. Fig. 88, second antenna. Fig. 89, mouth-parts (see fig. 46). Fig. 90, exopod of first swimming leg, left side. Fig. 91, endopod of first swimming leg, right side. Figs. 92 to 94, second, third, and fourth swimming legs.

PLATE 47.

Female of *Ergasilus mugilis* Vogt.

Fig. 95, dorsal view. Fig. 96, dorsal view of genital segment and abdomen, showing fusion of fifth and genital segments, fifth legs, and musculature of the oviduct openings. Fig. 97, second antenna. Figs. 98 to 101, first, second, third, and fourth swimming legs.

PLATE 48.

Female of *Tucca impressus* Kröyer.

Fig. 102, dorsal view. Fig. 103, ventral view, showing rudimentary third and fourth legs and muscles. Fig. 104, mouth-parts; *la.*, labrum; *md.*, mandible; *mx'* and *mx''*, first and second maxillæ. Fig. 105, second antenna. Figs. 106 to 108, second, third, and fourth swimming legs.

PLATE 49.

Male of *Tucca impressus* Kröyer.

Fig. 109, ventral view, showing rudimentary swimming legs and muscles connected with them. Fig. 110, side view of female, showing relative thickness of the body. Fig. 111, genital segment and abdomen of female, ventral view, showing anal laminae and openings of the oviducts. Fig. 112, chitin framework of the cephalothorax, after treatment with caustic potash. Fig. 113, cross section of egg-string of female. Fig. 114, second maxilla of male. Fig. 115, maxilliped. Figs. 116 and 117, first and second swimming legs of female of *Tucca corpulentus*. Figs. 118 to 120, third, fourth, and fifth swimming legs of male of *Tucca impressus*. Figs. 110 to 112 were drawn by Richard Rathbun.

PLATE 50.

Female of *Tucca corpulentus*, new species.

Fig. 121, dorsal view. Fig. 122, first antenna. Fig. 123, second antenna. Fig. 124, ventral view of cephalothorax, showing antennæ, mouth-parts, and first and second legs in natural position. Fig. 125, mouth-parts, except the maxillipeds, enlarged (see fig. 104). Figs. 126 and 127, third and fourth swimming legs.

PLATE 51.

Female of *Artacolax sætiger*, new species.

Fig. 128, dorsal view. Fig. 129, side view, showing fusion of third and fourth thorax segments. Fig. 130, second antenna. Fig. 131, mouth-parts: *la.* labrum; *md.*, mandible; *mx'* and *mx''*, first and second maxillæ; *p.*, paragnath. Fig. 132, maxilliped. Figs. 133 to 136, first, second, third, and fourth swimming legs. Fig. 137, one of the claws on the exopods of the swimming legs.

PLATE 52.

Female of *Artacolax ardeolæ* (Kröyer).

Fig. 138, dorsal view. Fig. 139, side view, showing fusion of third and fourth thorax segments. Fig. 140, mouth-parts (see fig. 131). Fig. 141, maxilliped. Figs. 142 to 145, first, second, fourth, and fifth swimming legs. Fig. 146, one of the claws on the exopods of the swimming legs.

PLATE 53.

Female of *Bomolochus eminens*, new species.

Fig. 147, third swimming leg of *Artacolax ardeolæ*. Fig. 148, dorsal view of *Bomolochus eminens*. Fig. 149, ventral view of genital segment and abdomen. Fig. 150,

second antenna. Fig. 151, mouth-parts: *la.*, labrum; *md.*, mandible; *mx.'* and *mx.ʹʹ*, first and second maxillæ; *mxp.*, maxilliped, the single one being drawn in the right position and of the correct size with reference to the other mouth-parts. Figs. 152 to 155, first, second, third, and fourth swimming legs.

PLATE 54.

Female of *Bomolochus concinnus*, new species.

Fig. 156, dorsal view. Fig. 157, first antenna. Fig. 158, second antenna. Fig. 159, mouth-parts (see fig. 151) of young female. Fig. 160, maxilliped of adult, showing lengthening of the claw. Figs. 161 to 165, first, second, third, fourth, and fifth swimming legs.

PLATE 55.

Male of *Bomolochus concinnus*, new species.

Fig. 166, first antenna of young female, showing division into 6 segments. Fig. 167, fourth leg of young female. Fig. 168, fifth leg of young female; note resemblance to fig. 176 and compare with fig. 165. Fig. 169, dorsal view of adult male. Fig. 170, dorsal view of very young male less than half a millimeter in length. Fig. 171, second antenna. Fig. 172, mandible. Fig. 173, first maxilla. Fig. 174, maxilliped. Figs. 175 and 176, first and fifth swimming legs.

PLATE 56.

Female of *Bomolochus nitidus*, new species.

Fig. 177, dorsal view. Fig. 178, first antenna. Figs. 179 to 183, first, second, third, fourth, and fifth swimming legs. (Fig. 181 is the fourth pair.)

PLATE 57.

Male and female of *Bomolochus soleæ* Claus.

Fig. 184, dorsal view of male. Fig. 185, ventral view of abdomen, showing armature of stiff bristles. Fig. 186, second antenna. Fig. 187, mandible and first maxilla. Fig. 188, second maxilla and paragnath. Fig. 189, fourth swimming leg. Fig. 190, side view of female.

PLATE 58.

Female of *Bomolochus exilipes*, new species.

Fig. 191, dorsal view. Fig. 192, ventral view of genital segment and abdomen. Figs. 193 and 194, first and second antenna. Figs. 195 to 199, first, second, third, fourth, and fifth swimming legs. Fig. 200, rudimentary sixth leg at the opening of the oviduct on the genital segment. Fig. 201, mouth-parts of *Bomolochus nitidus* (see fig. 151).

PLATE 59.

Female of *Bomolochus teres*, new species.

Fig. 202, dorsal view. Fig. 203, first antenna. Fig. 204, second antenna. Figs. 205 to 209, first, second, third, fourth, and fifth swimming legs. Fig. 210, one of the claws on the exopods of the swimming legs.

PLATE 60.

Female of *Tæniacanthus albidus*, new species.

Fig. 211, dorsal view. Fig. 212, ventral view of cephalothorax, showing antennæ, mouth-parts, and first swimming legs (compare with text figure 4). Fig. 213, first antenna. Fig. 214, second antenna. Figs. 215 to 218, second, third, fourth, and fifth swimming legs. Fig. 219, first swimming leg of male *Bomolochus soleæ*.

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